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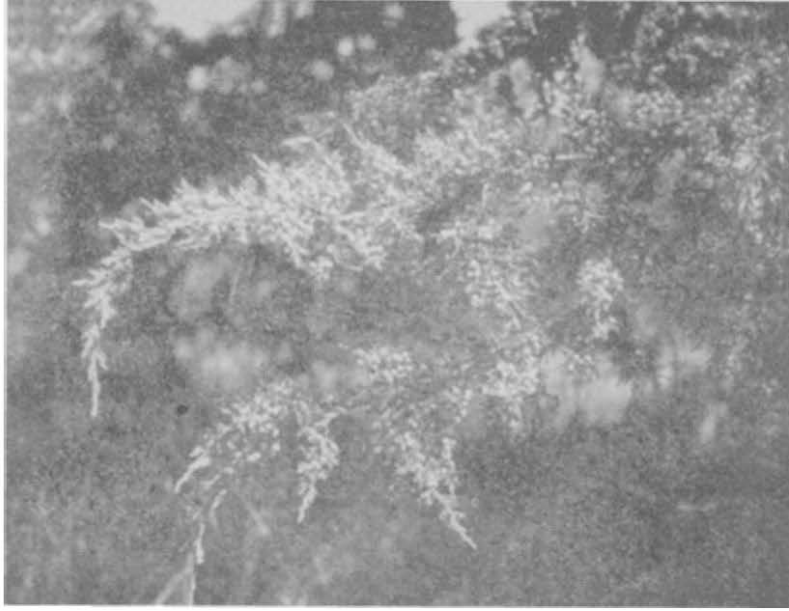

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Producing Seedlings of Eastern Red Cedar (*Juniperus virginiana* L.)

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CONTENTS

Producing Seedlings of Eastern Red Cedar

(*Juniperus virginiana* L.)

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Department of Horticulture

Eastern red cedar, *Juniperus virginiana* Linneaus, is found throughout Oklahoma, growing on dry slopes, rocky ledges, abandoned farmlands, and other areas that are unfit for cultivation. It is of considerable value to the state, being used extensively for forest and landscape plantings. Because of its durability, the wood of red cedar is valued as fence post material and for other outdoor uses. Due to its adaptabiltiy to adverse growing conditions and its evergreen character, red cedar is also one of the most desirable species for windbreak and shelterbelt plantings where such plantings are not in close proximity to apple orchards.

Production of seedlings of this cedar has presented considerable difficulty to commercial growers in Oklahoma and adjacent states, and no standard method of handling the seed has been accepted. Therefore the Oklahoma Agricultural Experiment Station undertook in 1938 to find a method which would give a uniformly good stand. Such a method is presented in this bulletin, together with a report of some of the experimental work upon which it is based. If the recommendations presented here are followed, there should be no reason why a good stand of red cedar seedlings cannot be grown every year.

COLLECTING, STORING, AND CLEANING SEED

Collection

The fruit of red cedar (see cover picture) ripens in Oklahoma in early November. Although it may remain on the tree throughout the winter, it should be harvested as early as possible. Early collection prevents loss to birds which feed upon the fruit, and also gives time for the long period of stratification and early spring planting which are necessary for insuring good stands of seedlings. Seed should be stratified by the middle of December to insure completion of after-ripening by planting time.

As soon as the cedar fruits are collected, they should be spread on a floor or table and allowed to dry for a week or ten days.

Because red cedar seeds often fail to develop properly, a cutting test on one to two hundred seeds should always precede seed collection. This test is made by cutting each seed in two and observing and recording the presence or absence of a kernel, and also its appearance and soundness. The quality of the seed is usually low. Crops containing 20 percent or less of sound, well filled seed are not uncommon, and a lot containing from 50 to 70 percent of such seed may be considered to be of good quality.

All seed of *Juniperus virginiana* used during this investigation was collected locally (Stillwater, Okla., and vicinity) in 1939 and 1940. Since many red cedar trees produce a high proportion of empty seeds, collection of seed was always preceded by a cutting test. Seed used in this study was of better than average quality; from 50 to 60 percent of all seeds were well filled and apparently sound, as shown in the following table:

Lot No.	Date of collection	Place of collection	Percent of filled sound seed
39 C	Nov. 6, 1939	Vicinity of Perkins, Okla.	51
39 D	Nov. 11, 1939	Vicinity of Perkins, Okla.	60
39 E	Dec. 2, 1939	Vicinity of Perkins, Okla.	53
40 B	Nov., 1940	Stillwater, Okla.	50+

Storage

The question of storing seed for use at a future date is of particular importance in the case of red cedar because abundant seed crops are produced only every second or third year and often are of extremely poor quality. A test was therefore made to see whether seed could be preserved in a viable and sound state to permit using it at a later time when a good crop of seed might not be available.

A sample lot of seed was cleaned and stored dry in an uncovered glass jar for seven months at 41 degrees Fahrenheit. Another sample of the same collection was not cleaned and was left as dry berries at room temperature for a year. A third sample was cleaned and stratified immediately. The results (Table 1) indicate that loss of viability during storage was negligible in both the cleaned and uncleaned seed, and that therefore seed can be stored dry in an abundant crop year for use the following year.

Table 1.—Effect of dry storage on viability of seed of Juniperus virginiana.

State of seed and place of storage	Period of storage (months)	Stratification period (days)	Germination at 70° F. (percent)
Stratified as soon as collected	none	106	73.5
Dry seed at 41° F.	7	73	66.0
Dry seed at 41° F.	7	73	72.5*
Dry fruit at room temperature	12	75	75.0

* Germination at 80° F.

Cleaning

Before being stratified the seed must be cleaned. This is facilitated by soaking the berries in water for three or four days. After the berries become soft, the pulp should be crushed, care being taken not to crack the seeds.* The use of a brick or a wooden block on a cemnt floor or on a large flat stone facilitates crushing of berries and cleaning of seeds. By placing the crushed berries in a large volume of water, the pulp and the majority of the empty seeds can be floated off. Most of the good seeds will sink.

The common practice of soaking the berries in a weak solution of lye seems to be of no value in cleaning red cedar seed. The use of lye during this investigation did not appear to contribute to either the ease of cleaning the seed or the improvement of germination.

Stratification of seed without removing the pulp (berry) hindered after-ripening. Germination of such seed after three months of stratification was only 10 percent as compared to 30 percent for seed cleaned prior to stratification.

TREATING SEED TO INSURE GERMINATION

Normal and Abnormal Germination Processes

The process of germination of the seed of *Juniperus virginiana* is essentially the same as in seed of other species which require after-ripening. Normal germination of red cedar seed begins with the growth and protrusion of the radicle through the endosperm (Figure 1). The cotyledons elongate slightly but remain enclosed within the seed and continue to absorb

* Scarification of seed during cleaning sometimes results in abnormal germination. See page 9.

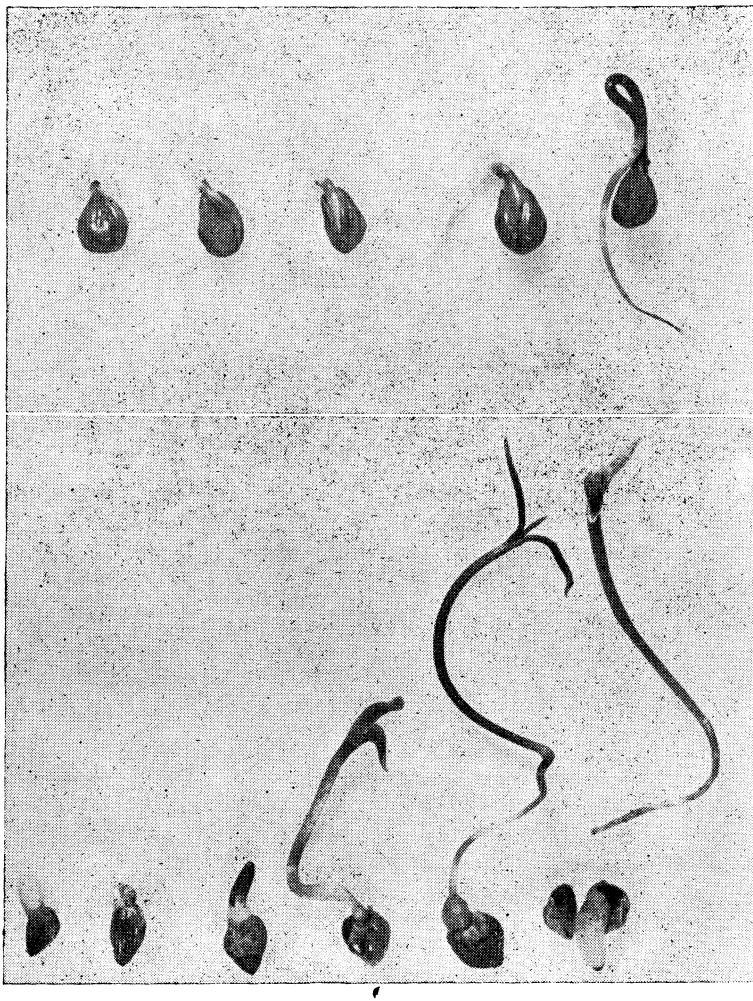

Fig. 1 (above).—Several stages of normal germination of seed of Juniperus virginiana.

Fig. 2 (below).—Abnormal germination of seed of Juniperus virginiana. **The emergence of the cotyledons and the hypocotyl precedes that of the radicle.**

the stored food from the endosperm. Only when this food is exhausted are they normally pulled out and appear above the soil. In certain cases and under certain conditions the growth of the cotyledons precedes that of the radicle (Figure 2). This abnormality has been found to be characteristic of seeds having a very dormant embryo and also of seeds in which dormancy of the various parts of the embryo is not of the same intensity.* It occurred during this study as a result of scarification of seed during the process of cleaning (Figure 3); and in another study was observed in seeds of *Juniperus scopulorum* which had been treated with sulfuric acid.

Germination Failure Caused by Dormacy of Embryo

Seed of red cedar is dormant at the time it normally reaches maturity. Experiments designed to check on all possible causes of seed dormancy as listed by Crocker** confirmed Pack's finding† that dormancy of the embryo is the basic cause of the inability of ripe seed to germinate. Seed absorbed water freely (18.52 percent of the air dry weight in 72 hours of soaking) and removal of the seed coat did not promote germination. Excised embryos failed to grow, and increased oxygen content of the air did not force germination.

Stratification Required to Break Dormancy

No method has been found for breaking the dormant period of red cedar seed by using forcing agents. Some nurserymen use treatments which they personally consider helpful, such as treatment of seed with sulfuric acid or maceration of berries in a weak solution of lye; but none of these has given enough assurance of a uniformly good stand of seedlings from year to year to bring about its adoption as a standard practice.

In the experiments reported in this bulletin, holding dormant seed in pure oxygen for 24 hours or treatment with a solution of vitamin B_1 for the same period not only failed to

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* Afanasiev, M.: "A physiological study of dormancy in seed of *Magnolia acuminata*." Cornell Univ. Agri. Exp. Sta. Memoir 208 (1937).

Thornton, Norwood C.: "Factors influencing germination and development of dormancy in cocklebur seeds." Boyce Thompson Institute. Contrib. 7:477-496 (1935).

** Crocker, William: "Mechanics of dormancy in seeds." *Am. Jour. of Bot.*, 3:99-120 (1916).

† Pack, Dean A.: "After-ripening and germination of Juniperus seeds." *Bot. Gaz.*, 71:32-60 (1921). References to Pack's work, which occur throughout the remainder of this bulletin, are all to this article.

hasten the after-ripening but actually slowed down this process (Table 2). Pack secured similar results with the use of oxygen. It therefore appears that neither oxygen nor vitamin B_1 should be used to supplement standard stratification at low temperature.

Method of Stratifying Seed

Peat moss is a good stratification medium for red cedar seed. It has a very large water-holding capacity and yet does not interfere with aeration. In these tests, granulated peat moss of horticultural grade and having a pH of 5 was used as the standard stratification medium.

The peat must be thoroughly moist but not too wet. The seed should be mixed with at least four times its volume of peat and placed in any convenient container, such as fruit baskets, boxes, or crates. If small amounts of seed are to be stratified, glass jars or coffee cans may be used. In these tests, glass jars with paper covers were used for small lots, while larger lots were placed in half-bushel baskets lined and covered with paper.

Pack found that stratification of seed at 41 degrees Fahrenheit provided the most desirable condition for after-ripening and that 100 days under these conditions was needed to complete the process. In the present investigation, this period

Table 2.—Effect of Pretreatment with Oxygen and Vitamin B_1 on After-ripening of Seed of Juniperus virginiana.

(Percentage of germination in 14 days.)

Stratification period (weeks)	TREATMENT*		
	Oxygen**	Vitamin B_1† 4 mg per liter; 24 hours	Check Soaked in tap water for 24 hours
0	0.0	0.0	0.0
2	0.0	0.0	0.0
4	0.5	0.0	0.5
6	10.5	9.5	12.0
8	29.0	25.5	33.0
10	62.0	62.2	77.0

* All treatments were immediately followed by stratification at 41° F.

** Seeds kept 24 hours in Erlenmeyer flasks in which the air was completely replaced by pure oxygen.

† Seeds stratified without being rinsed.

varied not only with individual lots and from season to season but with individual seeds as well. The data (Table 3) show that very little germination can be expected from seed stratified for six weeks or less, but that there is a rapid increase in the percentage of after-ripened seeds thereafter. In securing the data in Table 3, the stratified seed was placed in an electric refrigerator at an average temperature of 41° F. but varying from 36° F. to 45° F. Germination tests, each involving 200 seeds, were made at two-week intervals. The original intention was to continue the tests for 14 weeks; but, due to an abundant germination of seeds in the refrigerator, the tests had to be stopped earlier. At the end of the tenth week, germination in storage had reached 45 percent. Breaking of the embryo through the endosperm was considered as the beginning of germination. The figures in Table 3 are based on the total germination in the laboratory and in the refrigerator. Germination of 77.0 percent in the case of the lot of seed used was very close to the maximum that could possibly be attained; the lot, despite separation of good and poor seed by floating, still contained a number of empty seeds.

Table 3.—Effect of length of stratification at 41 F. on after-ripening of seed of Juniperus virginiana.

Stratification period (weeks)	2	4	6	8	10
Percentage of germination	0.0	0.5	12.0	33.0	77.0

Stratified seed should remain at low temperature until all seeds are completely after-ripened. Some seeds after-ripen much more rapidly than others, but a period of from 100 to 120 days is sufficiently long for most seeds.

The stratified seed should be inspected occasionally to check on the suply of moisture in the peat and to note the progress of after-ripening. Completion of after-ripening is marked by splitting of the seed coat.

Storing After-ripened Seed

Pack's results show that, in order to insure after-ripening of all seed, it is desirable to extend the period of stratification to 100 or more days. On the other hand, many seeds complete the process in 60 to 75 days (Table 3); and this sometimes creates difficulties because those seeds which complete the

process first will germinate at the temperature of stratification (See page 16). Difficulties created by the considerable variation in the stratification requirements of individual lots of seed suggested the need of a method which would prevent germination of after-ripened seed and yet would allow the seeds to maintain their germinative power.

Two methods of storing after-ripened seed were tried: drying and freezing. Drying of after-ripened seed reduced germination and caused reversion to secondary dormancy. Freezing for four weeks lowered germination only slightly, and that method of storage is therefore recommended for use in emergencies when after-ripened seed begins to germinate but cannot be planted immediately. Freezing cannot be recommended as a standard practice, however, because some loss of seed must be expected from such handling.

Dry Storage

To determine the effect of drying on after-ripened seed of red cedar, two samples of seed (lot 39C) were dried to a constant weight at room temperature and stored dry for various periods of time. One of the samples prior to drying was stratified 66 days and the other 91 days. Later the experiment was repeated on seeds of lot 39D with essentially the same results as those obtained in the first trial.

Drying of after-ripened seed at room temperature generally reduced germination (Table 4). This reduction was greater and more rapid in tests set at room temperature than in those carried on at 41° F., which should be attributed chiefly to the inhibitive effect of high temperature in germinators kept in the laboratory. Since the reduction in total germination at 41° F., caused by drying, was very gradual, and many seeds germinated after as many as 10 to 12 weeks of drying, the sharp reduction in germination percentage at room temperature cannot be attributed to the loss of viability caused by drying. It must be assumed that seeds tested at room temperature were as viable at the beginning of any germination test as those placed on the same day in germinators at 41° F. There appears to be no explanation for the low germination (5.5 percent) in Lot 39C dried for a period of one week.

Pack has observed reversion to secondary dormancy when after-ripened seed of red cedar was exposed to a temperature of 12° C. It appears quite possible that drying of after-ripened seed has exactly the same effect, although it is possible also

that the temperature of drying might also have been responsible for the reversion to secondary dormancy. The assumption of the existence of the secondary dormancy in dried seed is substantiated by the fact that germination of dried seed at 41° F. took a longer period of time than that of the seed which was not dried. Additional time required for germination at

Table 4.—Effect on germination of drying after-ripened seed of Juniperus virginiana.

Lot	Length of stratification period* (days)	Period of drying (weeks)	PERCENT GERMINATION			
			at room temp.		at 41° F.	
			percent	in days	percent	in days
39C	66	0	66.0	14	66.0	31
	66	1			49.0	54
	66	5	5.5	18	48.5	47
	66	9	0.0	18	25.5	46
39C	91	0	74.5	25	58.5	18
	91	1	9.0	20	5.5	20
	91	4	.5	20	68.5	50
	91	10	10.5	16	59.5	61
	91	12	9.5	30	45.0	56
39D	99	0	11.0	3		
	99	1	12.0	5		
	99	2	8.0	8		
	99	3	11.0	9		
	99	4	4.0	8		
	99	5	8.0	8		
	99	6	10.0	7		
	99	8	5.0	7		

* Prior to drying.

41° F. can be attributed to the need of after-ripening which, as shown before, takes place at that temperature. It is of interest to note that the period of cold moist storage required to break dormancy is much shorter than the period of stratification needed by the seed in its original state of dormancy.

Frozen Storage

In the tests of freezing, after-ripened seed was removed from the peat moss, frozen in blocks of ice, and left in that state in the freezing unit of an electric refrigerator. Samples of this seed were removed from time to time, thawed out, and placed in germinators: one-half of each sample at room temperature and one-half at 41° F. (Table 5). The tests at 41° F. are the more representative of the viability of the seed, since there was considerable variation in the conditions under which

the tests at room temperature were conducted. There was relatively small loss of viability in seed frozen for one and four weeks. Almost one-half of the originally viable seeds still remained viable after 24 weeks of freezing. This is contrary to findings of Pack, who reported that fully after-ripened seeds (cracked open and with water content increased to 52 percent) were killed by exposure to −5° C. (23° F.). In this investigation, only those seeds which started to germinate (radicles broken through) were killed by the exposure to freezing.

Other evidence tended to confirm the belief that freezing could be used as an emergency means of storing after-ripened seed. In another experiment, not included in Table 5, the seed remained viable after as long as six weeks of freezing. Still another lot, which had been completely after-ripened somewhat in advance of planting season, was planted in the nursery after about a month of frozen storage and produced a good stand of seedlings. A sample of seeds from this latter lot was withheld from planting and continued in frozen storage. Laboratory germination tests showed a reduction of germination from the original of 54 percent to 35 percent after 15 weeks of freezing and to 15 percent after 18 weeks.

Table 5.—Effect on seed viability of freezing after-ripened seed of Juniperus **virginiana.**

Period of time seed were kept frozen (weeks)	PERCENTAGE OF GERMINATION at 41° F.			PERCENTAGE OF GERMINATION AT ROOM TEMP.		
	Lot 39C(a)	Lot 39C(b)	Lot 39D(a)	Lot 39C(a)	Lot 39C(b)	Lot 39D(a)
0	58.5	66.0	44.0	74.5	66.0	40.0
1	72.0	49.0	44.5	56.0	42.0	40.0
4	70.0			65.0		
6		36.5	30.5		20.0	17.5
7	69.0			49.5		
10		26.5	14.5		53.0	33.5
12	75.0			16.5		
24	34.5			23.5		
52	0.0			0.0		

GROWING SEEDLINGS FROM AFTER-RIPENED SEED

Temperature Controls Time of Planting

Early planting of seed is desirable for two reasons. First, germination is favored by a relatively low temperature. Second, late planting shortens the first growing season and high summer temperatures have a dwarfing effect on young seedlings.

March is the best time for planting after-ripened seed of red cedar in Oklahoma. If, however, seed is not completely after-ripened at that time, it is better to postpone planting until the stratified seed has become completely after-ripened. The following experiments have shown that the reduction in germination due to the higher temperatures encountered by late plantings is not as large as the reduction caused by incomplete after-ripening.

As pointed out above (page 11), best results are secured by stratifying the seed early enough to insure that after-ripening will be completed by planting time in March. Late planting (April and May) should be resorted to only in exceptional cases when the seed were not stratified early enough.

Germination Best at 50°-70° F.

According to Pack, temperatures above 15° C. (59° F.) are extremely unfavorable if not entirely prohibitive to germinanation of red cedar seed. Preliminary tests performed during the present investigation contradicted Pack's results, and two experiments were therefore set up to determine more definitely the effect of temprature on germination and find the maximum temperature at which germination would take place.

Laboratory Experiment.—The first experiment was set up in the laboratory, using petri dishes with moist cotton as germinators.* They were kept at constant temperatures in insulated cabinets with thermostatic controls. The range of temperatures selected represents that of the outdoor temperatures prevailing in Oklahoma from February to May.

* This was the method generally used in these experiments for making laboratory germination tests.

At the end of 30 days seed set at 50° F. showed the highest percentage of germination (Table 6 and Figure 3). Germination at 60° and 70° F. was almost as good, but at 80° and 90° F. the final germination percentage fell off considerably. At 100° F. germination was the lowest with the exception of that at 32° F., at which temperature no germination took place at all.

The sharp decrease in germination at 100° F. is probably due to the high mortality of the embryos. Many seeds at that temperature showed definite signs of injury. High temperature affected not only the germination but growth of the seedlings as well. Embryos in seeds which germinated at 90° and 100° F. failed to grow normally and died shortly after the radicles broke through.

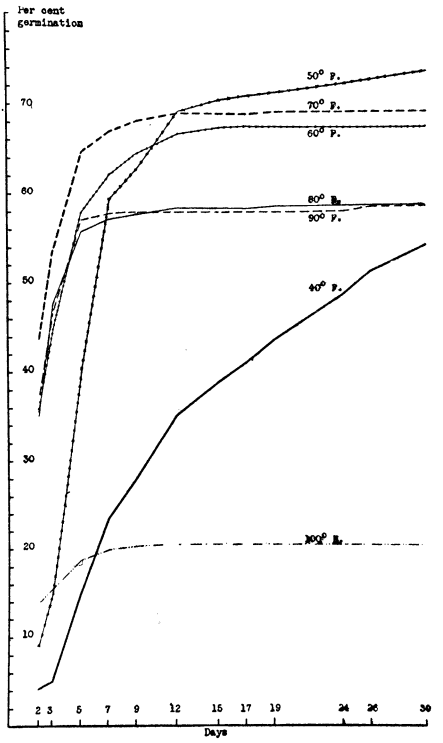

Figure 3. Effect of temperature on germination of after-ripened seeds of Juniperus virginiana.

NURSERY BED EXPERIMENT.—Results from a test with seed planted outdoors in a nursery bed (Table 7) were closely similar to those obtained in the laboratory. The percentage of seed which produced seedlings fell off gradually with the delay in planting, and this reduction in the percentage of seedlings is well correlated with the rise in temperature.

EARLY PLANTINGS PRODUCE STONGER SEEDLINGS

The better growth made during the first season by early planted seedlings is shown in Figure 4. Similar results were obtained in a laboratory experiment which demonstrated how

markedly the initial growth of seedlings is affected by temperature. In this experiment 50 fully after-ripened seeds were planted one-half inch deep in each of three pots of soil, and the pots were placed at temperatures of 50°, 70°, and 90° F. After 14 days, practically all seeds placed at 50° and 70° F. had germinated, while of those held at 90° F. only 10 percent had germinated. At that time, 36 seedlings had appeared above the soil surface in the pot kept at 70° F., but no seedlings had appeared at the surface in either of the other pots. The few seeds which germinated at 90° F. failed to produce normal seedlings. (Figure 5.)

Table 6.—Effect of temperature on germination of after-ripened seeds of Juniperus virginiana.*

(Percentage of germination; average of three tests)

Days	32° F.	40° F.	50° F.	60° F.	70° F.	80° F.	90° F.	100° F.
2	0.0	4.2	9.1	35.7	43.8	35.2	37.4	13.8
3	0.0	5.0	15.0	44.8	53.8	47.7	46.7	14.5
5	0.0	15.2	40.2	58.2	64.8	55.9	57.2	18.7
7	0.0	23.5	59.7	62.3	67.2	57.3	58.0	19.9
9	0.0	28.0	63.1	64.8	68.4	57.9	58.2	20.3
12	0.0	35.4	69.5	67.0	69.3	58.7	58.3	20.5
15	0.0	39.1	71.0	67.8	69.3	58.7	58.4	20.5
17	0.0	41.2	71.4	68.0	69.3	58.7	58.5	20.5
19	0.0	43.8	71.8	68.0	69.7	59.0	58.5	20.5
24	0.0	48.9	72.9	68.0	69.8	59.0	58.6	20.5
26	0.0	49.7	73.4	68.0	69.8	59.0	59.0	20.5
30	0.0	54.6	74.3	68.0	69.8	59.0	59.0	20.5

* Data represent tests of 900 seeds each except at 60° F. and 100° F., where 700 were used.

Table 7.—Effect of time of outdoor planting on emergence of after-ripened seed of Juniperus virginiana.

Lot	Period of stratification (days)	Number of seeds	Date planted	Percent germination in 4 weeks*	Mean soil temperature during germination (F°)
39C	84	300	3/30/40	55.3	61.3
39C	98	175	4/13/40	48.0**	63.0
39C	112	300	4/27/40	58.0**	71.2
39C	119	600	5/ 4/40	45.8	72.9
39E	102	300	3/30/40	51.7	61.3
39E	131	100	4/27/40	44.0	71.2
39E	138	200	5/ 4/40	23.5	72.9

* These percentages represent also the total emergence.

** The figures are somewhat lower than the actual percentage of emergence because of the destruction of a few seedlings by cutworms.

Fig. 4.—Emergence and growth of seedlings of J. virginiana as affected by the date of planting. Planting dates (1940): A, March 30; B, April 13; C, April 27; D, May 4.

Fall Planting of Dormant Seed Not Recommended

Fall planting of dormant seed of red cedar is a common practice among growers in Oklahoma. The success of such plantings depends upon three factors:

1. The temperature must remain low for a sufficiently long period to promote after-ripening of the seed.

2. The seed bed must be kept moist.

3. The seed must be protected against rodents and against danger of being washed away by heavy rains.

Warm winters and long periods of dry weather are rather common in Oklahoma, so that the first and second conditions may not be met. As a result, fall planted seed frequently fails to produce a good stand of seedlings, and fall planting is therefore not recommended.

Neither Vitamin B_1 Nor Excess Oxygen Increases Germination

Experiments designed to determine whether the percentage of germination of after-ripened seed could be further increased by treatments following stratification showed that neither vitamin B_1 nor excess oxygen was of value. The test with oxygen, however, did indicate that lack of oxygen reduced the percentage of germination.

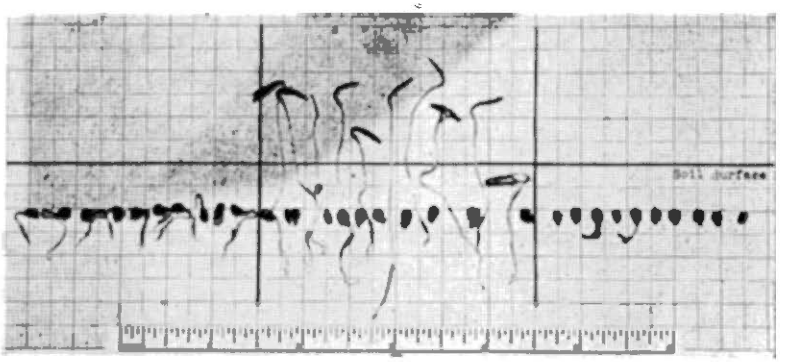

Fig. 5.—Growth of seedlings of Juniperus virginiana **as affected by the temperature. Left, 50 F.; center, 70 F.; right, 90 F.**

Samples of after-ripened seed soaked for 24 hours in a solution containing 4 mg. of vitamin B_1 crystals (thiamine hydrochloride) per liter germinated 73.0 percent in two weeks, while a check lot of untreated seed germinated 77.0 percent in the same period of time.

Four samples of after-ripened seed were held for 24 hours in atmospheres containing 5, 10, 20 (normal air) and 100 percent oxygen, and were then placed in petri dishes. After 20 days, the samples germinated 48.5, 53.5, 77.0 and 73.5 percent, respectively.

Good Aeration and Slightly Acid Reaction Best for Germination

The low percentage of germination when seed was allowed a sub-normal supply of oxygen indicaes the importance of not over-watering and of having a light, well drained soil in the seed bed, since excess moisture in the soil drives out the air and prevents the seeds from securing adequate oxygen.

Germination tests using media of varying degrees of acidity and alkalinity indicated that this cedar is fairly tolerant to reaction, but will probably germinate best in a slightly acid medium. The differences in total germination were too small to be significant (Table 8). However, in the two germination media of highest alkalinity, the growing radicles turned brown upon coming into contact with the solution; and growth seemed best on the slightly acid medium (pH 6.2).

Spacing Plants in Seed Bed

After-ripened seed of red cedar should be planted about one-half inch deep and preferably in rows five to six inches apart. Broadcasting the seed is easier and faster, but often results in a very uneven distribution of seedlings in the seed bed. It takes less time and labor to care for seedlings spaced uniformly in rows.

Spacing of seed in the row will depend upon the potential productivity of the seed, the purpose for which the plants are grown, and the care the plants are going to receive. One should also consider the possibilities of damping-off and of destruction by cutworms, unless measures are taken to prevent such loss.

Table 8.—Germination of seed of Juniperus virginiana *as affected by the reaction of the medium.*

(Percentage of germination.)

	REACTION OF THE GERMINATION MEDIA (pH):					
Days	4.40	5.28	6.20	7.00	7.80	8.40
1	35.5	35.0	40.5	35.0	43.5	38.0
3	63.0	59.0	69.5	60.0	60.5	60.0
6	66.5	62.5	72.6	63.0	64.0	64.5
9	67.5	63.0	73.0	64.5	65.0	66.0
13	68.0	63.5	73.0	65.5	65.0	66.0
15	68.5	64.5	73.0	66.0	65.0	66.0

SUMMARY

1. The cause of delayed germination in seed of *Juniperus virgniana* is a dormant embryo.

2. Seed of *J. virginiana* requires stratification at low temperature to complete after-ripening. Individual seeds and different lots of seed vary in the length of period required to complete this process. Seed used in this phase of the investigation was completely after-ripened after 70 days at a temperature of 41° F.

3. Holding dormant seed of *J. virginiana* in pure oxygen for 24 hours of treatment of seed with a solution of vitamin B_1 for the same period not only failed to hasten the after-ripening but actually slowed down this process.

4. Drying of after-ripened seed of *J. virginiana* reduced germination and caused reversion of seed to secondary dormancy. The period of stratification at low temperature required to overcome the secondary dormancy was much shorter than the stratification period needed to overcome the original dormancy. Seed dried for 28 and 35 days and set in germinators at 41° F. germinated in 50 and 47 days respectively.

5. Freezing of after-ripened seed of *J. virginiana* for four weeks lowered germination to only a small extent.

6. Temperature had a marked effect on germination of after-ripened seed of *J. virginiana.* The optimum germination temperature was 50° F. However at 60° and 70° F. germination percentage was only slightly lower than at 50° F. The rate of germination was directly correlated with the temperature within the range of 40° to 70° F., but above 70° F. germination was markedly retarded. Temperatures of 80° F. and higher affected unfavorably the extent and the rate of germination. A temperature of 100° F. was almost prohibitive to germination of seed and growth of seedlings.

7. Germination of seed of *J. virginiana* was not affected markedly by the reaction of the medium when pH of the latter varied between 4.4 and 8.4. The highest germination was obtained at a pH of 6.2.

8. Soaking after-ripened seed of *J. virginiana* in a solution of vitamin B_1 for 24 hours had no effect upon germination.

9. Holding after-ripened seed of *J. virginiana* in pure oxygen for 24 hours not only failed to help germination but actually lowered it. Reduction of oxygen content to 5 or 10 percent for 24 hours immediately preceding germination test, lowered the germination markedly.

10. One year of storage of cleaned seed of *J. virginiana* at low temperature (41° F.) and of dry berries at room temperature (70°-90° F.) did not reduce the viability of the seed.