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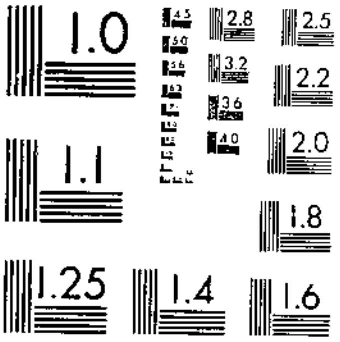

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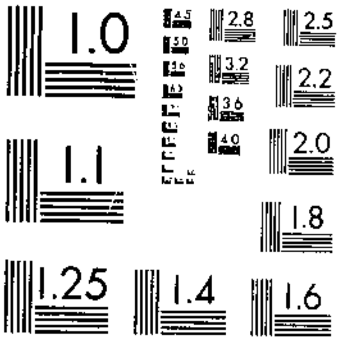

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TECHNICAL BULLETIN No. 261 — AUGUST, 1931

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# LONGEVITY AND GERMINATION OF SEEDS OF RIBES, PARTICULARLY R. ROTUNDIFOLIUM, UNDER LABORATORY AND NATURAL CONDITIONS[1]

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CONTENTS



## INTRODUCTION

For several years the writer has studied the life histories of certain species of Ribes[2] on their natural sites in the white pine (*Pinus strobus* L.) region of New York State. Ribes are primarily important in white pine regions as the alternate hosts necessary for the spread of the white pine blister rust, caused by *Cronartium ribicola* Fischer. This destructive fungous disease may be controlled locally by the removal of Ribes plants growing within infecting range of the white pines to be protected (*16*, *20*).[3]

Economic practices for the removal of Ribes to protect valuable white pine stands have been developed and are being applied in the infected Eastern States. The extent and duration of control obtained by applying these practices depends upon the thoroughness with which the work is done and upon the rate of increase of Ribes in size and numbers on the control area. This increase comes about through the continued growth of plants that are missed or incompletely removed and through the establishment of new plants from seeds. The number of plants missed or incompletely removed is governed

[1] The germination tests were made at the Boyce Thompson Institute and in the department's seed laboratory. The writer is indebted to William Crocker, director of the institute, and Johanna Giersbach, the latter making the tests, for permission to include the results in this bulletin. Credit is due W. L. Goss, botanist, for the tests made in the department.

[2] The term "Ribes" when used collectively in this bulletin refers to members of the family Grossulariaceae Dumort (currants and gooseberries).

[3] Italic numbers in parentheses refer to Literature Cited, p. 39.

by the thoroughness of the initial eradication operation. Efficient Ribes-eradication work normally removes all the plants capable of fruiting within the next several years. This interrupts the local production of Ribes seeds but does not eliminate seeds that may have been produced prior to the eradication. The importance of the latter in restocking control areas with Ribes depends on these seeds retaining their viability until such time as favorable conditions arise for their germination and the growth of the resulting seedlings.

If Ribes seeds can retain their viability for only three or four years, the supply of seeds available for restocking an area kept free of fruit-bearing bushes will be limited to seeds surviving from the last three or four fruiting seasons immediately preceding the first eradication. Moreover, if any restocking is to result from these seeds, conditions favorable for their germination will have to occur within three or four years after seed production is ended by the eradication of all the fruit-producing bushes. Therefore, if Ribes seeds are so short-lived, the danger that areas kept free of fruit-producing bushes will become restocked with Ribes from locally produced seeds is slight and ceases entirely after a period equivalent to that during which the seeds remain viable.

However, if Ribes seeds lying in the forest floor have the power of remaining dormant for many years, the supply of viable seeds available for restocking an area after eradication may be relatively large as the result of these seeds accumulating over many seasons. Under this assumption, restocking of the area with Ribes will promptly occur whenever conditions are favorable for seed germination and seedling survival. Thus, Ribes plants would have an important means of renewing their representation in the flora of forest areas after periods of years unfavorable for their growth and reproduction.

The ability of any plant species to regain a foothold promptly on its natural sites following periods during which environmental conditions prohibit the reproduction and growth of that species on such sites depends largely on the adaptation of its seeds for longevity or for wide dissemination. Observations have shown that a period of considerable length, during which sites favorable for the reproduction and growth of Ribes become decidedly unfavorable, occurs during the life of many stands of white pine in New York State. It was also observed that white pine areas from which the Ribes had been eradicated, as well as areas supporting dense stands of white pine from which the Ribes had disappeared naturally, became restocked with numerous Ribes seedlings following certain disturbances of the forest floor. The abundance and prompt appearance of these seedlings suggested that they came from seeds already present on the areas rather than from seeds recently disseminated from an outside source.

This bulletin reports observations and the results of systematic studies of the longevity of Ribes seeds, particularly those of *Ribes rotundifolium* Michx., and of the conditions under which they germinate. This species is one of the more common wild gooseberries of the white pine region of New York State.

## REVIEW OF LITERATURE

Very little information on either the germination or the longevity of Ribes seeds is available in literature. The seeds of cultivated species of currants and gooseberries have received but slight attention from investigators, because these plants are propagated largely by stem cuttings. The seeds of wild species of Ribes have escaped thorough investigation largely because these plants were unimportant shrubs of pasture, forest, and waste-land plant associations until their eradication became necessary as a means of preventing serious blister-rust damage to our valuable stands of white pine.

The literature on the subject of longevity of seeds is extensive, but only a small part of it deals with seeds occurring in forest duff or humus, and in this part only one record of Ribes seeds was found. However, a brief review of some of the literature dealing with the longevity of seeds other than those of Ribes will serve by analogy to establish a basis for the discussion of new observations on the longevity of Ribes seeds. For the sake of clarity, the literature will be considered chronologically under each of three headings: Records of seed longevity, causes of seed dormancy, and characteristics of Ribes seeds.

### RECORDS OF SEED LONGEVITY

As early as 1832 De Candolle (*4, v. 2, p. 618*) stated:

> All the means of dissemination of seeds are, despite their diversity, subordinate to another class of phenomena, namely, the varying degree in which each seed conserves more or less its power to germinate.[4]

He wrote of the temporary reappearance after each logging of tree species different from those which made up the lumbered forest and concluded that the seeds of these temporary species remained viable in the soil during the 20, 30, 50, or 100 years that the site was monopolized by the timber species. He observed (*4, v. 2, p. 626*) that—

> certain portions of soil which, by reason of terracing work, were exposed to the air after several centuries, covered themselves the first year with a multitude of individuals belonging to certain species, sometimes uncommon in the vicinity, and the seeds of which evidently had been preserved in the soil.

In 1885 Beal (*3*) reported preliminary results of an experiment with buried seeds. In the autumn of 1879 he placed 20 lots of fresh seeds of 21 plants, 50 seeds of each, in earth in uncorked bottles. These bottles were buried about 20 inches below the surface of the ground on a sandy knoll, together with 20 lots of seeds of 2 other species which were too large to be included in the bottles. The latter seeds were apparently decayed when he dug down to them three years later. On July 25, 1884, he took up one bottle, presumably containing seeds of 21 species, and kept the contents under conditions for germination until the middle of November, 1884, and from June 25 to July 31, 1885. The partly completed results of these tests on July 31, 1885, showed that germination was secured either in 1884 or 1885 from 13 out of 21 species tested. More recent results of this experiment as reported by Darlington (*8*) will be discussed later.

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[4] Translated.

In 1893 Peter (*18*) reported results of germination secured from soil samples taken from forests which had been growing for known periods on formerly cultivated fields. From such samples he secured the germination of numerous farm weeds, some of which, he estimated, grew from seeds that had been lying in the soil for 100 years.

In 1894 the Gardeners' Chronicle (*1*) related an observation of the longevity of weed seeds in a field which had been seeded down to grass and kept as a hayfield and pasture. Sixteen years after the elimination of the seed source, a heavy wagon was taken across this field after a hard frost and thaw; the wheels, sinking deeply, tore up the ground. The following spring these furrows were filled with charlocks (*Sinapis arvensis* L.), although there was not another charlock to be seen in the field.

In 1905 Duvel (*9*) reported preliminary results of an experiment concerning the germination of seeds buried in the ground in 1902. He placed 32 complete sets of 112 samples of seeds representing 109 species of plants, mixed with heavy clay soil, in well-baked earthen pots. These 3,584 pots, covered with inverted clay saucers, were buried outdoors at three different depths, 8 complete sets at 6 to 8 inches, 12 complete sets at 18 to 22 inches, and the remaining 12 complete sets at 36 to 42 inches below the surface of the ground. Germination tests were made in 1902 of samples of the bulk lots represented in the sets. Control samples from the same bulk lots were stored in cloth bags in a dry room. The first complete series of three sets of pots were taken up in November, 1903, 11 months after they had been buried. The contents of the pots were spread on sand in greenhouse flats for germination tests along with corresponding control samples which had been stored air-dry.

Of the 112 samples in each of the sets, the results from 1 should be discarded, as repeated tests failed to show any seeds from the bulk samples capable of germination. Twelve samples, buried samples and controls as well, gave only negative results when tested in the greenhouse. Some samples of all of the 99 remaining showed some germination. Of these 99 samples in the buried sets, 10 were unmistakably decayed when taken up and were not tested; 14 were seemingly decayed but were tested, giving negative results; and 75 retained some vitality at one or more of the three depths of burial. No data are available for 2 of these 75 samples, their tests having been interrupted. The buried seeds from one or more of the three depths, in 16 of the remaining 73 samples, showed higher germination than that secured from the 1902 tests of the bulk lots. Similarly, as compared with the controls stored air-dry, the buried seeds showed higher germination than the controls in 21 of the 73 samples.

Although Duvel (*9, p. 20*) concluded that "Vitality is best preserved, even in weed seeds, when the seeds are carefully harvested and stored in a dry and comparatively cool place," his data seem to indicate that in several species the germination of seeds was increased by 11-months' burial, not only over that of seeds kept in dry storage but over that of fresh seeds as well. Later results of this experiment, as reported by Goss (*11*), will be considered in due order.

In 1908 Ewart (*10, p. 190*) stated, while discussing the biological value of hard seeds, that such seeds distribute themselves in time rather than space, some of each year's crop "being destined to remain germinable in the soil for very many years until the parent plants have been cleared off by fire and drought." He suggested:

To some extent these macrobiotic seeds are adaptations to bush fires * * *. Such bush fires, after burning off the humus more or less, not only partially expose the seeds, but leave behind an alkaline ash, which the next rain falling on the warm ground aids in softening the coats of the hard seeds, and bringing about their germination * * *. In addition, slight charring of the surface of the seed makes it permeable to water without necessarily destroying the vitality of the contents.

He continued with this observation (*10, p. 191*):

I have, in fact, found Acacia seeds deeply buried in the soil of Gum forests, where no other signs of their presence could be seen, and where no other Acacias were present within at least a mile.

He found Acacia seeds in undisturbed Acacia forests as far as 18 inches below the surface of the ground which gave perfect germination.

In the deeper layers of soil the only seeds that remain viable are likely to be the hard macrobiotic ones, and Ewart found that all such seeds from below the surface needed treatment to produce swelling and germination, which he accomplished with the use of sulphuric acid.

Ewart also tested the seeds of over 600 species of plants that had been untouched in the original packages stored in a dry, airy, dark cupboard for 50 years, and secured some germination of seeds of 17 species. Among these was a lot of 1,000 seeds of *Melilotus gracilis* DC., from which he secured 70.3 per cent germination. Ewart tested other lots of seeds stored for periods varying up to 105 years. He listed 83 records of germination of seeds ranging in age from 51 to 105 years, including 57 species of plants.

In addition to listing the results of his own tests, which numbered nearly 3,000, Ewart included in his voluminous lists many germination-test results of other workers, including Becquerel, De Candolle, Desmoulins, Girardin, Heldreich, Hemsley, Lindley, Michalet, Peter, Poisson, Salter, Sirodot, and White. Some of these dealt with fresh seeds, others with old seeds stored under air-dry conditions for more or less definite periods, or in soil or submerged sea mud for indefinite periods. He discounted severely the results of workers with seeds stored in soil for indefinite periods and drew his conclusions of viability largely from the tests of seeds preserved in dry conditions, stating (*10, p. 181*):

It might be argued that the seed might last longer in the soil than when dried in air, but Duvel's comparisons of the germination of seeds buried in soil for a year, with the same preserved dry in air for a year, show that as a matter of fact the reverse is the case with all ordinary seeds. The only apparent exceptions appear to be with those hard seeds which Duvel seems not to have known how to treat to induce germination.

Ewart concluded his paper by dividing all plant seeds into three biological classes according to their duration of life under optimal conditions: Microbiotic, seeds whose duration of life does not exceed 3 years; mesobiotic, seeds which may remain viable from 3 to 15 years; and macrobiotic, seeds which may remain viable from 15 to over 100 years. This last class includes the least number of species, is "characterized by cuticularised or more or less impermeable seed coats," and "is restricted to a few natural orders, of which the Leguminosae greatly surpass all others, while the Malvaceae and Myrtaceae come next in importance." Ewart (*10, p. 184–185*) did not include any close relatives of Ribes in his list of macrobiotic seeds; in fact he stated: "Macrobiotic seeds are all seeds which show no special adaptation for dispersal * * * adhesive seeds or fruits are conspicuously absent among them." He stated further (*10, p. 199*):

Even the most resistant seeds after 50 to 100 years show a pronounced decrease in the percentage 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 (Leguminosae).

It would seem that Ewart, in omitting records of seeds stored in mineral soil, humus, or duff from due consideration overlooked what may constitute optimal conditions for the preservation of vitality in the seeds of some species of plants. As a result, his list and description of macrobiotic seeds, based largely on his own tests of air-dried samples, is far from complete in regard to the families and even the orders of the plant kingdom represented, as will be shown later.

In 1915 Howard (*13*) reported finding that the seeds of more than half of the plant species, both wild and cultivated, growing around Columbia, Mo., have a distinct period of dormancy.

In 1917 Hofmann (*12*) published considerable evidence of the seed-storage rôle of the forest floor, particularly in regard to seeds of forest trees in the Northwest. His results indicate the possibility that seeds of some forest trees will retain their viability in duff for at least 10 years.

In 1922 Darlington (*8*) reported the latest results of the experiments started by Beal (*3*). After 40 years' burial, some seeds of 10 species were found to have retained their power of germination. Among these were seeds belonging to five orders and seven families (Gray's classification) that are new to Ewart's list of macrobiotic seeds.

Perhaps the most convincing record of longevity of hard seeds is that reported in 1923 by Ohga (*17*). He secured 100 per cent germination of 35 seeds of *Nelumbo nucifera* Gaertn., the Hindu lotus, which had been found buried from one-half to two-thirds of a meter below the ground surface of the Pulantien River Valley in southern Manchuria, and 12½ meters above the present water level of the river. Judging from the age of willows on the bed of this former lake and from the rate of lowering of the water level of the river, he estimated the minimum length of the period of storage at 120 years, adding, "although it is probable that the seeds have remained buried 200 years or even 400 years." Even after this remarkably long period of dormancy, the seed coats had to be filed before germination could be induced.

In 1924 Goss (*11*) reported the latest results of experiments started by Duvel (*9*). Goss obtained some germination of seeds of plants belonging to 13 orders and 19 families (Gray's classification) after 20 years' burial in soil. Of these, 8 orders and 16 families are new to Ewart's list of macrobiotic seeds. Results by Goss check very closely with those reported by Darlington for the same species.

The results of germinative tests of seeds of known age, from the principal authoritative records in the literature, are summarized in Table 1. This table shows that some seeds germinated after being kept air-dry for 105 years, the maximum age tested; and that some seeds were still germinable after burial in soil for 40 years, the maximum period reported for seeds buried experimentally. The works of Peter (*18*) and Ohga (*17*) with seeds buried for estimated periods of 50 to more than 120 years indicate that some seeds lying in soil or peat remain viable for periods greatly in excess of those so far tested in controlled experiments.

There can be no doubt that some seeds retain their power of germination for many years, perhaps in some cases for centuries, and that seeds with hard coats are especially prominent among those found to be long-lived.

TABLE 1.—*Summary of results of germinative tests of seeds of known age, from the principal authoritative records in the literature*

| Treatment and number of years stored | Number tested | | Number retaining some germinative power | | Percentage retaining some germinative power | | Reference in the literature cited |
|---|---|---|---|---|---|---|---|
| | Species | Samples | Species | Samples | Species | Samples | |
| Seeds stored in dry air: | | | | | | | |
| Fresh | 105 | 110 | 102 | 107 | 97 | 97 | 9 |
| 1 | 104 | 204 | 90 | 182 | 87 | 89 | 9 |
| 0–3 | 37 | 138 | 29 | 94 | 73 | 68 | 10 |
| 4–15 | 357 | 462 | 141 | 192 | 39 | 42 | 10 |
| 16–25 | 206 | 250 | 57 | 68 | 28 | 27 | 10 |
| 26–50 | 800 | 963 | 50 | 61 | 6 | 6 | 10 |
| 51–75 | 922 | 1,102 | 50 | 74 | 5 | 7 | 10 |
| 76–100 | 28 | 32 | 5 | 7 | 18 | 22 | 10 |
| 101–105 | 5 | 5 | 2 | 2 | 40 | 40 | 10 |
| Seeds buried in soil: | | | | | | | |
| 1 | 104 | 327 | 71 | 196 | 68 | 60 | 9 |
| 3 | 104 | 327 | 61 | 173 | 59 | 53 | 11 |
| 5 | 23 | 23 | 13 | 13 | 57 | 57 | 3 |
| 6 | 106 | 333 | 68 | 176 | 64 | 53 | 11 |
| 10 | 20 | 20 | 11 | 11 | 55 | 55 | 7 |
| 10 | 106 | 333 | 68 | 189 | 64 | 57 | 11 |
| 15 | 20 | 20 | 13 | 13 | 65 | 65 | 7 |
| 16 | 100 | 329 | 51 | 128 | 48 | 39 | 11 |
| 20 | 20 | 20 | 11 | 11 | 55 | 55 | 7 |
| 20 | 106 | 333 | 51 | 140 | 48 | 42 | 11 |
| 25 | 20 | 20 | 11 | 11 | 55 | 55 | 7 |
| 30 | 20 | 20 | 9 | 9 | 45 | 45 | 7 |
| 35 | 20 | 20 | 6 | 6 | 30 | 30 | 7 |
| 40 | 22 | 22 | 10 | 10 | 45 | 45 | 7 |

## CAUSES OF SEED DORMANCY

In 1832 De Candolle (*4, v. 2, p. 628*) stated:

> The germination of a perfect seed can come about only by the reunion of three agents, moisture, oxygen, and a certain degree of heat; these are the conditions essential to the phenomenon; all others amount to nothing but causes which may facilitate or hinder it.

De Candolle also stated that fully matured seeds retain their vitality for varying lengths of time when these three conditions necessary to germination do not occur simultaneously. He believed that the restriction of oxygen and moisture is the factor that preserves vitality in seeds buried deeply in the ground.

Duvel (*9, p. 17–18*), in the buried-seed experiments already discussed, found that the average percentages of germination for the seeds buried 11 months at depths of 6 to 8 inches, 18 to 22 inches, and 36 to 42 inches were 20.5, 26.5, and 31.0, respectively. Duvel explained the fact that the average germination increased with the depth at which the seeds had been buried as probably due to a difference in the three factors that govern germination—heat, moisture, and oxygen. He also stated:

> The greater number of seeds germinate best when subjected to daily alternations in temperature. These alternations do not take place at a depth of 3 feet below the surface; consequently there is a better preservation of vitality at that depth as a result of the more dormant condition of the seeds.

Duvel apparently did not consider the restrictions of moisture and oxygen imposed on the germination of hard-coated seeds by the seed coat itself. Of such seeds, Crocker (*6, p. 285*) stated:

> In nature, in short, they have the most favorable storage conditions up to the time when the coats, through partial decay or long exposure to water, admit moisture and germination begins. It is not wonderful that such seeds lie in the ground twenty to twenty-five years and yet retain their vitality.

Crocker also suggested the influence of restrictions, due to deep burial, on the oxygen and moisture necessary for the germination of seeds.

Crocker (*7, p. 99–100*) stated in a later work:

> In plants of the Temperate Zone, the seeds generally have a rest period * * * more general and much more persistent among wild than cultivated forms * * *. Seeds of many plants have a dormancy that persists only until the spring following ripening. Others are carried over two or more winters in the quiescent condition, while still others have the germination of a single crop distributed over the growing season of from one to many years.

He gave the following as causes for dormancy of seeds (*7, p. 105*):

> Rudimentary embryos that must mature before germination can begin.
>
> Complete inhibition of water absorption.
>
> Mechanical resistance to the expansion of the embryo and seed contents by enclosing structures.
>
> Encasing structures interfering with oxygen absorption by the embryo and perhaps carbon dioxide elimination from it, resulting in the limitation of processes dependent upon these.
>
> A state of dormancy in the embryo itself or some organ of it, in consequence of which it is unable to grow when naked and supplied with all ordinary germinative conditions.
>
> Combinations of two or more of these.
>
> Assumption of secondary dormancy.

Crocker attributed most of the delay in germination of seeds to the influence of the seed-coat characters, especially to the exclusion of moisture and oxygen by hard seed coats.

Investigators seem to agree generally that burial of seeds may prevent germination by restricting some or all of the three factors, oxygen, moisture, and temperature, considered essential to this phenomenon. It also seems evident that certain seeds with hard coats are naturally adapted to longevity, the seed coats restricting absorption of oxygen and water.

## GERMINATION AND OTHER CHARACTERISTICS OF RIBES SEEDS

Janczewski (*14, p. 222, 223*) in his monograph of the Grossulariaceae, stated:

> The germinability of preserved seeds is fairly good in certain species (Berisia) [one of Janczewski's subgenera of Ribes, native in the Old World

only], very poor in others, either the percentage of seeds germinating is greatly restricted or sometimes not any (*R. ambiguum*). It seems to cease entirely after three years. Desiccation, even inside the fruit, seems to be disastrous to them. We have seen really abundant germination only in open air, underneath the bushes, whose fruit had not been picked but buried in the soil by the spade of the gardener.[5]

He continued:

The seeds of gooseberries [including currants] sown and maintained at temperatures of 12° to 20° come up very irregularly and very slowly in general. In the Berisia, the germination is more prompt than in other subgenera and almost entirely independent of the season; the first germs break through the soil in 15 to 24 days and are followed by others either soon, during several weeks, * * * or in the following spring. Habitually, it is necessary to wait two to eight months, more than a year * * *, even two years * * * before noting the first plantules. In many cases the season has no manifest influence on the period of germination (Berisia, Coreosma[6]); in others (Ribesia,[6] Grossularia,[6] Parilla[6]) its influence appears probable or certain. Thus the seeds of *R. velutinum* obtained from the same crop, sown in October, 1905, June and October, 1906, began to grow at the same time, in January, 1907, after a rest of 15, 7, or 3 months, while the seeds sown in December, 1906, began to rise in February, 1907, that is, after only 2 months, with a delay of approximately 30 days.

As to *R. rotundifolium*, he noted: "Germination quite prompt; some seeds grow after six to eight weeks * * *."

Janczewski apparently did not investigate the reasons for the variations in germinability, nor did he consider the probability of extended dormancy in Ribes seeds. If he restricted his germination tests to constant temperatures between 12° and 30° C., it is not at all strange that he secured poor germination, as will be shown later.

The seed coats of Ribes were well described by Janczewski as follows:

The testa or "spermoderme" is made up of: First, a gelatinous layer, vitreous, sometimes very thick, whose cells are filled with a gummy substance and covered by a thin undulated membrane; second, two or three layers composed of small cells and showing nothing in particular; third, a layer the cells of which contain crystals of calcium oxalate and are surrounded by thickened and brownish membranes; fourth, a brown layer of disorganized tissue.

No very successful procedure for germinating the fresh seeds of Ribes was found in the literature reviewed. Adams (*2*) was successful in attempts to germinate seeds of two wild species, *R. americanum*, the American black currant, and *R. cynosbati*, the pasture gooseberry, both well known in the white pine region of the northeastern United States. He gathered the fruit as soon as ripe, washed the seeds to free them from pulp, and divided those of each species into four lots of 100 seeds each. Groups A and B were sown a few days after collection, the former in shallow boxes placed out of doors and left there during the winter, and the latter in pots kept in a greenhouse. Seeds of Group C were dried, put up in packets, and the packets put in a tin box which was kept in a sheltered spot out of doors during the winter (subjected to a temperature far below 0° F. on several occasions). Seeds of Group D, after drying, were

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[5] Translated.

[6] The species of Ribes known in the northeastern United States which Janczewski groups in these subgenera are: Coreosma, *R. glandulosum* Grauer, *R. aureum* Pursh., *R. americanum* Mill., and *R. nigrum* L.; Ribesia, *R. vulgare* Lam., and *R. triste* Pall.; Grossularia, *R. cynosbati* L., *R. reclinatum* L., *R. rotundifolium*, and *R. hirtellum* Michx.; Parilla, native to the Old World and to South America.

stored in a heated room during the winter. Both Groups C and D were sown the following March. Adams's data on the germination of these Ribes seeds are copied in Table 2.

TABLE 2.—*Germination of seeds of Ribes americanum and R. cynosbati*

[Rearrangement of table by Adams (*2*). Each lot comprised 100 seeds, collected on Aug. 31 and Sept. 3, 1924]

| Species and group | Date of sowing | Percentage of germination after period of days stated | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 42 | 93 | 144 | 182 | 202 | 221 | 228 | 247 | 264 | 290 | 332 | 432 | 462 | 576 | 633 | Final |
| *R. americanum*: | | | | | | | | | | | | | | | | | |
| A | Sept. 11, 1924 | | | | | 74 | | | | 74 | | | | | | | 74 |
| B | do | | | | 5 | | 13 | | | | | 29 | | | 35 | | 35 |
| C | Mar. 4, 1925 | | 2 | | | | | | | | | | 16 | | | | 16 |
| D | do | | 1 | | | | | | | | | | 7 | | | | 7 |
| *R. cynosbati*: | | | | | | | | | | | | | | | | | |
| A | Sept. 15, 1924 | | | | | | | 79 | | | 84 | | | | | | 84 |
| B | do | | | 7 | | | | | 25 | | | | | | | 26 | 26 |
| C | Mar. 5, 1925 | 2 | | | | | | | | | | | | 7 | | | 7 |
| D | do | 13 | | | | | | | | | | | | 19 | | | 19 |

It would seem from these data that the seeds of these Ribes germinate best when planted out of doors immediately after collection. This is not necessarily true, for it is possible that secondary dormancy, as described by Crocker (*7*), was induced by drying in those groups kept over the first winter (C and D), and that the germinative conditions of the following spring were not capable of breaking down this dormancy. It is noticeable that in three of the four groups C and D, Adams secured greater germination during the second spring after planting than during the first, suggesting the possibility that some part of the treatment, probably the dry storage, induced a secondary dormancy which prevented some seeds from germinating immediately when planted. It is unfortunate that he did not continue his tests for several years more, in order to obtain the germination of the more latent seeds.

Records of germination of Ribes, both from old and from fresh seeds, are few in the literature of seed testing. Ewart (*10*) tested the following Ribes seeds that were included in the aforementioned lot stored for 50 years in a dry cupboard:

*Ribes sanguineum* Pursh, 10 seeds.

"*Ribes sanguineum* var. *atrosanguineum*" (probably a garden form of the species and not a true variety), 30 seeds.

"*Ribes sanguineum* var. *glutinosum*" (probably *R. glutinosum* Bentham), 34 seeds.

The tests were carried on at a temperature of about 25° C., and when the seeds refused to germinate the temperature was increased to 30° and then to 40°. No germination was secured. As will be indicated later, it is probable that these temperatures were too high to be favorable for germination of Ribes seeds, and the negative results secured do not prove necessarily that these seeds had lost their vitality.

Howard (*13*) found that the seeds of *Ribes nigrum* and *R. gracile* Michx., have a distinct period of dormancy. Cooper (*5*), in his report on a preliminary study of the ecological life history of some of the eastern gooseberries, apparently overlooked the possibility that Ribes seeds may remain viable for a considerable period in duff or humus. York[7] found seedlings of skunk currant (*R. glandulosum*) germinating on a small plot which had been cleared of parent plants five years previously and concluded that the seeds of this species may remain viable in the duff for at least five years.

## LABORATORY INVESTIGATIONS OF THE GERMINATION OF RIBES SEEDS

Inadequate facilities for seed testing prevented the writer from attempting any extensive laboratory experiments with Ribes seeds. However, seeds of Ribes were sent to the division of seed investigations of the Bureau of Plant Industry, and the Boyce Thompson Institute for Plant Research, Yonkers, N. Y., for germination tests.

Berries of *Ribes missouriense* Nutt., *R. cynosbati*, and *R. americanum* were collected during July, 1926, by H. J. Ninman in the southern part of Dunn County, Wis., on each of three dates approximately two weeks apart. The first collection consisted of green berries, the second of berries approaching maturity, and the third of mature berries. The berries were delivered to W. L. Goss at Washington, D. C., on July 9, July 21, and about August 1, 1926, respectively.

All the collections were kept in the packages as received and placed in an ice box where they remained until January 11, 1927. On that date berries from each of the nine lots were put to soak in Petri dishes in the 15° C. chamber. Ten days later 25 seeds were extracted from the soaked berries of each lot. These were placed immediately on moist blotting paper and returned to the 15° C. chamber where they remained for 13 months. Nearly 45 per cent of the total number of seeds so tested appeared to be still sound after six and one-half months. However, during the 13-month test period, only 1 seed germinated out of the total of 225 seeds tested. This one was a seed of *Ribes americanum* from the lot of berries collected when fully mature. The practically negative results of this germination test indicated that the conditions in the 15° C. chamber were apparently unfavorable for the germination of these seeds.

One lot of berries of *Ribes cynosbati* and two lots of *R. rotundifolium* were collected by the writer in July and in September, 1927, in Warren and Essex Counties, N. Y. The berries were dried in the sun and then kept at room temperature until November or December, 1927, the exact dates varying with the different lots. The dry berries were then broken open and the seeds removed by hand. The extracted seeds were stored in homeopathic vials and sent to the Boyce Thompson Institute on December 14, 1927. The subsequent treatment of the seeds and the results of the tests were reported by Johanna Giersbach, who conducted the tests.

The seeds were soaked in tap water as soon as received, in order to soften the adhering pulp particles which were rubbed off with cheesecloth. Twenty-eight samples of 100 seeds each were taken from each of the three lots for testing. Nineteen samples from each lot were sterilized with Uspulun.[8] This treatment consisted of

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[7] York, H. H. Some observations on the sprouting and reseeding of skunk currant (Ribes glandulosum) at North Conway, N. H. U. S. Dept. Agr., Bur. Plant Indus. Blister Rust News (Sup.) 10: 241–251. 1926. [Mimeographed.]

[8] An organic mercury seed disinfectant manufactured in Germany.

soaking the seeds in a one-half of 1 per cent solution of Uspulun for one-half hour and then rinsing them thoroughly in tap water. The seeds were put into germination condition immediately while still wet from the cleaning. Nine sterilized samples from each lot were stratified in peat which had been neutralized with calcium carbonate. Eighteen samples from each lot, nine of which had been sterilized, were stratified in natural peat. One sterilized sample from each lot was planted immediately in soil in a greenhouse and kept at about 18° C. Three samples from each lot, one of sterilized seeds in neutralized peat, one of sterilized seeds in natural peat, and one of unsterilized seeds in natural peat, were tested at each of the constant temperatures: 5°, 10°, 15°, 20°, 25°, 32°, and at daily alternations between 10° and 25°, 15° and 32°, and 20° and 32°.

The seeds tested at the higher constant temperatures (25° and 32° C.) did not germinate during two months and were then transferred to temperatures with a daily alternation between 10° and 25°. The tests at alternating temperatures were continued for five months, but no additional germination occurred during the fifth month. The tests at constant temperatures of 5°, 10°, 15°, and 20° were continued for nine and three-fourths months. The tests in greenhouse soil were discarded after six months. The results of the tests are shown in Table 3.

TABLE 3.—*Germination of seeds of Ribes rotundifolium and R. cynosbati at various temperatures*

[All tests, which were conducted by Johanna Giersbach at the Boyce Thompson Institute, were begun on Dec. 22, 1927. The berries of *R. rotundifolium* (lot 1) were collected July 28, 1927, and the seeds were extracted Dec. 8; those of *R. rotundifolium* (lot 2) were collected Sept. 14, 1927, and the seeds were extracted Dec. 10; those of *R. cynosbati* were collected July 25, 1927, and the seeds were extracted in November. Seeds were sterilized by soaking one-half hour in a one-half of 1 per cent solution of Uspulun. N. P. indicates peat neutralized with calcium carbonate]

| Species and lot of seeds and temperatures (° C.) | Medium | Seeds sterilized | Cumulative germination percentages at the ends of the indicated periods (in months) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 1½ | 3 | 4 | 5 | 6 | 7 | 8 | 9¾ |
| R. rotundifolium (lot 1): | | | | | | | | | | | |
| 5° | N. P. | Yes | 0 | 0 | 15 | 15 | 15 | 15 | 21 | 21 | 21 |
| | Peat | No | 0 | 0 | 32 | 32 | 32 | 32 | 37 | 37 | 37 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10° | N. P. | do | 0 | 0 | 15 | 16 | 16 | 22 | 22 | 27 | 28 |
| | Peat | No | 0 | 0 | 2 | 4 | 10 | 11 | 17 | 17 | 17 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 |
| 15° | N. P. | do | 5 | 5 | 5 | 5 | 5 | 7 | 7 | 7 | 7 |
| | Peat | No | 0 | 0 | 0 | 14 | 19 | 19 | 19 | 21 | 21 |
| | do | Yes | 0 | 0 | 0 | 8 | 8 | 8 | 15 | 15 | 15 |
| 20° | N. P. | do | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Peat | No | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25° for 2 months, then daily alternation between 10° and 25°. | N. P. | do | 0 | 0 | 0 | 18 | [1] 18 | | | | |
| | Peat | No | 0 | 0 | 66 | 72 | [1] 72 | | | | |
| | do | Yes | 0 | 0 | 0 | 2 | [1] 2 | | | | |
| 32° for 2 months, then daily alternation between 10° and 25°. | N. P. | do | 0 | 0 | 0 | 7 | [1] 7 | | | | |
| | Peat | No | 0 | 0 | 52 | 59 | [1] 59 | | | | |
| | do | Yes | 0 | 0 | 0 | 0 | [1] 0 | | | | |
| Daily alternation between 10° and 25°. | N. P. | do | 35 | 52 | 63 | 63 | [1] 63 | | | | |
| | Peat | No | 59 | 74 | 76 | 76 | [1] 76 | | | | |
| | do | Yes | 6 | 22 | 38 | 38 | [1] 38 | | | | |
| Daily alternation between 15° and 32°. | N. P. | do | 0 | 0 | 0 | 6 | [1] 6 | | | | |
| | Peat | No | 0 | 0 | 18 | 18 | [1] 18 | | | | |
| | do | Yes | 0 | 0 | 0 | 0 | [1] 0 | | | | |
| Daily alternation between 20° and 32°. | N. P. | do | 0 | 0 | 0 | 0 | [1] 0 | | | | |
| | Peat | No | 0 | 0 | 0 | 0 | [1] 0 | | | | |
| | do | Yes | 0 | 0 | 0 | 0 | [1] 0 | | | | |
| About 18° | Soil | do | 0 | 0 | 5 | 5 | 5 | [2] 5 | | | |

[1] Discarded May 22, 1928.

[2] Discarded in July, 1928.

TABLE 3.—*Germination of seeds of Ribes rotundifolium and R. cynosbati at various temperatures*—Continued

| Species and lot of seeds and temperatures (° C.) | Medium | Seeds sterilized | Cumulative germination percentages at the ends of the indicated periods (in months) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 1½ | 3 | 4 | 5 | 6 | 7 | 8 | 9¾ |
| R. rotundifolium (lot 2): | | | | | | | | | | | |
| 5° | N. P | Yes | 0 | 0 | 3 | 5 | 5 | 10 | 17 | 17 | 24 |
| | Peat | No | 0 | 0 | 0 | 2 | 7 | 8 | 11 | 12 | 12 |
| | do | Yes | 0 | 0 | 0 | 12 | 12 | 21 | 29 | 29 | 29 |
| 10° | N. P | do | 0 | 0 | 3 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Peat | No | 0 | 0 | 0 | 1 | 1 | 1 | 8 | 12 | 18 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 7 | 7 |
| 15° | N. P | do | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 4 |
| | Peat | No | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 20° | N. P | do | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Peat | No | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25° for 2 months, then daily alternation between 10° and 25°. | N. P | do | 0 | 0 | 0 | 36 | [1] 36 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 0 | 0 | 7 | [1] 7 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 0 | 0 | 4 | [1] 4 | ---- | ---- | ---- | ---- |
| 32° for 2 months, then daily alternation between 10° and 25°. | N. P | do | 0 | 0 | 0 | 35 | [1] 35 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 0 | 33 | 46 | [1] 46 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 0 | 2 | 2 | [1] 2 | ---- | ---- | ---- | ---- |
| Daily alternation between 10° and 25°. | N. P | do | 37 | 54 | 74 | 74 | [1] 74 | ---- | ---- | ---- | ---- |
| | Peat | No | 94 | 100 | 100 | 100 | [1] 100 | ---- | ---- | ---- | ---- |
| | do | Yes | 2 | 8 | 16 | 16 | [1] 16 | ---- | ---- | ---- | ---- |
| Daily alternation between 15° and 32°. | N. P | do | 0 | 6 | 6 | 6 | [1] 6 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 5 | 5 | 5 | [1] 5 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 4 | 4 | 4 | [1] 4 | ---- | ---- | ---- | ---- |
| Daily alternation between 20° and 32°. | N. P | do | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| About 18° | Soil | do | 0 | 0 | 0 | 0 | 0 | [2] 0 | ---- | ---- | ---- |
| R. cynosbati: | | | | | | | | | | | |
| 5° | N. P | do | 0 | 0 | 0 | 5 | 8 | 8 | 12 | 13 | 13 |
| | Peat | No | 0 | 0 | 0 | 16 | 16 | 16 | 18 | 21 | 21 |
| | do | Yes | 0 | 0 | 0 | 1 | 1 | 4 | 7 | 7 | 7 |
| 10° | N. P | do | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 5 | 5 |
| | Peat | No | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 5 | 5 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 |
| 15° | N. P | do | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| | Peat | No | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20° | N. P | do | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Peat | No | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | do | Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25° for 2 months, then daily alternation between 10° and 25°. | N. P | do | 0 | 0 | 0 | 6 | [1] 6 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 0 | 5 | 11 | [1] 11 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 0 | 0 | 8 | [1] 8 | ---- | ---- | ---- | ---- |
| 32° for 2 months, then daily alternation between 10° and 25°. | N. P | do | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 0 | 11 | 37 | [1] 37 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| Daily alternation between 10° and 25°. | N. P | do | 3 | 17 | 17 | 17 | [1] 17 | ---- | ---- | ---- | ---- |
| | Peat | No | 21 | 22 | 22 | 22 | [1] 22 | ---- | ---- | ---- | ---- |
| | do | Yes | 6 | 12 | 12 | 12 | [1] 12 | ---- | ---- | ---- | ---- |
| Daily alternation between 15° and 32°. | N. P | do | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| Daily alternation between 20° and 32°. | N. P | do | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| | Peat | No | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| | do | Yes | 0 | 0 | 0 | 0 | [1] 0 | ---- | ---- | ---- | ---- |
| About 18° | Soil | do | 0 | 0 | 0 | 0 | 0 | [2] 0 | ---- | ---- | ---- |

[1] Discarded May 22, 1928.
[2] Discarded in July, 1928.

As shown in Table 3, no germination of *Ribes rotundifolium* seeds had occurred within one and one-half months in 34 of the 36 samples kept at constant temperatures. In the remaining 2 samples, one from each lot, germination of 5 and 4 per cent of the seeds, respectively, occurred after one month at 15° C. After nine and three-fourths months, some seeds of this species had germinated in all but 1 of the 18 samples kept at constant temperatures of 5°, 10°, and

15°. The average percentage of germination for the 6 samples at 5° was 20.5; for the 6 at 10°, 13.2; and for the 6 at 15°, 8.7. No germination was secured from the 6 samples kept at 20° for nine and three-fourths months or from the 6 samples kept at each of the constant temperatures, 25° and 32°, for two months.

Since no germination was secured at constant temperatures above 15° C., it is suggested that this temperature represents about the maximum constant temperature at which germination of seeds of this species will take place. These tests indicate that 5° was the most favorable constant temperature tested for the germination of seeds of this gooseberry. The fact that the highest germination percentage secured at 5° was but 37 after nine and three-fourths months indicates that constant temperatures at best are not optimum for prompt germination of seeds of *R. rotundifolium*.

Better germination percentages were secured in a shorter period from some of the samples subjected to daily alternation of temperature. Each of the six samples of *Ribes rotundifolium* seeds showed some germination after one month at daily alternation between 10° and 25° C. (Table 3.) Even the samples that had been kept at constant temperatures of 25° and 32° for two months with negative results showed some germination in 11 out of 12 cases within two months after they were changed to daily alternation between 10° and 25°. Five of the six samples of this species that were subjected to daily alternation between 15° and 32° showed some germination after three months, but none was secured from the corresponding six samples kept at daily alternation between 20° and 32° for five months. Daily temperature alternation between 10° and 25° which resulted in complete germination in one sample within two months, and in a mean percentage germination for the six samples of 61 after three months, gave the highest germination. Since no germination was secured from the six samples of *R. rotundifolium* seeds after five months at daily alternation between 20° and 32°, it is evident that this temperature range was above the highest temperature favorable for the germination of these seeds.

In the tests at alternating temperatures, all germination secured took place within three months (largely within one and one-half months), indicating that alternating temperatures are favorable for the prompt germination of *Ribes rotundifolium* seeds. On the other hand, of the 17 samples showing germination at constant temperatures, the earliest germination occurred in 2 cases in the 1-month period; in 6 cases, in the 3-month period; in 5 cases, in the 4-month period; and in 4 cases in the 7-month period. Also, in three of these cases some seeds germinated during the 9¾-month period. These tests show a more delayed germination at constant than at alternating temperatures and suggest that the test period was not long enough to secure final germination in at least some of the samples at constant temperatures.

In tests at corresponding constant temperatures, seeds of *Ribes cynosbati* germinated more slowly and, except in one case, less abundantly than those of *R. rotundifolium* collected at approximately the same time (lot 1). At daily alternation between 10° and 25° C., the seeds of *R. cynosbati* germinated as soon as those of *R. rotundifolium*, but less abundantly. Seeds of the former species did not germinate within five months at daily alternating temperatures between 15° and 32°, but some germination of the latter species was secured at these temperatures. Otherwise, the same general results were obtained with the seeds of *R. cynosbati* as with those of *R. rotundifolium*. The relatively poor germination of *R. cynosbati* seeds indicates either that the seeds tested were of low vitality or that the most favorable conditions for their germination were not included in these tests.

Incidentally, the indicated influences on germination of Uspulun sterilization of the seeds and of neutralization of the peat are of interest. Comparison of germination results of tests in which Uspulun sterilization was the only controllable variable shows that higher germination was secured from the untreated samples than from the sterilized seeds in 19 of the 27 pairs of tests, while the reverse is true for 1 pair of tests. (Seven pairs of tests produced no germination.) The mean germination for the untreated seeds was 29.55 per cent, and for the treated seeds 7.6 per cent. Comparison of germination results of tests in which peat neutralization with $CaCO_3$ was the only controllable variable shows that higher germination was secured from samples stratified in neutralized peat than from samples stratified in natural peat in 15 of the 27 pairs of tests, while the reverse is true for 4 pairs of tests. (Eight pairs of tests produced no germination.) The mean percentage of germination for samples in neutralized peat was 19.74 per cent, as compared with 8 per cent for samples in natural peat.

The writer conducted a small germination test at Washington, D. C., using seeds of *Ribes rotundifolium* from the same bulk lot (lot 2) which is represented in Table 3. Two samples of 50 seeds each were placed between wet blotters on April 10, 1928, one after soaking several hours in tap water, the other after soaking 35 minutes in commercial sulphuric acid, drying between blotters, and washing in tap water. A wick of blotting paper connecting the improvised germination blotters with a supply of tap water kept the seeds moist at all times. The seeds were kept in the office, and temperature records were not made. The results of the test, which was continued for 34 days, are shown in Table 4.

TABLE 4.—*Comparative germination of untreated seeds of Ribes rotundifolium and of those treated with commercial sulphuric acid*

[Experiment began Apr. 10 and ended May 14, 1928]

| Treatment | Cumulative germination percentages at the end of— | | | | |
|---|---|---|---|---|---|
| | 15 days | 20 days | 25 days | 30 days | 34 days |
| Acid treated | 12 | 24 | 28 | 30 | 34 |
| Untreated | 0 | 4 | 12 | 16 | 16 |

At the end of the test period, the percentages of ungerminated seeds that appeared to be still sound were 97 and 93, respectively, for the acid-treated and the untreated seeds. Although the data are meager, both as to number of seeds tested and as to duration of experiment, the results given in Table 4 indicate that the 35-minute treatment with sulphuric acid increased both the speed and the percentage of germination of seeds of this species.

A second experiment was started on June 15, 1928, at Warrensburg, N. Y., with seeds from the same bulk lot as used in the preceding experiment. Instead of the commercial grade of sulphuric acid, that used was of analytical reagent quality, fuming, with 50 per cent free sulphur trioxide. Three samples of 120 seeds each were soaked in acid for periods of 10, 20, and 30 minutes, respectively, after which the seeds were rubbed between moist blotting papers. Because of the strength of the acid and the use of moist blotting paper in cleaning the seeds after treatment, some of the seeds were completely destroyed, and others seemed badly damaged. The seeds not completely destroyed by the treatment were placed between wet blotters, together with 100 untreated seeds from the same bulk lot, and kept in a well-ventilated room. Moisture was maintained as in the preceding experiment, and also no temperature records were made. The results are shown in Table 5.

TABLE 5.—*Comparative germination of untreated seeds of Ribes rotundifolium and of those treated with fuming sulphuric acid*

[Experiment began June 15 and ended July 23, 1928]

| Duration of acid treatment (minutes) | Seeds treated | Seeds tested for germination | Cumulative germination results after— 15 days | | 38 days | |
|---|---|---|---|---|---|---|
| | *Number* | *Number* | *Number* | *Per cent* | *Number* | *Per cent* |
| 0 | 0 | 100 | 8 | 8 | 24 | 24 |
| 10 | 120 | 109 | 7 | 6 | 7 | 6 |
| 20 | 120 | 107 | 4 | 4 | 4 | 4 |
| 30 | 120 | 107 | 9 | 8 | 10 | 9 |

It is evident from Table 5 that the acid treatment was too severe in this case. The untreated seeds germinated much better than the treated seeds. The striking fact demonstrated by these two experiments, however, is that the seed coats of some seeds of *Ribes rotundifolium* have resistance sufficient to protect the embryo for at least 35 minutes in sulphuric acid.

In order to test the viability of older seeds of Ribes, berries of various species were taken from herbarium specimens 3 to 9 years old and sent to the Boyce Thompson Institute for testing. The herbarium specimens had been pressed and kept between sheets of newspapers in a dry, partly lighted cupboard at office temperatures in Washington, D. C. The seeds were extracted by hand from individual berries between February 18 and 23, 1928, and mailed in vials or in paper packets on April 20, 1928. The tests at the Boyce Thompson Institute were conducted by Johanna Giersbach, who reported that the seeds were planted without sterilization on April 23, 1928, in natural peat at 10° to 25° C. daily alternation. The results of the germination tests are shown in Table 6.

TABLE 6.—*Germination of Ribes seeds from herbarium specimens of known age*

[Seeds stratified in natural peat on Apr. 23, 1928, at the Boyce Thompson Institute]

| Lot No. | Species, place, and date of collection | Age of seeds (years) | Number of seeds tested | Cumulative percentages of germination after— | | | |
|---|---|---|---|---|---|---|---|
| | | | | 5 weeks | 6 weeks | 10 weeks | 14 weeks |
| 1 | R. vulgare, Massachusetts, 1925 | 3 | 55 | 3.6 | 5.4 | 14.5 | 16.3 |
| 2 | R. cynosbati, Keshena, Wis., Sept. 26, 1919 | 9 | 70 | 0 | 0 | 0 | 0 |
| 3 | R. cynosbati, Temple, N. H., July, 1921 | 7 | 50 | 8 | 8 | 8 | 8 |
| 4 | R. irriguum Dougl., Post Falls, Idaho, June 3, 1921 | 7 | 80 | 0 | 0 | 0 | 0 |
| 5 | R. hirtellum, New Hampshire, July 25, 1921 | 7 | 50 | 0 | 0 | 0 | 0 |
| 6 | R. hirtellum, South Berwick Junction, Me., Aug. 5, 1920 | 8 | 50 | 0 | 0 | 0 | 0 |
| 7 | R. cynosbati, New Hampshire, July 25, 1921 | 7 | 16 | 0 | 0 | 0 | 0 |
| 8 | R. glandulosum, Littleton, N. H., July 25, 1921 | 7 | 50 | 0 | 0 | 0 | 0 |
| 9 | R. triste, Shawano, Wis., May 28, 1919 | 9 | 25 | 0 | 0 | 0 | 0 |
| 10 | R. americanum, Crawford, Nebr., June 28, 1921 | 7 | 14 | 0 | 0 | 0 | 0 |

Table 6 shows that some seeds of *Ribes vulgare* germinated after nearly three years and that some of *R. cynosbati* germinated after nearly seven years of storage in the herbarium. These results disagree with the observation made by Janczewski (*14*) that germination of Ribes seeds ceases entirely after three years.

## FIELD INVESTIGATIONS OF NATURAL GERMINATION OF RIBES SEEDS FOLLOWING DISTURBANCE OF THE FOREST FLOOR

Since 1922 the writer has given considerable time to field investigations of the life histories of Ribes species associated with white pine in New York and New England. In 1927 an investigation was started in the southeastern Adirondack region to obtain the principal facts concerning the amount and cause of the fluctuation of Ribes in size and numbers during the rotation of a pine crop. During the course of this investigation it was observed on numerous occasions that an abundant restocking of Ribes from seeds was not dependent on the simultaneous presence of fruit-producing plants in the vicinity. Frequently large numbers of young Ribes seedlings were found on sites where it was evident that fruit had not been produced for several years.

It was also observed in practically every case where Ribes seedlings were abundant that some recent major disturbance of the forest floor had preceded their germination. These observations led to the systematic investigation in 1927 and 1928 of the relation of forest-floor disturbances to the occurrence of Ribes seedlings. Sample areas located in the southeastern Adirondack region and recently subjected to such disturbances were studied in detail. In addition, several plots located in places where the forest floor had remained undisturbed were experimentally disturbed in 1927 and thoroughly reexamined in 1928. On all these areas and plots, *Ribes rotundifolium* was the principal species of Ribes, and when no other specific name is mentioned, the following discussion applies to this species.

### LUMBERING DISTURBANCE

The white pine areas of the southeastern Adirondack region are, for the most part, subject to frequent lumbering operations. These are often carried on while the ground is not protected by snow, and, as a result, the forest floor is usually torn up considerably during the process of felling the trees and taking out the logs.

A plot typifying both general logging disturbance and haul-road disturbance was located near the village of Warrensburg, N. Y., for the purpose of studying the Ribes following such disturbances. This plot was 60 feet wide by 109 feet long. It was located at the foot of a gentle slope forested with pine, hemlock, and hardwood that had been logged for the better softwoods in 1923 and 1924. The plot was laid out so as to include portions of two haul roads.

Sufficient information of the history of the area was available in 1927 to permit determination of the status of the forest stand and the Ribes population as of 1923, before the logging. In 1923 the plot supported a dense growth of pine, hemlock, and hardwood, varying in age from 30 to 150 years and having a total basal area of 23.1911 square feet, or 154.5 square feet per acre. The trees, 5 inches or more in diameter breast high, then present numbered 28, or at the rate of 186 per acre. According to considerable unpublished data obtained by the writer on the life history of *Ribes rotundifolium*, the competition of this stand was sufficient to prevent the bearing of fruit by any plants of this species that were then present on the plot.

In 1927, 10 plants of *Ribes rotundifolium* that had been in existence prior to the logging were found on this plot. All these plants conformed to a typical habit of growth of suppressed gooseberries, being reclining and partly buried bits of stem tufted with a few leaves above the surface and a few feeder roots below, adding barely enough growth above to offset the decay of the buried end. It is known that gooseberries in this condition of growth do not produce fruit. These data indicate that no Ribes fruit had been produced on this plot in recent years.

When the plot was logged selectively in 1923, all the merchantable white pines, along with a few hemlocks and hardwoods, were cut. Seven of the 28 trees 5 inches or more in diameter breast high were left by the loggers. Three of these, old hemlocks of 21, 23, and 25 inches diameter breast high, being in poor form, were left standing in the central portion of the plot. The logging disturbance under these trees was slight, but elsewhere over the plot the disturbance of the forest floor was general. In the two haul roads crossing the plot the litter and duff were ground into the mineral soil in taking out the logs. The locations of the haul roads, of the three remaining hemlocks, and of all the Ribes found on the plot in 1927 are shown in Figure 1.

In 1927, 244 seedlings of *Ribes rotundifolium* resulting from seed germination since the 1923 logging were found on this plot. It is evident from Figure 1 that the great majority of these occurred in the haul roads, where the forest floor disturbance was greatest. As a comparison, the Ribes seedlings occurring since the logging were present in the haul roads at the rate of 3,818 per acre, while over the rest of the plot the occurrence was at the rate of 654 per acre.

A careful examination of the seedlings showed that 21 had originated in 1924, 122 in 1925, 81 in 1926, and 20 in 1927. Yearly observations by the writer on other plots show that a considerable mortality takes place among seedlings of *Ribes rotundifolium* during the first and second years after seed germination. It is probable, therefore, that many more Ribes seeds germinated following the logging disturbance on this plot than is indicated by the number of seedlings remaining in 1927, four years after the disturbance took place.

The seeds responsible for these plants had probably remained dormant in the litter, duff, and humus of the forest floor from a time when forest conditions on and near the plot were favorable for the production of Ribes fruit until the forest-floor disturbance caused by the logging operation brought about conditions favorable for their

FIGURE 1.—Map of the study plot near Warrensburg, N. Y., which was logged in 1923. The haul roads that crossed the plot are shaded. The circles and black dots mark the location of the Ribes found on the plot in 1927, four years after the logging, the former representing the Ribes that were present on the plot in 1923 before the logging and the latter the Ribes plants that originated after the logging. The crosses mark the location of the three large hemlocks left by the loggers

germination. Unfortunately, it was impossible to locate a comparable area in the vicinity which had not been recently logged and which could be properly used as a check against the conditions just described.

### FIRE DISTURBANCE

The disturbance of the forest floor caused by fire differs somewhat from that caused by lumbering. Lumbering scores, mixes, and agitates to varying degrees the various floor layers, while fire consumes the inflammable portions of these layers to varying depths, exposing but not agitating lower layers of the forest floor which have been buried for widely varying periods. Light burning removes merely the dry litter and some of the duff, while heavy burning under favorable conditions may consume practically all the material down to the mineral soil.

In addition to exposing lower layers of the forest floor, fire may reduce the acidity of the soil. Skutch (*19*) found that the soil acidity in the Mount Desert Island burn of 1924 tested a year later ranged from pH 5.3 to 6.6, while the soil of the near-by unburned forest had an acidity of pH 4.5 to 5.0. Since neutralized peat was found to be a much better medium for the germination of the seeds of *Ribes rotundifolium* and *R. cynosbati* than natural peat in the laboratory tests already described, it is probable that the reduction of soil acidity in pine forests by fire is an important factor in providing conditions favorable for the germination of seeds of these species.

Most of the forest fires in the white pine areas of the southeastern Adirondack region occur either on grassy fields growing the first crop of forest trees since cultivation or on areas recently logged. Observations by the writer indicate that abandoned fields growing the first crop of forest trees since cultivation are practically free of Ribes. On such areas the only Ribes seeds that may accumulate in the litter and duff during the first forest rotation are those introduced from extraneous sources. The Ribes seeds produced on such areas before the period of cultivation began are no longer a factor; those which may still be viable have been buried too deep by the cultivation to become important as a source of new plants. As a result, fire disturbances on such areas are seldom followed by a prompt and general restocking of Ribes.

This is well illustrated by the data taken on a plot, 0.1303 of an acre in area, located near Warrensburg, N. Y. Data obtained in 1927 indicated that this plot was part of an abandoned hayfield that began to seed in with white pine about 1890. In early May, 1925, the plot supported a dense growth of pure white pine, numbering 417 individuals from 1 to 11 inches in diameter breast high, or at the rate of 3,200 per acre. At that time the total basal area of the stand on the plot was 20.7313 square feet, or 159.1 square feet per acre. On May 13, 1925, the plot was swept by a crown fire that killed all but two of the trees and burned off the dry litter and part of the duff of the forest floor. Careful examination in 1927 revealed but two Ribes, both 1926 seedlings, on this plot, or at the rate of 15 per acre.

By way of contrast, an adjoining old forest area, which had recently been logged and which was likewise swept clear of living trees by the same fire, had 296 Ribes seedlings per acre in 1927, as shown by the data from two sample plots which will be discussed in the next few paragraphs. Fire disturbance on the old field plot failed to result in a more general regeneration of Ribes, evidently because no seeds had been produced on the plot subsequent to the period of cultivation, the only Ribes seeds accumulated in the forest floor being the few presumably introduced from extraneous sources.

When Ribes seedlings occur on an area that has been recently logged and burned, it is often impossible to separate definitely the influences of these disturbances on the germination of Ribes seeds. Unfortunately, no site was found for a study of the effect of fire alone on the Ribes restocking of an old pine area. However, an old forest area near Warrensburg, N. Y., on which fire disturbance had followed a lumbering operation, was studied to determine the extent of Ribes seed germination following such disturbances.

Two plots totaling 0.4966 of an acre were laid out in a shallow and dry depression about in the center of this area, which was lumbered in 1923 and 1924 and burned on May 13, 1925. The data on the two plots, one situated in the bottom of the depression, the other within 100 feet of the first on a gentle slope, differed very little and are therefore grouped for presentation and discussion.

Stump data taken in 1927 showed that these plots supported a full-stocked stand of uneven-aged white pine, hemlock, and scattered hardwoods before the 1923 logging. At that time 114 trees, or 230 per acre, 5 inches or more in diameter breast high and from 30 to 95 years of age, were present on the plots. The basal area of the forest stand on the plots was 77.8146 square feet, or 156.69 square feet per acre. The shade of this stand was sufficient to prohibit any Ribes present from bearing fruit.

In 1923 and 1924 the lumbering operation removed 70 of the 114 trees. The fire of May 13, 1925, killed the 44 remaining trees as well as all of the smaller ones left by the lumberman. The trees killed by the fire were removed for firewood later in 1925. On these plots, therefore, a series of three disturbances occurred. The logging of the mature timber in 1923 and 1924 undoubtedly was responsible for a considerable mixing up of the layers of the forest floor. The fire in turn burned off all of the logging débris and litter and most of the dry duff. The subsequent removal of deadwood, because of the small size of the remaining individual trees, probably caused but slight disturbance of the surface exposed by the fire.

In July, 1927, a total of 147 *Ribes rotundifolium* plants, or 296 per acre, were found on these two plots. Only 5 Ribes of the 147 found were plants originating before the logging of the mature stand. An examination of the root systems of these five plants showed that each one had originated from a layering stem of another Ribes plant which had subsequently gone out of existence.[8] The roots of these natural layers were typical of those of suppressed Ribes, which do not produce fruit.

In 1924, the year following the logging, a number of Ribes seedlings started to grow from the disturbed forest floor. Of this unknown number, 23 established themselves well enough in one growing season to survive the spring fire of 1925. Then, immediately following the fire in 1925, a large germination of Ribes seeds occurred, and 101 of these seedlings were living in 1927. Germination continued probably at a much reduced rate in 1926, the year after the fire, as only 17 seedlings of 1926 origin were found in 1927. Apparently the germination of Ribes seeds had practically ceased in 1927, since but one plant originating in that year was found. Although several thousands of young seedlings of *R. rotundifolium* have been observed by the writer, none have been found bearing fruit within four years after germination from seed. On this basis, all the seedlings found on these plots in 1927 were too young to produce fruit.

The most logical explanation of the occurrence of these Ribes seedlings, as will be corroborated by additional observations reported in this bulletin, is that they resulted from the germination of seeds that had been lying in the deeper duff or humus. These seeds had probably been disseminated over the forest floor during that portion of the past forest rotation favorable for the fruiting of Ribes and had remained dormant until the forest-floor disturbance caused by logging and fire exposed them to conditions favorable for germination.

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[8] For the sake of brevity, Ribes that originated in this manner will be referred to in this bulletin as natural layers, in contrast to seedlings, or plants that grew directly from seeds.

### WINDFALL DISTURBANCE

Although not a region frequented by storms of cyclonic proportions, the southeastern Adirondacks occasionally suffer severe windstorms. The soil mantle covering the bedrock in the forested slopes of this region is generally shallow, and such storms upturn many softwood trees with shallow root systems. The root systems of these wind-thrown trees raise above the ground level irregular patches of the forest floor, often exposing the underlying bedrock. The layers of the forest floor are more or less disturbed over semicircular areas from 4 to 20 feet in diameter about each upturned tree. The major feature of the disturbance is the exposure of portions of floor layers which have been buried for many years under the accumulating forest litter.

The site selected for studying the effect of windfall disturbance on Ribes restocking was located near the top of a hillside east of the Schroon River, between the small settlements of Schroon Falls and Schroon River, N. Y. The study area was situated about in the center of a 543-acre block of State land from which the Ribes had been eradicated in 1923 by hand methods (*16*) to protect the white pine from blister rust. The eradication crew had removed over 100 Ribes per acre from this block, the principal species being *R. rotundifolium* and *R. glandulosum*. The exposure of the hillside was western and southwestern, the slopes were moderate, and a few low ledges occurred in the portion affected by the windfall. The type was mixed pine and hardwood, ranging up to about 70 years of age. No older trees were found, nor were any stumps of a preceding stand located on the study area. The forest canopy was irregular because of the uneven age of the stand and the frequency of small areas of exposed bedrock. These areas had smooth surfaces and gentle to moderate slopes terminating in more or less irregular benches. The benches, as well as other subsurface irregularities on this area, were characterized by a soil-humus horizon containing charcoal and sometimes several inches deep.

These observations relating to forest and site indicate that a severe fire preceded the present forest stand by an indeterminate period. The mineral soil was sand and gravel, very shallow for the most part. In a few places where the soil was found to be 2 or 3 feet deep, it contained large angular bowlders. Humus occurred also in an individual and shallow layer on the mineral soil or soil-humus horizons and in thin sheets on some of the rock outcrops, covered lightly by duff and litter or sometimes by moss. In places, water could be squeezed out of the humus, duff, and moss several days after a rain in midsummer. The coolness of the site was a noticeable characteristic even on the hottest summer days. The elevation of the hilltop is given as 1,672 feet above sea level on the United States Geological Survey maps.

Because the white pine on this eradication block had suffered considerable damage from blister rust prior to the removal of the Ribes, the writer has visited it several times annually since October, 1922, except in 1926. On the first visit in 1927 it was noticed that a severe windstorm had uprooted about 100 trees scattered over about 30 acres in the central portion of the eradicated area. This windfall occurred during the autumn of 1925 or the spring of 1926, perhaps during the windstorm of October 25, 1925. This portion of the area and some of the surrounding region within this eradication block were carefully scouted at random for Ribes during July, 1927. The search revealed but few old Ribes. All those found were small and incapable of bearing fruit, being for the most part layered fragments of bushes removed in 1923. The dried remains of hundreds of large bushes which had been uprooted in 1923 were still visible in crotches of trees or on exposed rock surfaces where they had been placed by the men who had performed the eradication work.

However, in spite of the fact that the production of Ribes seeds was stopped by the 1923 eradication, a large number of seedlings were found in 1927. On examination, these proved to be largely of 1927 germination, although some were of 1924, 1925, and 1926 origin. Ninety-one per cent of the 1926 and 1927 seedlings were found within the zones of ground disturbance around upturned trees. The remainder of the 1926 and 1927 seedlings found were widely scattered and definitely associated with minor disturbances of the forest floor. Since the evidence of minor disturbances is soon effaced, no attempt was made to associate the seedlings of 1924 and 1925 origin definitely with minor disturbances that may have preceded their inception. Some of the minor disturbances which preceded the appearance of the younger seedlings were obviously caused by the following:

Erosion of exposed mineral soil, humus, duff, and litter, especially at the edges of the thin mantle partly covering rock outcrops, and in crevices of ledges and bedrock.

Removal of large Ribes plants in 1923 which disturbed the litter, duff, humus, and mineral soil, exposing these to erosion.

Pawing or scratching of the surface by animals.

Without further discussion of the relatively few Ribes seedlings found in association with these minor disturbances, consideration will be given to the large number of seedlings of *R. rotundifolium* of 1926 and 1927 origin found within the areas disturbed by upturned trees. The unusual location of many of these with relation to the normal ground surface furnishes valuable information on the longevity of the seeds from which they originated.

The region of disturbance around each upturned tree was studied separately because the scattered distribution of upturns prevented their inclusion in one plot. The seedlings found on and near the upturns were classified according to their exact location with relation to the upturned tree. The seven zones of location used are shown in Figure 2.

Of the many upturns on this area resulting from the storm late in 1925 or early in 1926, the first 53 located were thoroughly examined and were numbered in order as found. Ribes seedlings of 1926 or 1927 origin were found on 38 upturns, or 72 per cent of the 53 examined. Of these upturns, 16 per cent had seedlings in zone A, 66 per cent in B, 37 per cent in C, 61 per cent in D, 37 per cent in E, 26 per cent in F, and 5 per cent in G. Table 7 contains the pertinent data on these 38 upturns, including the number of seedlings found in each zone of disturbance around each upturned tree. The 15 upturns omitted from this table represent those on which no Ribes seedlings were found. The angles of these upturns ranged from 20° to 90°, and the ages of the trees from 35 to 70 years.

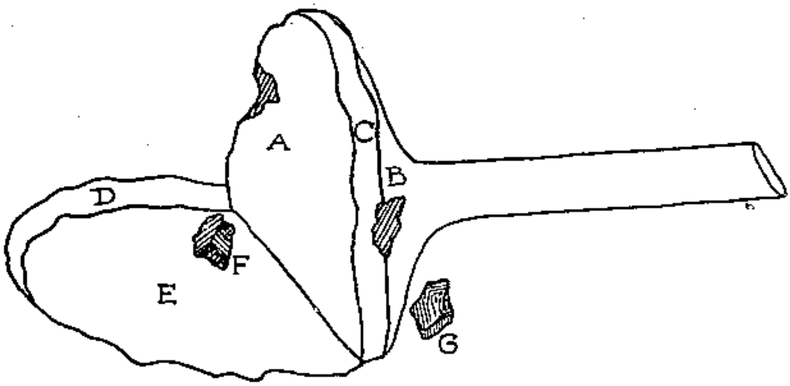



FIGURE 2.—Diagrammatic view of upturn to show zones referred to in text: A, Under face of root ball; B, upper face of root ball; C, edge of root ball; D, edge of hole; E, bottom of hole; F, clod dropped back into hole; G, clod thrown ahead of upturn

TABLE 7.—*Location and number of Ribes seedlings of 1926 and 1927 origin found during July and September, 1927, on 38 upturns near Schroon River, N. Y.*

[The trees were wind thrown during the autumn of 1925 or the spring of 1926; the zone represented by each letter is shown in fig. 2]

| Upturn No. | Age of upturned tree | Angle of upturned mass | Number of seedlings in zone— | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | All |
| | *Years* | *Degrees* | | | | | | | | |
| 2 | 60 | 90 | 18 | 3 | 1 | 4 | 3 | 5 | 8 | 42 |
| 3 | 60 | 85 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 3 |
| 4 | 60 | 50 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 5 |
| 5 | 50 | 80 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 8 |
| 6 | 58 | 80 | 28 | 69 | 3 | 13 | 11 | 13 | 0 | 157 |
| 7 | 55 | 45 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 |
| 8 | 55 | 30 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 9 | 55 | 45 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| 11 | 55 | 70 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 12 | 60 | 50 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 14 | 65 | 75 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| 15 | 60 | 60 | 0 | 2 | 0 | 0 | 2 | 1 | 0 | 5 |
| 16 | 55 | 50 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 5 |
| 17 | 25 | 100 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 18 | 60 | 75 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| 21 | 60 | 90 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| 22 | 55 | 90 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| 26 | 50 | 100 | 5 | 1 | 0 | 0 | 0 | 0 | 1 | 7 |
| 27 | 55 | 60 | 0 | 4 | 1 | 5 | 0 | 0 | 0 | 10 |
| 28 | 60 | 80 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 14 |
| 29 | 45 | 90 | 1 | 8 | 1 | 0 | 1 | 0 | 0 | 11 |
| 30 | 55 | 90-180 | 2 | 6 | 9 | 17 | 0 | 16 | 0 | 50 |
| 31 | 35 | 72 | 12 | 6 | 2 | 4 | 0 | 0 | 0 | 24 |
| 33 | 70 | 60 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 34 | 60 | 75 | 0 | 4 | 5 | 2 | 1 | 0 | 0 | 12 |
| 36 | 30 | 50 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 5 |
| 37 | 50 | 15 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 4 |
| 38 | 35 | 60 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| 39 | 60 | 80 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 4 |
| 40 | 60 | 80 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| 42 | 55 | 85 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 43 | 40 | 80 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 |
| 46 | 40 | 70 | 0 | 1 | 0 | 9 | 0 | 0 | 0 | 10 |
| 48 | 45 | 60-100 | 0 | 1 | 0 | 14 | 0 | 12 | 0 | 27 |
| 49 | 70 | 40 | 0 | 3 | 0 | 0 | 0 | 14 | 0 | 17 |
| 51 | 50 | 65 | 0 | 7 | 0 | 1 | 1 | 12 | 0 | 21 |
| 52 | 45 | 70 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 53 | 70 | 55 | 0 | 6 | 4 | 4 | 0 | 6 | 0 | 20 |
| Total | | | 66 | 169 | 35 | 90 | 30 | 81 | 9 | 495 |

A total of 495 Ribes seedlings were found in the zones of disturbance of these 38 upturns in 1927. Of these seedlings, 13 per cent occurred in zone A, 34 per cent in B, 7 per cent in C, 20 per cent in D, 7 per cent in E, 17 per cent in F, and 2 per cent in G. Only 43 of these were of 1926 origin, and none of these were found in zones A and G. (Table 8.) Because of the severe winters in this region and the added exposure of sites on the raised root masses, it is probable that winterkilling had materially reduced the number of 1926 seedlings before the study was started. Of the total of 495 plants, 27 were *R. glandulosum* and 468 were *R. rotundifolium*. Ribes seedlings were found most frequently on the upper face of the root ball and around the edge of the hole left by the upturn (zones B and D). Fifty-five per cent of the 495 plants were found in these two zones (B and D) on 66 per cent and 61 per cent, respectively, of the 38 upturns having Ribes seedlings.

TABLE 8.—*Species and year of origin of the Ribes seedlings listed in Table 7*

| Species | Year of origin | Number of seedlings found in zone— | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | All |
| R. rotundifolium | 1926 | 0 | 8 | 4 | 8 | 3 | 5 | 0 | 28 |
| | 1927 | 66 | 153 | 31 | 90 | 33 | 58 | 9 | 440 |
| R. glandulosum | 1926 | 0 | 2 | 0 | 1 | 0 | 12 | 0 | 15 |
| | 1927 | 0 | 6 | 0 | 0 | 0 | 6 | 0 | 12 |
| Both | 1926 | 0 | 10 | 4 | 9 | 3 | 17 | 0 | 43 |
| | 1927 | 66 | 159 | 31 | 90 | 33 | 64 | 9 | 452 |
| Total | | 66 | 169 | 35 | 99 | 36 | 81 | 9 | 495 |

Seedlings of *Ribes rotundifolium*, 66 in number and all of 1927 origin, were found on the under faces of the root masses (zone A) of 6 of the 38 upturns. (Table 7.) The important bearing of this discovery on the subject of longevity of Ribes seeds will be developed by the consideration in detail of the circumstances of their occurrence.

Upturn No. 31 was one of the six having Ribes seedlings on the under face of the root ball. This upturned tree was a small white pine about 35 years old which had been growing from a blanket of mineral soil, soil humus, duff, and litter 1 to 10 inches in depth over bedrock. When blown over, the roots of this pine lifted up a semicircular portion of this blanket, 6 feet long by 3 feet in height, and 3 to 9 inches in thickness, practically baring the underlying bedrock. The tree fell uphill, and, as a result, the root mass did not reach a perpendicular position. Its under face had an overhang of 1 foot in 3 feet of height, being raised to an angle of only 72° from horizontal.

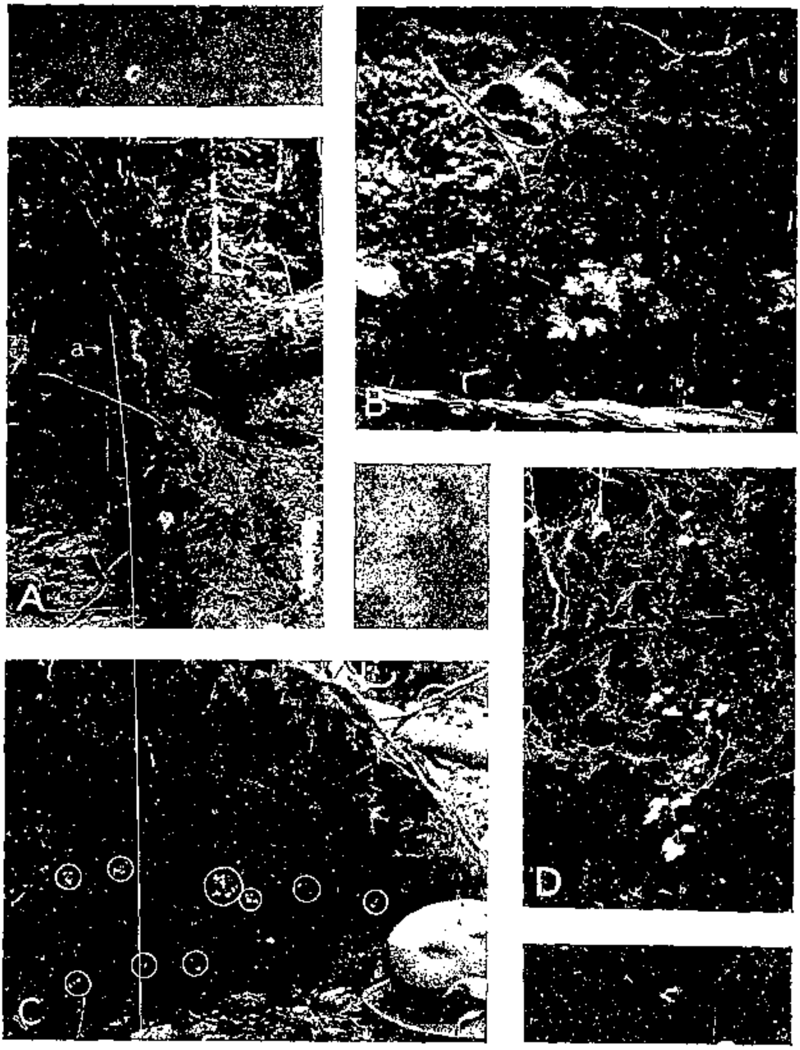
When this upturn was examined in July, 1927, 12 Ribes seedlings were found growing from the under face of the mass of mineral soil and humus woven with the fibrous and large roots of the upturned tree, as shown in Plate 1, D. These 12 plants were shallowly rooted in this overhanging surface in five separate groups. The thickness of the root mass measured at the location of each of the five groups of seedlings varied from 5 to 7 inches. The first 3 to 5 inches from the under face was composed of a compact layer of mineral soil and humus, thick with fibrous roots; the remaining 2 inches nearest the upper face was duff and litter.

Because of the angle of overhang of the under face of this upturn, the seeds from which these plants grew could not have become lodged there after the windfall occurred through any natural means of dispersal. These Ribes seedlings were growing from that portion of the forest floor which had been 5 to 7 inches below the normal surface prior to the windfall. Close inspection failed to indicate means whereby the seeds responsible for these plants might have been forced or carried to the soil-humus layer subsequent to its formation. The only reasonable explanation of the presence of viable Ribes seeds 5 to 7 inches below the normal surface of the forest floor is that they were deposited there while the now compact lower layers of mineral soil and humus were accumulating on the bedrock, and that they have lain there in a dormant condition throughout the intervening years.

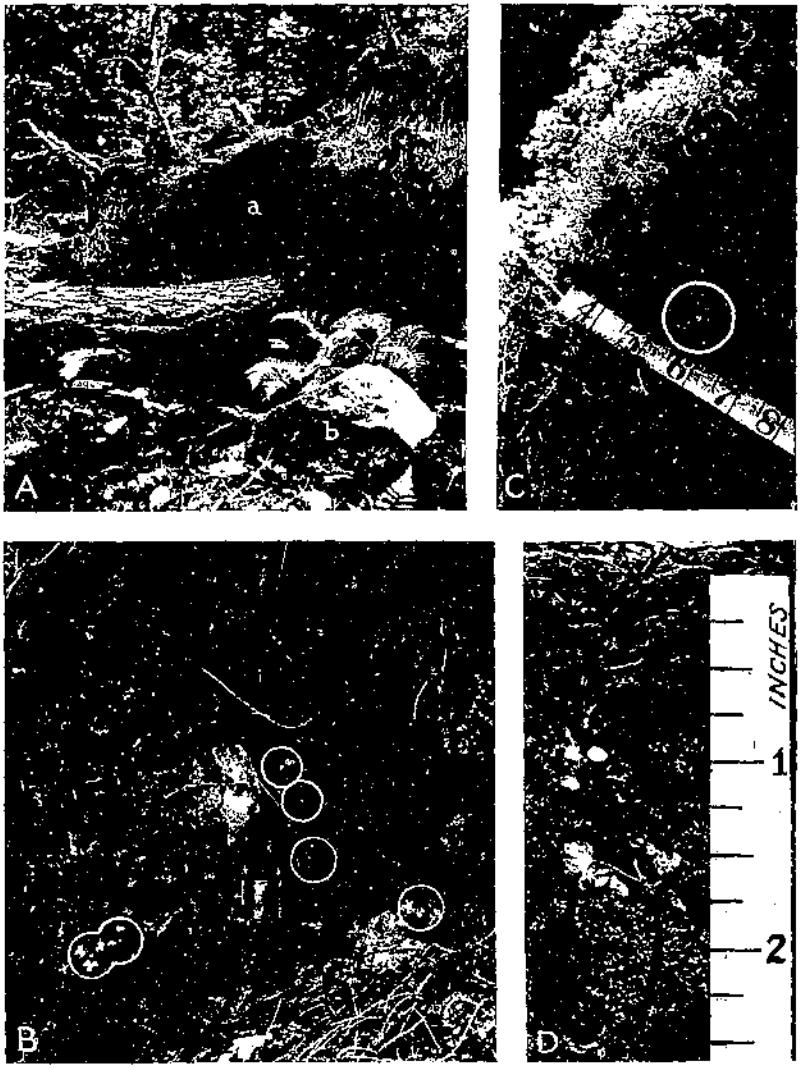
Ribes seedlings were found in correspondingly similar situations on other upturns examined. On the under face of upturn No. 6, for instance, 28 Ribes seedlings of 1927 origin were found. (Table 7 and pl. 1, C.) This white pine tree was approximately 58 years of age. It was rooted in a thin blanket of soil humus and mineral soil resting on bedrock. When blown over, the root system lifted up to an angle of approximately 80° with horizontal, an irregular patch of this blanket, 13 feet long by 7 feet high. The angle of overhang of the under face of this mass is shown by the perpendicular string, Plate 1, A, *a*. The thickness of the upturn varied from 1 to 12 inches, but most of it ranged from 2 to 4 inches. Of the 28 seedlings found growing from the under face of this upturn, 19 were located near one end and 9 near the other end or wing of the upturned mass. The thickness of the mass where the 19 plants were found (pl. 1, C) varied from 1½ to 3½ inches, of which 1 inch was duff and litter and the rest a compact mass of soil humus threaded with fibrous roots of the tree. The nine seedlings found near the other end on the underside of the upturned mass were growing from a soil-humus layer 3 to 4½ inches below the normal surface. At both ends the seedlings were shallowly rooted in the lower surface of the soil-humus layer of the forest floor that had been raised off the bedrock by the upturning of the tree.

A total of 169 Ribes seedlings, 8 of which were *R. glandulosum* (Tables 7, 8), were found growing from the upper faces of the root masses (zone B) of 25 of the 38 upturns. The seedlings found growing on the upper faces, as well as those on the under faces, were usually located near the ends or wings of the root mass. The favorableness of these wing portions of zones A and B for the occurrence of Ribes seedlings was observed on practically every upturn where seedlings were found in either of these two zones. Also it was observed that these portions, being nearest the undisturbed forest floor, were less subjected to drying out. It may be that the moisture conditions were more favorable for Ribes germination and survival on the wings than elsewhere on the upturned root ball.

The largest number of seedlings found growing on the upper face of an upturned mass was the 89 recorded for upturn No. 6, already




A.—Upturn No. 6, typical of many that were examined, showing the blanket of litter, duff, soil-humus and mineral soil lifted off the bedrock by the root system of the wind-thrown tree. Note the overhang of the lower face of the upturned mass as compared with the perpendicular string *a*.
B.—Upper face of one end or wing of upturn No. 6 (shown in the foreground of A), showing 73 Ribes seedlings of 1926 and 1927 germination growing above the normal ground line, as marked by the stick. No Ribes were found on the undisturbed forest floor adjacent.
C.—Underface of the same wing of upturn No. 6, showing most of the 19 Ribes seedlings of 1927 germination found growing there (circled in white). These seedlings were growing from that part of the soil-humus layer which was resting on bedrock before the disturbance, $1\frac{1}{2}$ to $3\frac{1}{2}$ inches below the normal surface of the forest floor.
D.—Close-up view of a group of six of the Ribes seedlings of 1927 germination found growing from the underface of upturn No. 31. Before the windfall, this fibrous surface of the soil-humus layer, in which the seedlings were shallowly rooted, was resting on bedrock, 5 to 7 inches below the surface of the forest floor.




A.—Upturn No. 29 showing in the foreground a large rock *b*, which was dislodged by the windfall, and the deep pit *a*, that it left in the litter, duff, and soil-humus of the upper face of the upturned mass.

B.—Close-up view of the pit *a*, seen in A, showing six Ribes seedlings (circled in white) of 1927 germination *growing from* the upturned bottom of the pit.

C.—Section of the forest floor exposed by windfall of tree No. 39, showing a 1927 seedling Ribes (circled in white) growing *from the soil-humus layer* 2½ *inches below the normal surface of the* duff.

D.—A soil section bearing the Ribes seedling shown in C was collected without disturbing the plant and is shown here with a scale in inches. Note that the Ribes was rooted 1½ inches down in the soil-humus layer, above which was a 1-inch layer of duff and litter covered by lichens and moss.

described. Those on the upper face of one of the wings are shown in Plate 1, B. These plants were rooted in the humus and soil-humus layers below the 1-inch horizon of litter and duff and evidently grew from seeds occurring in these layers beneath the duff. The mantle of litter and duff had been loosened and in some places largely dislodged by the movement of the root mass when the tree was blown down. This disturbance may have brought about favorable conditions for germination of seed lying in the humus and soil-humus layers. At any rate, since an examination of the undisturbed forest floor in the vicinity of this upturn failed to reveal any Ribes seedlings, it appears that the causes of this seed germination on the root ball are definitely associated with the disturbances of normal conditions by the upturn.

The direct connection between disturbance of the forest floor and germination of Ribes seeds from the lower layers of the same is well illustrated by the case of upturn No. 29. This was a white pine tree approximately 45 years of age. When it was blown down late in 1925 or early in 1926 a rock 9 by 14 by 20 inches in size (pl. 2, A, *b*) was dislodged from its position at the foot of this tree, leaving a pit 5 to 9 inches deep in the upper face of the upturned mass. (Pl. 2, A, *a*.) The sides of this pit, consisting of an accumulation of litter and duff 2 to 3 inches deep and a lower layer of mixed humus and mineral soil 3 to 6 inches deep, were still intact when first seen in July, 1927. (Pl. 2, A.) The irregular bottom of the pit, raised to a perpendicular position by the windfall, consisted entirely of mixed mineral soil, humus, and small stones, held together by the fibrous roots of the tree. Evidently the rock had been lying on this spot throughout the life of the tree.

In July, 1927, six Ribes seedlings of 1927 germination were found growing from the upright bottom of this pit. (Pl. 2, D.) Apparently the seeds responsible for these plants had been lying in this soil-humus layer since a period between the time of the severe fire and that of the regrowth of the forest cover, when considerable shifting of the soil, humus, and loose rock probably occurred.

A total of 134 Ribes seedlings, including one 1926 seedling of *R. glandulosum*, were found growing from the edges of the root ball (zone C) and on the edges of the holes (zone D) of 25 upturns. (Tables 7 and 8.) These seedlings were all growing from sections of the forest floor exposed by the windfall. The point of origin of these plants was consistently in the humus and soil-humus layers, from 1 to 4 inches below the normal surface of the forest floor. A typical one of these plants is shown in Plate 2, B. This is a view, taken horizontally, of the edge of upturn No. 39, presenting a cross section of the layers which made up the root ball of this upturned tree. The upper layer, about 1 inch in thickness, was litter and duff on which occurred a dense mat of lichens and moss. Below the duff there was a compact layer of mixed humus and mineral soil several inches thick, held together by the root system of the tree.

Above the 6-inch mark on the tape in Plate 2, B, may be seen a Ribes seedling of 1927 origin. The roots of this seedling were shallowly buried in the soil-humus layer at a point normally 2½ inches below the surface of the forest floor. The edge of the upturned mass at this point presented a nearly smooth face with an overhang of 1 inch in 8 of perpendicular distance. The soil humus from which the seedling grew was so closely packed that a section of it including this plant was successfully cut out. This specimen of upturn cross section is shown in Plate 2, C. Evidently the seed responsible for this plant was incorporated in this layer of the forest floor at the time of its formation many years ago.

A total of 36 seedlings of *Ribes rotundifolium* were found growing from the bottom of the holes (zone E) left in the forest floor by 14 upturned trees. (Table 7.) All of these plants were growing in small pockets of soil humus left in crevices and depressions in the bedrock bared by uplifted root masses of windfallen trees. Some of these were located under the overhanging root masses of the upturned trees. For instance, 6 of the 11 seedlings found in the hole of upturn No. 6 were located in crevices well under the overhanging lower face of the root mass, too far under to have grown from any seeds that may have fallen from the upper surface or edges of the upturned mass. Since the bedrock sloped away from the lower face of the upturn (pl. 1, A), the seeds could not have been washed into these crevices from the upper layers of the forest floor after the windfall occurred. Before the windfall, the soil humus that later gave rise to these plants was situated below a 1-inch layer of litter and duff and a compact 2 to 6 inch layer of mineral soil mixed with humus, or a total of 3 to 7 inches below the normal surface of the forest floor. Evidently these six seedlings found in rock crevices under the overhanging root mass originated from seeds deposited years ago when these crevices were being filled and covered over by erosion or by the natural soil-building action of the vegetation.

Of the 90 Ribes seedlings found growing from clods of mineral soil, soil humus, and duff that dropped off the root masses of 11 upturned trees (zones F and G, Table 7), 18 were identified as *R. glandulosum* and 72 as *R. rotundifolium*. These seedlings were growing from the soil-humus layers of the clods, but because of the scrambled condition of these portions of the forest floor no accurate data could be obtained on the original position in the soil layers of the seeds responsible for these plants.

All the 495 Ribes seedlings of 1926 and 1927 origin found on or near the upturn were rooted in the humus or in the mixed humus and mineral soil layers of the forest floor. The seeds from which many of these plants originated had been lying not merely on the surface of the humus layer just beneath the duff but actually well within the humus or the soil-humus layers. Specific cases have just been described wherein the seeds responsible for some of these Ribes seedlings had been situated at depths of 2 to 7 inches below the normal surface prior to the upheaval of portions of the forest floor by the wind-thrown trees. In fact, the seeds responsible for 66 of the 270 seedlings found on the upturned masses were situated so much nearer the under face than the upper surface of the upturned masses that the plants grew out from the under face.

Many Ribes seeds were undoubtedly produced on this area previous to the 1923 eradication. When visiting the area in 1922 and in 1923, while Ribes eradication was in progress, the writer saw many large fruit-producing bushes, especially in the lightly shaded or open rock outcrops that were so prevalent on this tract. That over 100 plants per acre were removed in 1923 and that as late as 1928 bundles of large dead Ribes were still conspicuous in the crotches of trees where they were placed to dry out when uprooted by eradication crews in 1923 are additional indications of the thriftiness of Ribes on this site prior to 1923.

Since the only major changes in the density of the forest cover subsequent to the severe fire that occurred some time prior to 1857 and up to the windfall late in 1925 or early in 1926 have been on the side of increasing shade, it is reasonable to presume that forest conditions on this site had been still more favorable for Ribes growth and fruit production during the earlier portion of the present rotation than they were in 1922 and 1923, when first observed. It is also probable that the fire of unknown date had an influence in aiding the restocking of this area with Ribes and that these plants flourished on the site before the oldest trees of the present stand started to grow. Undoubtedly, during the period of more than 65 years between the fire and the 1923 eradication of Ribes, a large quantity of Ribes seeds was produced and disseminated locally on this area.

During the early portions of this period, before the vegetation and the young forest cover succeeded in anchoring generally the mineral soil and the remaining humus and duff exposed by the fire, it is conceivable that erosion, even on the more moderate slopes of this hillside, caused considerable shifting of the exposed soil. This is indicated by the presence at the time of examination of many areas of bare bedrock 20 to 50 feet in diameter, usually fairly smooth and with but moderate slope, together with the compact accumulation of mixed mineral soil and humus found on the tables or shelves and over the more irregular areas of bedrock lying between the outcrops. The presence of the large rock, which had been lying partly embedded in a mixture of mineral soil and humus until dislodged by upturn No. 29, may also be explained as resulting from soil movement occurring after the severe fire and before the subsequent regrowth of the forest.

The shifting of material as disclosed by these observations undoubtedly resulted in the burial of many Ribes seeds which, as has been indicated, were probably being produced on the area at that time. In addition, many of the Ribes seeds that were produced after erosion had been largely checked by vegetation became distributed locally in the duff and litter of the new forest. As this duff increased and disintegrated, the seeds that were not destroyed were gradually covered by the newly formed humus and as a result were present in the humus layer at the time of the windfall.

During the period of erosion following the fire and subsequently, while the duff of the new forest was building up the humus layer, some of these seeds retained their power to germinate. It seems probable that this dormancy was enforced by the lack of proper conditions for germination. At first, when the fresh seeds are lying near the surface of the forest floor, the responsibility for their dormancy may rest on one or more of several factors, such as the rapid drying out of the litter and duff, the impermeability of the seed coats of fresh seeds, the afterripening of the embryo, and the resistance to disintegration of the fruit skin and pulp which harden on drying. Later, when the litter and duff accumulation of several years has covered the seeds more deeply, it is probable that their dormancy is favored by temperature conditions.

It has already been shown that seeds of this species of Ribes did not germinate promptly or abundantly at constant temperatures, but that prompt and abundant germination resulted when the seeds were exposed to daily temperature alternation of 10° and 25° C. Li (*15*) has shown that the daily range of soil temperatures below the floor surface of a forested area is much smaller than that of air temperatures 3 feet above the floor surfaces. The comparative figures from Li's work, changed from the Fahrenheit to the Centigrade scale, are shown in Table 9.

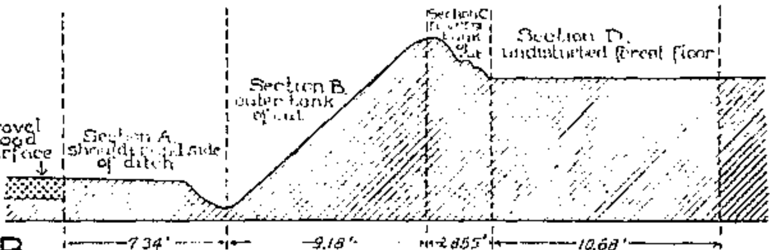
TABLE 9.—*Monthly arithmetical mean of the daily ranges of temperature at different locations in white-pine forests near Keene, N. H., in 1924*

[Rearranged from Li's (*15*) tables]

| Location | Arithmetical means of the daily ranges of temperature for— | | | |
|---|---|---|---|---|
| | July | August | September | October |
| | ° *C.* | ° *C.* | ° *C.* | ° *C.* |
| Young forest: | | | | |
| 3 feet above the surface | 16.4 | 14.3 | 13.9 | 17.3 |
| At the surface | 5.1 | 4.7 | 4.7 | 4.8 |
| 6 inches below the surface | 1.5 | 1.0 | 1.1 | 1.1 |
| Old forest: | | | | |
| 3 feet above the surface | 16.3 | 14.5 | 13.9 | 17.4 |
| At the surface | ------ | 3.8 | 4.0 | 3.8 |
| 6 inches below the surface | 1.4 | .9 | .9 | .9 |

Although it is likely that the daily range of temperature is greater during May and June, when much of the germination of Ribes seeds occurs in nature, than during July, August, September, and October, for which figures are given, it is not conceivable that the daily range of soil temperatures 6 inches below the surface approaches the 15° C. daily range used so successfully in germination tests at the Boyce Thompson Institute. It seems reasonable that the raising of humus containing dormant Ribes seeds from a depth of 5 to 7 inches to heights as great as 10 feet above the forest floor by the roots of upturning trees increased the daily range of temperature at the surface of the newly exposed humus to a point favorable for the germination of the viable seeds which were lying within the portions so affected.

It is impossible to estimate the maximum age of the seeds which produced Ribes seedlings on this upturn area in 1926 and 1927. Some of the seeds responsible may have antedated the severe fire, while it is reasonably certain that some were produced shortly after the fire, before vegetation completely anchored the exposed mineral soil and remaining humus. Unfortunately, the detailed forest-fire records for this region are comparatively recent, and no information could be found as to the date of the fire. Since the maximum age of trees examined on this area was approximately 70 years, these trees showing no fire scars, the fire occurred some time prior to 1857. Conservatively, the length of the period during which the Ribes


B

A. Sections A and B of plot adjoining the surface of road rebuilt in 1926. Ribes seedlings of 1927 germination were generally distributed over the exposed mineral soil, from the very edge of the hard surface to the top of the cut.

B. Profile showing divisions of the road-side plot.

seeds responsible for many of the seedlings had remained viable may be placed at about the age of the trees which were upturned, from 25 to 70 years.

### ROAD-BUILDING DISTURBANCE

Many miles of highways have been cut through the forests of the southeastern Adirondack region. Constant effort is made by the highway forces to improve this road system by relocating to reduce curves and grades and by widening the right of way, as well as by renewing the traction surfaces. In relocating and widening highways running through forested areas, the forest floor is disturbed over long narrow strips on each side of the roadbeds. On these strips the trees are cut, the stumps, bowlders, and rock outcrops are removed, and new cuts or fills, shoulders, and ditches are made. This work exposes new profiles of the forest floor and mixes up generally the litter, duff, humus, and mineral soil layers on the roadside strips.

Typical disturbance of this description was found along the highway from Paradox to Ticonderoga, N. Y., which was in the process of reconstruction during 1926. At the point to be described here, this work consisted of widening a cut where the road passed through a stand of mixed pine and hardwood, excavating new ditches, and building a new gravel road with wide earthen shoulders. This roadside stand of pine and hardwood was fully stocked, having a basal area of 116 square feet per acre at an age of 25 to 35 years. It extended over a strip 75 to 150 feet wide, separating the highway from a pastured area which supported scattering white pines mixed with brush. In 1927, this pasture from which the roadside forest had evolved still had an abnormally large population of mature *Ribes rotundifolium* plants. Under the dense forest stand fringing the roadside, the dead or dying remains of large Ribes indicated that these plants had thrived there also, before the competition of the growing forest became too keen for their survival.

In rebuilding the highway through this area in 1926, the right of way was widened into the roadside fringe of pine and hardwood. In July, 1927, an abundance of *Ribes rotundifolium* seedlings of 1927 germination were found growing on the side of the road where fresh soil had been exposed in 1926. A study plot, 85 feet long and 30 feet wide, was laid out along this roadside (pl. 3, A) to include the shoulder of the new road beginning at the edge of the hard surface, the sides and bottom of the ditch, the side of the cut, the turned edge on the back of the cut, and an undisturbed strip of adjacent woodland. The plot was divided longitudinally into four sections, as shown in Plate 3, B.

A total of 259 *Ribes rotundifolium* seedlings of 1927 origin were found on this plot during several thorough searches made in July, August, and September 1927, and in August, 1928. (Table 10.) In addition, 21 older plants of the same species were located. One of these grew in a clod of forest duff and mineral soil that had slipped part way down the incline of section B, 5 others were found on clods within section C, and the remaining 15 grew on the undisturbed forest floor within section D. Of these 21 old Ribes, nearly all of which were natural layers from large bushes that had evidently existed on the plot before the closing in of the forest canopy, only 3 had more than 4 linear feet of live stem, and 2 of these had but 8 feet of live stem. The third of these three plants was still a large bush with about 100 feet of live stem and was the only bush on this plot found bearing fruit (very few berries) in 1927. One of the other bushes had fruit canes still alive which may have borne fruit in recent years.

Nineteen of the 21 old bushes, including the 2 with fruit stems, were found in a group within 13 feet of the eastern end of the plot. Fifteen of the old bushes grew on section D, but only one of these was more than 13 feet from the eastern end of the strip. All the Ribes found on section D were natural layers from a preceding generation of Ribes. The 1927 seedlings were found generally distributed over the entire length and width of sections A, B, and C. All Ribes found were uprooted.

TABLE 10.—*Seedlings of 1927 germination and older bushes of Ribes rotundifolium found on the roadside plot near Paradox, N. Y., during several thorough searches made in July, August, and September, 1927, and in August, 1928*

| Section | Area | 1927 seedlings | | Total number of older Ribes |
|---|---|---|---|---|
| | | Total number | Rate per acre | |
| | *Square feet* | | | |
| A | 624 | 54 | 3,770 | 0 |
| B | 780 | 150 | 8,377 | 1 |
| C | 244 | 55 | 9,819 | 5 |
| D | 907 | 0 | 0 | 15 |
| Total | 2,555 | 259 | ---------- | 21 |

The striking point in the data shown in Table 10 is that *Ribes rotundifolium* seedlings of 1927 germination were found on the fresh earth surfaces of sections A, B, and C at rates ranging from 3,770 to 9,819 plants per acre, while no 1927 seedlings whatsoever were found on section D, which included only the undisturbed forest floor.

These data indicate that general germination of Ribes seeds is ordinarily secured only where the forest floor has been disturbed. The absence of abundantly fruiting bushes along this roadside, together with the finding of a number of layered fragments of large bushes which had probably borne fruit before prohibited by the competition of the forest, leads to the conclusion that many, if not all, of the 1927 seedlings found probably germinated from seeds that had lain dormant in the forest floor from the time that the area supported abundantly fruiting Ribes until the road builders, by breaking up and distributing the litter, duff, humus, and mineral soil of the forest floor, released the Ribes seeds and unwittingly prepared a seed bed where conditions were favorable for their germination.

### EXPERIMENTAL DISTURBANCE

On September 13 and 14, 1927, when relatively few berries remained on the Ribes in the locality, section D, of the Paradox roadside plot already described, was experimentally disturbed. Section D was 85 feet long and averaged 10.68 feet in width. This area of

0.0208 of an acre was cleared of slash and bowlders, and the vegetation, except for trees over 1 inch in diameter, was pulled up and thrown outside of the plot. All the 2 to 3 inch layer of litter, duff, and humus, except for stray bits which lodged in the surface irregularities, was removed with a rake and a pitchfork and piled outside the ends and edge of section D. The mineral soil was exposed over the entire section.

This roadside plot was not thoroughly reexamined until August 3 and 4, 1928. At that time all sections of the plot were carefully searched for Ribes. Many Ribes seedlings of 1928 origin were found in all the sections, as shown in Table 11. A comparison of this table with Table 10 shows that while slightly fewer seedlings originated in 1928 than in 1927 on sections A and C, many more originated in 1928 than in 1927 on section B. The proportionately greater germination of Ribes seeds in 1928 on section B than on either sections A or C may possibly be explained by the fact that this section, which included the longest and steepest slope (pl. 3, A and B) on the plot, was eroded more than either of the other two divisions. Evidently, erosion had exposed a greater number of buried seeds to conditions favorable for their germination on section B than on either sections A or C.

**Table 11.**—*Ribes rotundifolium seedlings of 1928 origin on the roadside plot near Paradox, N. Y., in August, 1928*

| Section | Area | 1928 seedlings | |
|---|---|---|---|
| | | Total | Rate per acre |
| | *Square feet* | | |
| A | 624 | 38 | 2,653 |
| B | 780 | 268 | 14,967 |
| C | 244 | 40 | 8,748 |
| D | 907 | 942 | 61,666 |
| Duff piles outside D | | 342 | |
| Total | 2,555 | 1,639 | |

Section D, where no Ribes seedlings had occurred in 1927 (Table 10), and which had been experimentally disturbed on September 13 and 14, 1927, was a veritable seed bed full of Ribes in August, 1928. On the strip itself, 942 seedlings were counted (Table 11), while 342 were found on the piles of litter, duff, and humus removed from the strip. Seedlings grew on section D and from the organic mantle removed from this strip, at the rate of 61,666 plants per acre. These figures are low, since young Ribes are easily overlooked and the examination was made late in the season after some early mortality had undoubtedly occurred. The seeds responsible for these plants had evidently been lying dormant in the duff, humus, and mineral soil of the forest floor prior to the disturbance.

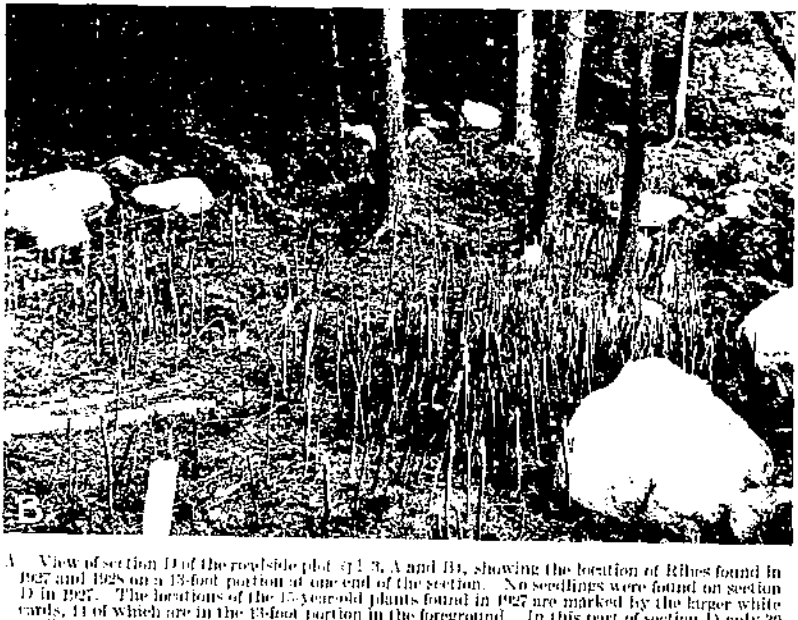
In considering the distribution of the 1928 seedlings, it should be remembered that 14 of the 15 old Ribes removed from section D in 1927, including the two plants with fruit stems, were found within 13 feet of the eastern end of the plot. The portion of the plot supporting these 14 old bushes in 1927 on an area of 150 square feet produced 30 seedlings in 1928, or 8,712 per acre. On the remaining 757 square feet of section D, excluding the plants found on the duff piled outside the strip, 912 seedlings were found in 1928, or 52,479 per acre.

Plate 4, A, shows the distribution of the 1928 seedlings as well as the location of the old plants removed in 1927. It is evident that 14 of the 15 bushes removed in 1927 were responsible for very few of the seeds which resulted in the 1928 crop of seedlings. The last one of the 15 old plants removed in 1927 was nearer the other end of the plot. This 7-year-old plant was a natural layer from a much larger bush which apparently had succumbed to the influence of increasing competition of the forest. Judging from the age of the remaining fragment of this old plant, it was estimated that the latter had declined too far by 1917 to bear fruit. In 1928 many seedlings were found on the site of this old plant. (Pl. 4, B.) It therefore seems probable that these seedlings grew from seeds that had lain dormant in the duff and soil for 10 years or more.

These data indicate that seeds of *Ribes rotundifolium* may remain viable in the forest floor for several years after the parent plants have been eliminated and that a disturbance of the forest floor brings about their germination.

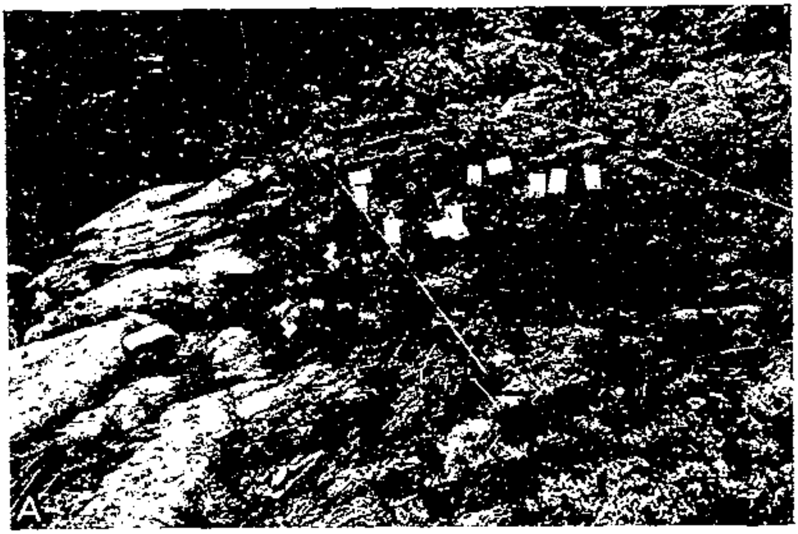
Data resulting from the experimental disturbance of a small area near upturn No. 30 also showed that Ribes seeds lying in the forest floor ordinarily germinate only after some disturbance of the duff brings about favorable conditions. The upturn occurred late in 1925 or early in 1926, and on July 27, 1927, 17 Ribes seedlings of 1926 and 1927 origin were found growing in zone D. (Table 7.) No seedlings were growing beyond the disturbed edge of the hole left by the upturn. On September 22, 1927, an area of the forest floor 3 by 9 feet in extent and lying just outside of the disturbance caused by upturn No. 30, was disturbed by furrowing the area down to bedrock with a pointed stick. Although no seedlings were found on this plot before it was disturbed in 1927, 11 Ribes seedlings of 1928 origin were found there on August 17, 1928. (Pl. 5, A.) These grew, as the direct result of the experimental disturbance, from seeds that had been lying in the duff and humus since the eradication of Ribes from this forest area in 1923.

Interesting results were also secured from the experimental disturbance of strips across a plot 90 by 100 feet in size, located on an eastern slope at the southern end of Hackensack Mountain, Warrensburg, N. Y. This slope was densely wooded, supporting a pure stand of white pine about 75 years of age. The basal area of the trees on the plot, at 1 foot above the ground and inside the bark, was equivalent to 267 square feet per acre. Unpublished data obtained by the writer on the life history of *Ribes rotundifolium* indicate that the bearing of fruit by plants of this species, growing under fully stocked coniferous stands, ceases before the basal area of the stand reaches 150 square feet per acre. The stand on this plot, with 267 square feet, is estimated to have passed the 150 square feet basal area mark between 1887 and 1897, based on growth measurements of stumps on the right of way for a telephone line recently cut through another part of the stand. This indicates that fruit production of this Ribes has been lacking or very limited on this area during the last 35 to 40 years.


A. View of section D of the roadside plot (pl. 3, A and B), showing the location of Ribes found in 1927 and 1928 on a 13-foot portion at one end of the section. No seedlings were found on section D in 1927. The locations of the 15-year-old plants found in 1927 are marked by the larger white cards, 11 of which are in the 13-foot portion in the foreground. In this part of section D only 30 seedlings were found in 1928 following the experimental disturbance of the forest floor. These are marked by the smaller white cards. Beyond these may be seen many of the stakes marking locations of the 1928 seedlings found on the rest of the strip.

B. A view of the numerous stakes, each marking a 1928 Ribes seedling, in another portion of section D of the roadside plot. The white card marks the site where a 7-year-old vegetative fragment of an otherwise extinct Ribes bush was removed in 1927. The vegetative fragment removed had never borne fruit, and it seems probable that the parent plant, of which no other trace was found, had ceased to bear fruit by 1917. The numerous seedlings appearing in 1928 as a result of the experimental disturbance of the forest floor probably originated from seeds at least 10 years old.



A.—View of edge of hole left in the forest floor by upturn No. 30. In 1927, 17 Ribes seedlings of 1926 and 1927 origin were found growing along the broken edge of the duff adjoining the bedrock bared by the upturn. No Ribes were found outside the zone of disturbance created by the upturned tree. On September 22, 1927, a plot 3 by 9 feet in size, marked in this illustration by white string and lying outside of the zone of upturn disturbance, was experimentally disturbed. On August 17, 1928, 11 Ribes seedlings of 1928 origin were found on this plot where none grew in 1927 prior to the disturbance. The large white cards mark the 1928 seedlings found on the plot and the small white cards the 11 survivors in 1928 of the 17 plants found in 1927 in the zone disturbed by the upturn.

B.—View looking across strip E of the Hackensack Mountain plot. Note the heavy shade of the 75-year-old stand of pure white pine. It is estimated that no Ribes have borne fruit on this area in the last 35 or 40 years because of the shade. All Ribes on this plot were removed in July, 1927, and in September, 1927, the layer of litter, averaging 1½ inches in depth, was carefully removed from this strip in such a manner as to avoid the distribution of material removed over any portion already treated. By September 11, 1928, 30 Ribes seedlings of 1928 origin had been found on this strip and 2 more on the piles of litter removed from this strip. This illustration shows the distribution of 28 of the 30 seedlings found on the strip, marked by white cards.

On July 20 and 21, 1927, several careful searches of this plot yielded 35 Ribes plants, 30 of which were *R. rotundifolium*, and 5 *R. vulgare*. All the Ribes were of small size, 18 having less than 1 foot of live stem while the largest had but 4.3 feet of live stem. The Ribes population was equivalent to 169 plants per acre. These Ribes were either of spindling upright form or of reclining vinelike form, both of which are common types for Ribes existing under heavy shade. The writer has never found *R. rotundifolium* or *R. vulgare* of these types bearing fruit. All Ribes found were removed from this plot in 1927.

During September 7 to 10, 1927, the plot on Hackensack Mountain was divided by strings into 9 strips, each 10 feet wide by 100 feet long and extending from the higher to the lower end of the plot. The nine strips, designated consecutively by letters from A to I, received the following individual treatment:

*Strip A.*—All vegetation was removed and thrown outside the plot. An attempt was made to remove from this strip all the litter, duff, and humus, together with a thin layer of mineral soil, without spilling any of this material on the portion of the strip already bared. A shovel was forced through the upper part of the mineral soil in a horizontal direction, and complete sections of the forest floor with layers intact were carefully lifted on the shovel over the unworked portion of the strip. This material was thrown outside of the strip at the ends and along the outer edge. In spite of the care used, obstructions such as roots and bowlders occasionally caused the dropping of small bits of the organic mantle on the bared portions of the strip. The layer of material removed averaged about 2½ inches in depth, most of which was pine-needle litter. The mineral soil exposed, a sandy loam of light-brown color, was then raked to loosen the surface and thus provide better conditions for the germination of seeds that might remain on the strip.

*Strip C.*—All vegetation and loose stones were removed from the strip. Beginning at the ends of the strip, practically all the 2-inch layer of litter, duff, and humus was removed with a rake and pitchfork. The organic mantle of the middle portions of the strip was tossed and raked over the mineral-soil surfaces already exposed at either end, in an attempt to sift out of this material any Ribes seeds it might contain and leave these on the strip. The material removed was piled outside the ends of the strip.

*Strip E.*—All vegetation and loose stones were removed from the strip. Beginning near the middle of the strip and using the loop side of a lawn rake the 1½-inch layer of litter was raked toward the ends of the strip, exposing duff, humus, and, in some places, mineral soil. The raking was carefully done so as to avoid scattering any of the removed litter over the newly exposed surface of the strip. The material removed was piled outside the ends of the strip.

*Strip G.*—All branch litter, vegetation, and loose stones were removed from the strip. None of the leaf litter or duff was moved off the strip, but the forest floor down into the mineral soil was thoroughly agitated with rake, shovel, and pitchfork.

*Strip I.*—All branch litter and vegetation were carefully removed with as little forest-floor disturbance as possible. Over 200 rocks showing above the surface were similarly removed. No other treatment was used on this strip.

*Strips B, D, F, and H.*—These alternate strips were left as checks and were not disturbed intentionally. However, a slight disturbance of the forest floor may have been caused by the removal of the Ribes from these strips in 1927 and by having branches and stones from the adjoining treated strips thrown on them. A slight local disturbance of the forest floor of check strip B was later observed, as the owner had removed a dead tree for fuel during the winter of 1927–28.

All the strips were carefully searched for Ribes seedlings five times between May 24 and September 14, 1928. The total number of these plants found on each strip and on the piles of material removed from strips A, C, and E is given in Table 12.

TABLE 12.—*Ribes seedlings of 1928 germination found between May 24 and September 14, 1928, on strips treated in various ways on the Hackensack Mountain plot, Warrensburg, N. Y.*

[Detailed descriptions of the treatments are given on p. 35]

| Strip | Treatment | Seedlings | | |
|---|---|---|---|---|
| | | On strip itself | On duff piled outside of strip | Total |
| A | All organic mantle removed without releasing fine particles | 6 | 27 | 33 |
| B (check) | No intentional disturbance. (Removal of one tree by owner caused slight local agitation of forest floor.) | 3 | | 3 |
| C | All organic mantle removed after thorough agitation to release fine particles. | 20 | 11 | 31 |
| D (check) | No intentional disturbance | 1 | | 1 |
| E | Litter removed without releasing fine particles or agitating lower duff layer. | 30 | 2 | 32 |
| F (check) | No intentional disturbance | 0 | | 0 |
| G | No material removed, but forest floor thoroughly agitated to mineral soil. | 20 | | 20 |
| H (check) | No intentional disturbance | 0 | | 0 |
| I | Vegetation and exposed rocks removed without agitation or removal of litter and duff. | [1] 4 | | [1] 4 |

[1] One of these plants was *Ribes vulgare;* all the others were *R. rotundifolium.*

The data on Ribes seedlings of 1928 germination found on the Hackensack Mountain plot (Table 12) furnish valuable indications of the depths below the normal surface of the forest floor at which the seeds producing the plants were lying. On strip A, where all the forest floor down into the mineral soil was removed as completely as possible, only six seedlings were found. Two of these were growing from the cross section of the duff and humus layer exposed at the extreme edge of the strip. The other four plants came up in the strip proper from the mineral soil which had been bared by the removal of the organic mantle. It is likely that some particles of duff and humus which were accidentally dropped on the mineral-soil surface of this strip during the process of removing this material included some viable Ribes seeds from which these four plants may have originated. The fact that 27 seedlings were found growing from the material removed from the strip and piled outside of the plot indicates that the litter, duff, humus, and upper mineral-soil layers removed harbored most if not all of the viable Ribes seeds present in the forest floor. Thirty-three seedlings came up in 1928 on strip A and on the material removed therefrom.

On strip C proper and on the material removed from strip C, 31 plants were found in 1928, or very nearly the same number as on strip A. The difference in the method of removing the organic mantle on strip C, where this material was thoroughly agitated and raked over the exposed mineral soil before removal, resulted in a higher proportion of the Ribes seeds contained in the litter, duff, or humus being left on the strip itself.

On strip E 32 Ribes seedlings were found on the strip itself and on the material removed from the strip, as compared with 33 for strip A and 31 for strip C. In the case of strip E, however, all but 2 of these 32 plants came up on the strip itself, indicating that few of the viable Ribes seeds were included in the material removed. Since this material (the surface layer of litter) was removed without distributing any particles of it over the completed portions of the strip, it seems certain that most, if not all, of the seeds responsible for the 32 plants found were present in the duff layer 1½ inches or more below the surface of the forest floor before the strip was treated. The fact that the carefully removed layer of litter, averaging 1½ inches in depth, produced but 2 of the 32 seedlings found on this strip indicates that few, if any, of these plants grew from recently disseminated seeds.

On strips G and I, 20 and 4 Ribes seedlings, respectively, were found. Assuming that Ribes seeds as indicated by the amount of germination obtained on strips A, C, and E, were evenly distributed over the entire area, it is evident that the treatment of strips G and I was not so effective in causing germination of dormant Ribes seeds lying in the forest floor as was the treatment of strips A, C, and E.

On the check strips, B, D, F, and H, but four seedlings were found in 1928. Two of these, located on strip B, were definitely associated with the local disturbance of the forest floor caused by the felling of a dead tree on this strip during the winter of 1927–28. The fact that only two other seedlings were found on these four strips, on which a slight disturbance could not be avoided, is further indication that the general germination of dormant Ribes seeds lying in the forest floor is primarily dependent on major disturbances of the organic horizons.

The seeds responsible for the relatively large number of seedlings of 1928 germination occurring on the treated strips (on strips A, C, and E at the rate of 1,394 per acre) had either been produced on the area before the shade of the forest stand became prohibitive for the fruiting of Ribes or had been gradually introduced from extraneous sources and had accumulated in the litter and duff during the life of the stand. The fact that most of the Ribes seedlings grew definitely from the duff horizon indicates that the seeds responsible had been lying dormant in the forest floor for a considerable period of years, perhaps 40 years or longer.

In addition to the experiments already discussed, 20 small spots in various locations in the southeastern Adirondack region were artificially disturbed late in 1927 by raking off by hand the surface layer of litter in order to test further the response to this treatment as measured in the resulting number of Ribes seedlings. Only 15 of these spots could be found in 1928. The results of the examination of these are shown in Table 13. The spots were circular for the most part, averaging about 4 feet in diameter.

TABLE 13.—*Ribes seedlings found in 1928 on spots artificially disturbed late in 1927 at various points in the southeastern Adirondack region*

| Location of spot with reference to old Ribes | Number of spots | Number of 1928 seedlings on each spot | Total | Average per spot |
|---|---|---|---|---|
| Picked at random in Schroon River upturn area | 1 | 0 | 0 | 0 |
| Under dying Ribes bush | 1 | 1 | 1 | 1.00 |
| On sites where large Ribes bushes were hung up during 1923 eradication season | 4 | 0, 0, 2, 3 | 5 | 1.25 |
| On sites of large Ribes bearing fruit in 1927 | 6 | 0, 0, 0, 1, 3, 59 | 63 | 10.50 |
| On original site of large Ribes eradicated in 1923 | 2 | 16, 28 | 44 | 22.00 |
| Under large, dead Ribes bush in heavy pine shade | 1 | 89 | 89 | 89.00 |

Of the 15 spots disturbed in 1927 and reexamined in 1928, 9 had Ribes seedlings of 1928 origin, from 1 to 89 in number. In only four spots were more than three seedlings found in 1928. It is interesting to note that in three of these four cases there had been no recent source of seeds. The two spots on original sites of Ribes eradicated in 1923 produced a total of 44 seedlings, although there had been no source of seeds in the vicinity since 1923. One spot, 44 inches in diameter, under a large dead Ribes bush had 89 seedlings in 1928, despite the fact that the bush had been dead at least 5 years and probably had not produced any fruit in the last 10 years, because of its position in the dense shade of pine trees 45 years old. These data are additional indications both of the longevity of Ribes seeds contained in the forest floor and of the necessity, under ordinary conditions of a forest-floor disturbance, for their general germination.

Ribes seedlings came up on the Hackensack Mountain plot, on section D of the Paradox roadside plot, on the small plot near upturn No. 30, and on the nine small artificially disturbed spots, as a direct result of forest-floor disturbance unaccompanied by any abrupt change in the forest canopy. This fact indicates that the shade of the forest canopy was not the principal factor controlling the dormancy of the seeds lying in the forest floor.

## SUMMARY

Experiments and observations reported in this bulletin indicate that viable seeds of some species of currants and gooseberries, particularly of *Ribes rotundifolium*, accumulate in the forest floor of white pine areas during periods favorable for the bearing of fruit by plants of these species; that these seeds may remain dormant in the forest floor for protracted periods; and that they germinate soon after the occurrence of forest-floor disturbances such as are caused by ground fires, logging operations, windfalls, and road building. Apparently, such disturbances of the forest floor are essential for the general germination of these naturally stored Ribes seeds. These seeds may germinate under a heavy forest canopy if the forest floor is disturbed down to the mineral soil.

Laboratory tests show that seeds of *Ribes rotundifolium* and *R. cynosbati* germinate more abundantly and more promptly when subjected to daily alternation of temperature than when the temperature remains constant. Daily alternation of temperature from 10° to 25° C. gave the best results. It seems probable that the much narrower daily range of temperature below the surface of the forest floor may be an important cause of the dormancy of Ribes seeds lying below the surface.

Seeds of these species tested under laboratory conditions germinated less promptly and less abundantly in natural peat than in peat neutralized with calcium carbonate. These results suggest soil acidity as another factor that may favor dormancy in Ribes seeds. Other investigators have suggested various causes for the dormancy of seeds, such as immaturity of embryos, dormancy of embryos, mechanical resistance to expansion by the structures inclosing the seed, and the impermeability of seed coats of some seeds. While it was not possible from the studies reported in this bulletin to determine what factor or combination of factors is responsible for the dormancy of Ribes seeds stored naturally in the forest floor, it is obvious that this dormancy occurs.

From the standpoint of blister-rust control, it is necessary to retain white pine areas relatively free of Ribes plants because the extent of the damage caused to pines by the blister-rust disease is proportionate to the abundance and susceptibility of Ribes leafage within approximately 900 feet of the trees. To this end, on areas where conditions are favorable for the growth of Ribes, the prevention of ground fires and the minimization of other forest disturbances that bring about the germination of naturally stored Ribes seeds are of importance in control work. It is also important that control operations be timed so as to keep white pine areas free of fruit-producing Ribes plants, in order to prevent the accumulation of seeds in the forest floor.

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