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Development and Evaluation of the R-55/graphite Seed Coating Treatment

by

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Preliminary data - not for general release

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Introduction

Since 1960 the Canadian Wildlife Service has been involved in a research project aimed at determining to what extent small mammal populations influence forest regeneration in western Alberta.

Early approaches to the project centered largely on live trapping and ear tagging studies to determine what small mammal species could occur on newly cut white spruce forest lands, how the population built up following cutting, how the population varied from year to year, what vegetation changes followed cutting and scarification, how the home range of individuals of each small mammal species varied, and finally, by examination of stomach contents, ascertain which species were actually consuming coniferous seeds. Much of the information obtained on these aspects were presented in Progress Reports 1 and 2 of the study (Radvanyi 1960, 1962).

In 1962, while continuing the small mammal aspects of the study, a new approach was introduced in order to obtain information on the fate of individual coniferous seeds in the natural environment -- that of the radiotracer technique -- in which, in essence, each seed is equipped with a miniature radio-transmitter. By detecting the signals given off, the seed could be left in the field for up to a full year, checked at intervals as to location and finally recovered in total or as a fragment of the seed coat. If destroyed, by microscopic examination and comparison with seeds of known fate, the radiotagged seeds could subsequently be placed into one of several probable seed fate categories.

Progress Reports 3, 4, 5, and 6 (Radvanyi 1963, 1966a, 1967, 1968) outlined data obtained in four years of radiotagging studies. $Scandium_{46}$, $Zinc_{65}$ and $Cobalt_{60}$ radioisotopes had been used in labelling 11,800 white spruce and 1,900 lodgepole pine seeds. Recovery success on the two seed species to that point was 90.97 and 76.47 percent respectively. The radiotracer technique provided some of the first data on coniferous seed fate obtained from field studies in Canada and possibly the first anywhere on seeds as small as those of white spruce. The study showed despite the fact that the seeds had been provided with a protective coating used widely throughout North America, nevertheless, as much as one half of the seed supply could be destroyed by small mammals during some years and this could occur within three months following spring seeding. Two overwinter studies of seed fate indicated that only about one-third as many seeds may be destroyed by small mammals following winter seeding and germination could be improved several fold as compared with spring seeding.

That so many seeds could still be destroyed despite the use of the aluminum powder, endrin, arasan, latex coating formulation developed by Spencer (1952) turned the main emphasis of this study in 1968 toward a somewhat critical examination of seed coating procedures. Progress Report # 7 (Radvanyi 1969) dealt almost exclusively with the numerous experiments carried out in the development and subsequent publication of a new seed coating treatment for coniferous seeds (Radvanyi 1970a). While not developed in time to enable a dual comparison in 1968-69 of winter vs. spring seeding and the new treatment vs. old treatment on subsequent seed fate, some preliminary field testing was attempted as described in Progress Report # 8 (Radvanyi 1970b).

During the past year, several more experiments were undertaken with the aims of improving even more the procedures involved in the new seed coating technique and in preparation for a larger scale field testing evaluation of the method. A review of these experiments constitutes the greater part of this report.

Aims of the 1970-1971 studies

1. To conduct further experiments aimed at improving to an even greater degree the effectiveness of the new seed coating treatment developed during the previous year. The major emphasis of these tests are to examine possible alternate latex solutions and dilution factors which could be used in binding the other coating ingredients to coniferous seeds.
2. To repeat the weathering test on treated seeds under conditions resembling more closely the field situation than had been employed in the 1969-70 weathering test.
3. To conduct additional seed coating experiments to examine what variables might be encountered in the application methods and to establish weight and volume measures of each of the ingredients which foresters would require to treat bulk units of 20 pounds of seed at a time.
4. To establish field plots for placement of additional radiotagged

seeds for comparing fate of seeds receiving no treatment, the old Spencerian treatment, and the newly developed seed coating treatment. Seeds are to be placed in early winter and late winter or early spring. Small mammal population studies are to be conducted on the area prior to seed placement and during the 1971 evaluation year.

Methods and Results

Study area, site preparation, and small mammal studies.

After nine years of study of small mammal influence on forest regeneration on deep duff locations near Hinton, Alberta, a new site was selected for field testing of the new seed coating treatment and its potential in protecting the seeds against small mammal depredation. The new location is situated approximately forty-five miles south west of Rocky Mountain House, Alberta, and lies within the 4,000 acre Fisher Mill burn of 1968. Near the center of a flat square-shaped tract of near 100 acres size, a study area of 20 acres was selected for the small mammal and seed fate studies. The entire large block had been scarified during 1969 and abundant grasses and fireweed were rapidly taking over soil surface.

As in previous years, 300 Sherman-type live traps were used in the small mammal study. Individual traps were spaced at 50 foot intervals along rows 50 feet apart on the 15 by 20 point grid. In order to determine what small mammal species were present on the study area prior to placement of radiotagged spruce seeds, a live trapping and tagging program was carried out between October 5 and 14, 1970.

Heavy snowfall just prior to the trapping period hampered the efficiency of the program during the first five days as reflected in the small numbers of animals taken. With the return of warmer weather and reduction of snow cover, trapping success improved. The traps were checked twice daily - during early morning and late afternoon hours.

A total of 65 small mammals were handled on the study area during the 10-day trapping period in a total of 133 captures and recaptures. The frequency of occurrence by species were as follows:

Species	# trapped live	dead	Total captures and recaptures
Clethrionomys gapperi	28	1	76
Microtus pennsylvanicus	19	4	38
Peromyscus maniculatus	8	-	14
Sorex cinereus	1	4	5
Totals	56	9	133

Using the method of Hayne (1949) and considering the number of new animals encountered each day, the ratio of recaptured animals in the total daily catch and the numbers of tagged animals available for recapture, the small mammal population on the study area during the October trapping period was calculated to be 84.9 animals with 95% fiducial limits of lying between 52.6 and 220.8. The wide spread of the fiducial limit figures is most probably due to the poor trap returns caused by snow cover during the early aspects of the trapping program. On an area basis, the figures indicate the presence of 4.6 small mammals per acre during the October 1970 period.

Radiotagged white spruce seed fate study

As part of the continuing study on the fate of white spruce seeds in the natural environment, 48 seed plots (each to accommodate 100 radiotagged seeds) were set up on the small mammal study area. As in past years, 100 or more feet separated the plots over the entire study area. Within each 36' x 36' plot, wooden stakes spaced at 4 - foot intervals on a 10 x 10 point grid served as markers for the placement of the 100 radiotagged seeds. Seeds were placed 6 inches in a pre-determined direction from the stakes.

The fate of radiotagged spruce seeds is to be determined following use of three different seed coating treatments and two different time of seed placement. The coating treatments include a) nil treatment; b) the old Spencerian treatment consisting of aluminum powder-endrin-arasan-latex; and c) our new coating treatment of R-55 repellent-graphite-latex. Randomization of placement time and treatment of seeds which were to be placed on each of the plots was done by drawing plot numbers out of a hat. The treatment sequence resulting from this randomization is illustrated in Figure 1.

Twenty-four hundred white spruce seeds were radiotagged in three equal size lots using $Cobalt_{60}$ radioisotope on November 10, 1970. The seeds were allowed to soak in the radioactive solution for four hours and then air dried over night. The next day the coating materials were applied and the seeds transported to Rocky Mountain House for field placement during the following day. A heavy snow fall began in the area on November 11th and continued all day while seeds were being placed on the 12th. By the time the seeds had been set out, up

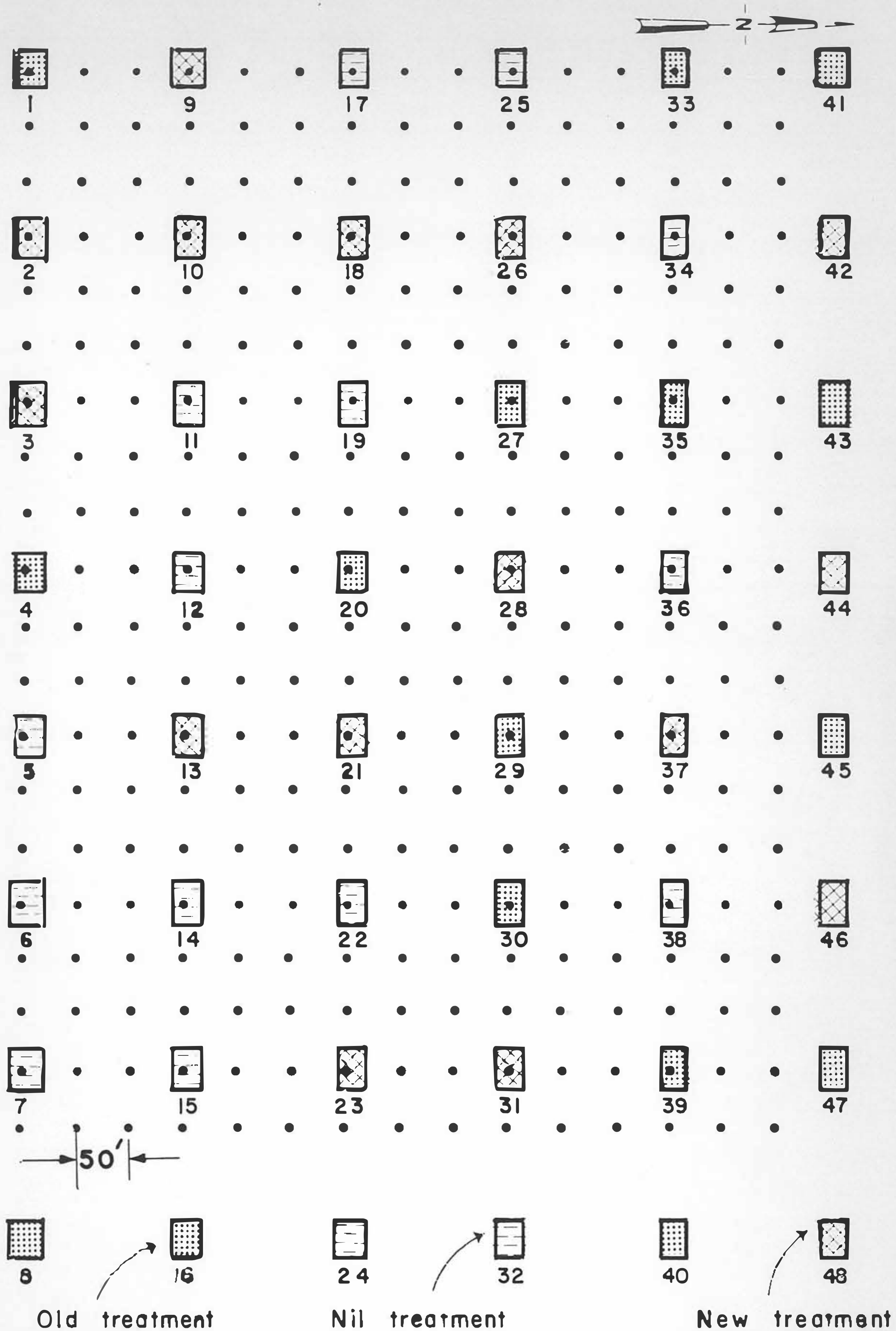


Fig. 1. 1970-71 study area showing randomized seed treatment (100 radio-tagged seeds/plot ▭) and distribution of 300 small mammal live traps (·).

to five inches of heavy wet snow covered the study area. This snow cover persisted throughout the winter. Approximately 20 inches of snow covered the area when checked in early January 1971 and more than two feet depth was reported by forestry officials in the area in early March 1971.

To circumvent a possible bias, due to presence or absence of a latex coating, the 800 seeds receiving "nil" treatment were actually coated with latex solution and graphite, but no repellent or insecticide was used. A subsequent feeding test was conducted in which non-treated spruce seeds from cold storage stock and an equal number of seeds coated with latex and graphite were presented on alternate days to a single Peromyscus during a six day feeding test. The sequence of treatment, the number of seeds presented and the numbers of each destroyed are presented below. As stored seeds are usually consumed as soon as the food supply becomes scarce, for purposes of this test, such stored seeds were considered as also destroyed.

Day	Seed coating	Number seeds presented	Number seeds destroyed
1	none	1000	973
2	Latex and graphite	1000	992
3	none	1000	797
4	Latex and graphite	1000	1000 (155 eaten & 845 stored)
5	none	1000	996 (528 eaten & 468 stored)
6	Latex and graphite	1000	994 (227 eaten & 767 stored)

A total of 2,726 out of 3000 or 90.9 percent of seeds receiving no prior treatment had been eaten or stored while 2,986 out of 3000, or 99.53 percent, of seeds coated with latex and graphite were destroyed or stored. The latex and graphite coating does not appear to deter seed destruction and consideration of seeds so coated as having received nil treatment appears valid.

Twenty-four hundred radiotagged spruce seeds receiving in equal numbers the three coating treatments were set out on randomized plots in November 1970. An additional 2400 were set out in mid-April, 1971 on the remaining plots. Placement of these was to coincide with the melting of the last 10 - 12 inches of snow on the area.

The location of radiotagged seeds is to be checked at least twice prior to recoveries being made during summer 1971. It is intended 1200 tagged seeds be recovered during late May, June, July and August so as to provide more precise data as to when seeds germinate or are destroyed. Examination of the recovered seeds will also provide data on the comparative effectiveness of the three coating treatments in protecting the seeds from small mammal depredation.

Weathering tests

That a coating treatment is effective in protecting the seeds from being destroyed by small mammals shortly after the seeds had been coated with protective materials is in itself not good enough. The protection must persist under conditions of the natural environment long enough and with sufficient effectiveness to permit an adequate number of the seeds to germinate. This means, -- should seeding be carried out in late March -- the protection is needed for at least three months or more. One such weathering experiment was carried out on R-55/graphite treated white spruce seeds during the summer of 1969 (Radvanyi 1970). Under conditions of that experiment, the newly applied coating proved to be 94.2 percent effective in preventing seed destruction by Peromyscus. After 41 days of weathering, the coating was still 79.7 percent effective but declined rapidly thereafter. In examining the experiment in retrospect, it is apparent too frequent handling of the seeds may largely have been the cause for the notable decline in protection effectiveness. In that experiment approximately 70,000 white spruce seeds had been coated with R-55/graphite/arasan-latex and placed into a fine wire mesh tray on the flat roof of a building for direct exposure to sunlight, heavy rains, alternating temperatures. Each week the seeds were poured into a jar, wetted, and placed for two days into a refrigerator, following which they were returned to the roof for more exposure. At intervals, usually two weeks, the seeds were removed and 10,000 seeds counted out for use in feeding experiments. The remainder were again returned to the roof. With such repeated handling more and more of the coating material were inadvertently rubbed off the seed leading to subsequently larger numbers of treated seeds being destroyed.

To circumvent, at least in part, this experimenter-induced bias, the weathering test is being repeated with several modifications. First, since the initial test, the manufacturer has brought out R-55 in a new improved granular form instead of large resinous lumps. Both forms required further pulverization prior to use in our formulation. Second, while again approximately 70,000 white spruce seeds were treated with R-55-graphite-latex (no arasan is included in the treatment), the seeds were placed into 70 small aluminum dishes fastened to two sides of a board which was suspended out of doors for seed weathering. Under this arrangement, only those seeds to be used in any particular feeding trial need be handled. Figures 2 and 3 illustrate the seed weathering set up. Non-treated spruce seeds used in feeding trials are also being weathered. Third, in order to determine weathering influences on the effectiveness of the seed coating during a period when seeds might be placed into the field, the current weathering test was commenced in late November 1970 and is intended to continue until late June 1971 by which time germination of seeds in the field should have occurred.

In feeding trials in the initial weathering tests, 2,000 non-treated seeds were presented to each of ten Peromyscus during each of two nights prior to introduction of treated seeds into the experiment. Prior to the tests the animals had been maintained on pelleted vitacube laboratory preparations. Seeds were presented in small crucible type dishes. On the third night each of the ten animals was presented with 2000 non-treated white spruce seeds in one dish and 1000 R-55-graphite-arasan-latex treated seeds in a second dish. The following morning the dishes were removed, the seeds remaining in each dish were sorted and counted to determine the numbers from each dish which had been destroyed. The average number of seeds destroyed by the ten animals was used in calculation of the effectiveness of the coating treatment. The formula of Besser and Welch (1959)

$$\frac{\text{\% untreated seeds destroyed} - \text{\% treated seeds destroyed}}{\text{\% untreated seeds destroyed}} = \text{effectiveness of treatment}$$

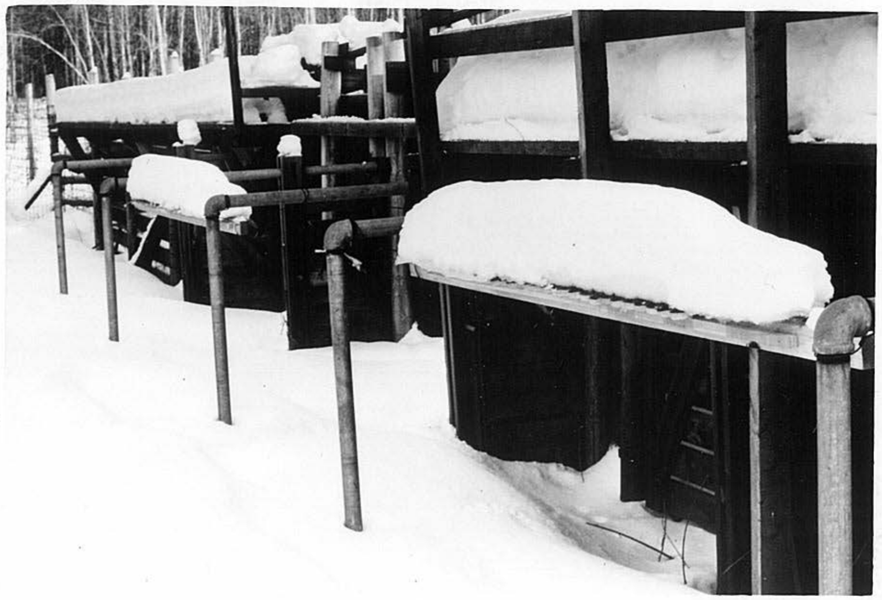


Fig. 2 Weathering test set-up at the Elk Island Lab. 140,000 white spruce seeds, 1/2 treated with R-55/graphite are exposed to the elements.

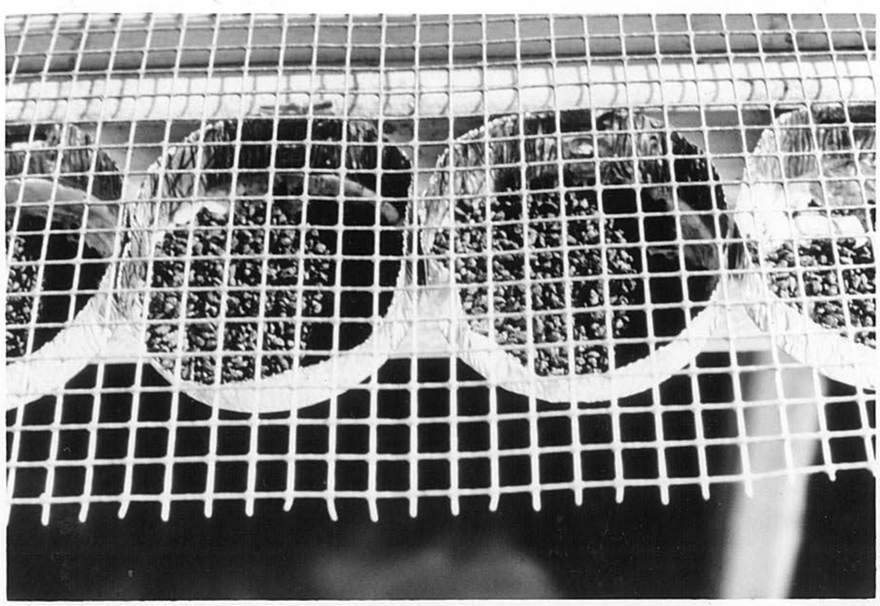


Fig. 3 Close-up showing 1000 treated white spruce seeds in each of the aluminum dishes in weather exposure tests.

was used to evaluate the degree of effectiveness in protecting the treated seeds.

R-55 rodent repellent has a very strong pungent odour. Placing a thousand spruce seeds coated with this ingredient into the dimensions of a small feeding dish not only intensifies the odour factor but at the same time may give an erroneous indication of how effective the coating may be on individual isolated seeds such as would be the situation in the field environment. An attempt was made in the repeat experiment currently under way to circumvent in part this bias of odour originating from many seeds. In the new experiment 2000 non-treated and 1000 R-55 graphite-latex treated seeds are scattered and mixed on the floor of a small room and a single Peromyscus introduced. A nest box is provided as well as a water supply. No pre-feeding on non-treated seeds is done before a feeding trial. Twenty-four hours later, the seeds are swept up, and whole seeds - treated and non-treated-separated manually and counted to ascertain the numbers of each which had been consumed. Because of the space requirement for feeding trials done in this manner, only one animal is used at a time. The test is repeated over five consecutive days, usually during each third week since seeds were set out to weather in late November. To avoid conditioning of the animals, each mouse is used for only one five-day feeding trial. Only adult Peromyscus are being used and the sexes alternated with consecutive feeding trials. The experiment to check the effect of weathering on treated seeds is scheduled to continue until mid-June 1971. The calculated percentage effectiveness of the new coating on white spruce seeds based on six feeding trials conducted between

November 1970 and April 1971 with up to 105 days of exposure to winter weather are shown in Figure 4.

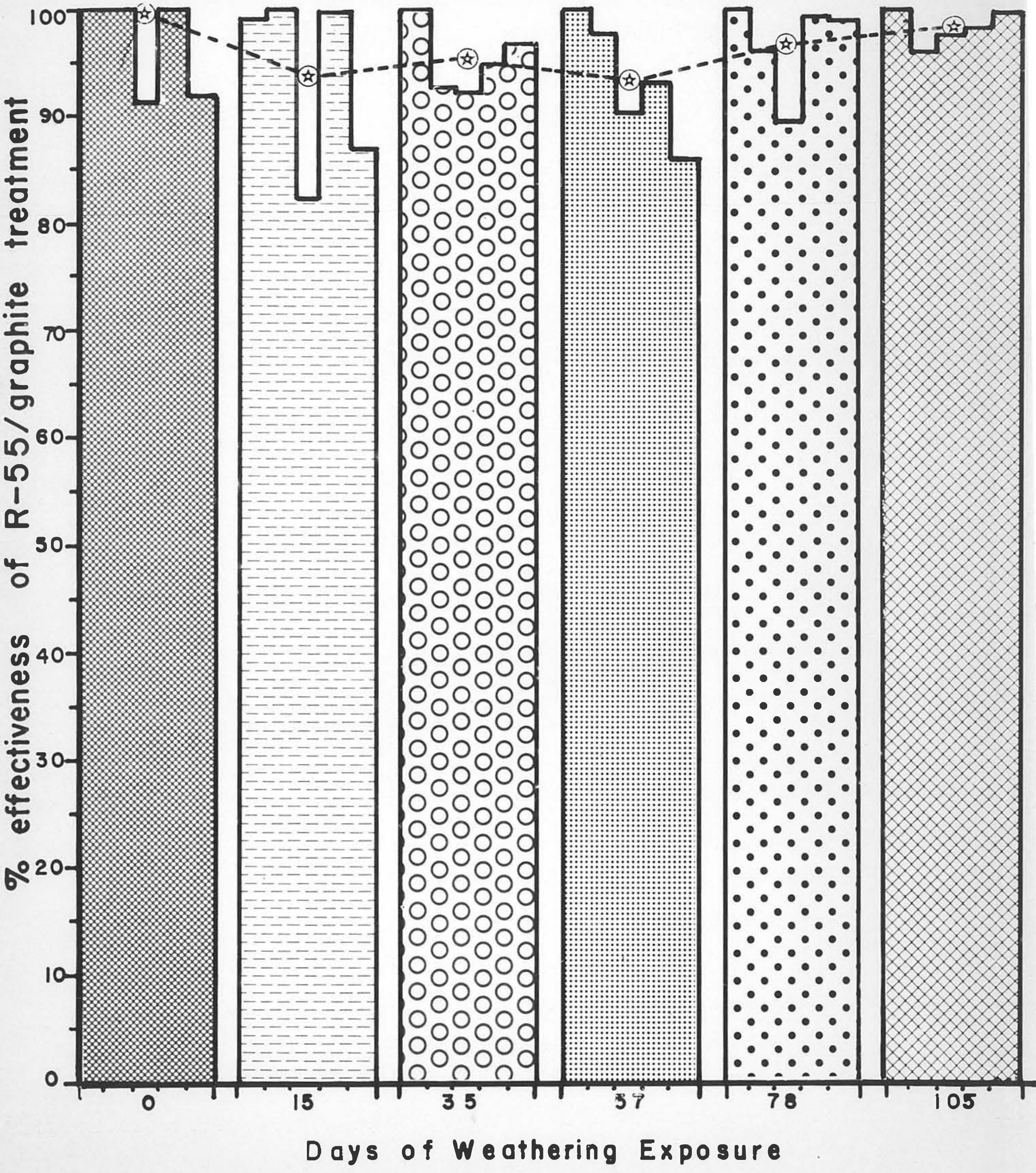
A small-scale spot seeding trial at the Alberta Tree Nursery

On May 7, 1970 a small scale spot seeding trial was set out on approximately one-quarter acre of newly tilled dark soil near the greenhouses at the Alberta Tree Nursery. Wire markers were used to locate fifty spots spaced two feet apart along 20 rows. Treated seeds and non-treated seeds were placed along alternate rows. Two hundred and fifty spots were seeded with 12 - 15 treated white spruce seeds at each spot; a similar number of non-treated seeds were placed at spots along the alternate rows. A similar grid was used for treated and non-treated lodgepole pine.

A cursory examination of the seed spots was made one week following seeding. Treated and non-treated spruce seeds were still undisturbed and exposed, as were the treated lodgepole pine seed. At between 90 and 95 percent of the non-treated lodgepole pine seed spots, only empty seed hulls remained. Not a whole seed remained. Each seed coat appeared to have been split along the edge and the entire embryo and endosperm was missing. No teeth marks along the edges of the seed coats could be made out with the naked eye. The pattern of seed destruction resembled none of the patterns established for pine seed destruction in earlier aspects of this study (Radvanyi 1966, 1971). It would appear still another destroyer of seeds not previously encountered is operating at the tree nursery and effectively so. Other field commitments did not permit establishing a trapping program at the nursery to establish the identity of the new culprit.

Figure 4. **WEATHERING TESTS**

R-55/graphite treated white spruce seeds



Several weeks of very warm and dry weather followed the spot seeding trial. A visit to the plots in early June 1970 revealed still no germinants. A thermometer placed on the bare ground between 3 and 4:00 pm indicated a soil surface temperature of 145°F. Re-examination of the plots in late summer revealed only one-half dozen spruce and pine germinants. As indicated previously, use of the dark, new coating treatment on coniferous seeds could just as easily have deleterious effects on germination if seeding is carried out in late spring and hot dry weather arrives before the seeds had time to germinate.

Additional seed treatment and germination tests

Much along the line of experiments reported in Progress Report # 7 several additional probing tests were carried out to ascertain whether various pretreatments would improve germination on non-treated and repellent treated white spruce seeds.

Many foresters in the past have held to the theory that white spruce seed possesses an inherent dormancy factor which is broken only by a pre-chilling treatment. While our own studies in earlier years on this project have suggested more seeds germinate following seeding into snow than when seeds had been placed into the more highly xeric conditions of late spring, that the greater success in the former instance was actually due to a naturally provided pre-chilling treatment was not proven.

Experiment 1. To test whether chilling would improve germination, two batches of 100 spruce seeds were submerged in water and placed in a refrigerator for 48 hours. A control lot of 200 seeds were similarly soaked but retained at room temperature. The rate of germination following the two treatments are shown in Table 1. While a slight advantage appears to have existed in the early part of the experiment with cold soaking of the seeds, the final results were near identical and it would appear that a pre-chilling treatment *per se* is not a controlling factor in white spruce seed germination.

Experiment 2. The Stokes garden seed catalogue (1970, p. 55) refers to a hot water treatment of tomato seeds to kill most seed borne diseases without harming germination. To test whether any benefit might be obtained from such a pre-treatment, five replications of 100 white spruce seeds were set up in a three treatment experiment; a) seeds pre-chilled for 48 hours in a refrigerator prior to mounting for germination; b) seeds soaked for 25 minutes in water maintained at 122°F; c) dry seed from cold storage. The rates of germination are shown as averaged in Table 2. As in Experiment 1, little or no advantage could be demonstrated by the varied pre-treatments used.

Experiment 3. Would a germination advantage be shown to exist if a hot pre-treatment was followed by a pre-chill treatment before germination? To test this hypothesis a) spruce seeds in five replications of 100 were soaked in water at 122°F for 25 minutes, then put moist into a freezer for 48 hours prior to placement into the germinator; b) dry seed from cold storage served as control. The rate of germination following the two pre-treatments are shown as averaged in Table 3. Again, no significant germination advantage could be demonstrated in hot and cold pre-treatment of white spruce seed over seeds drawn

Table 1. Percentage white spruce seed germination (averages) following cold and room-temperature soaking.

Pre-treatment	Days in germinator								
	5	7	10	12	15	17	20	23	26
Cold-soaking for 48 hours	3.5	34.0	79.5	86.0	88.5	89.5	89.5	89.5	89.5
Soaking at room temperature for 48 hours	2.0	26.5	73.5	78.5	84.0	84.5	86.0	87.0	87.5

Table 2. Spruce seed germination following prechilling, hot treatment, nil treatment.

Treatment	Days in germinator								
	6	7	9	11	13	15	18	22	25
Soaked 48 hrs. in refrigerator	5.8	15.8	73.2	82.4	85.0	86.0	87.4	87.8	88.2
Soaked 25 min. in 122°F water	3.0	7.4	57.2	75.6	80.8	84.6	85.0	87.6	88.6
Dry seed from cold storage	6.2	15.8	64.0	74.2	79.0	82.4	86.4	87.8	88.4

Table 3. Spruce seed germination following hot-cold, and nil pre-treatment.

Treatment	Days in germinator													
	6	7	10	11	12	14	17	19	21	23	25	27	29	31
Soaked at 122°F for 25 min. then stored in freezer for 48 hrs.	6.8	17.2	61.6	70.6	76.2	81.8	83.6	84.2	85.6	86.0	86.2	85.0	85.0	85.4
Stock seed from cold storage	11.6	22.6	64.8	71.6	76.4	81.0	83.6	84.2	84.4	84.6	84.6	84.6	87.0	87.2

directly from cold storage facilities. The line of approach was abandoned at that point.

Experiment 4. Could the effectiveness of R-55 rodent repellent be made more long lasting if applied to spruce seeds in the form of a solution instead of the powdered form? R-55 is near insoluble in water. Two solvents in which R-55 will dissolve in fair quantities are DSMO (Dimethyl sulfoxide) and acetone. Before using these solvents as a possible carrier for R-55, germination tests were conducted to check for phytotoxic properties of the solvents themselves which might inhibit spruce seed germination. As before, seeds (5 replications of 100) were a) quick dipped in DSMO and dried prior to placement in the germinator; b) quick dipped in acetone and dried; c) seeds from cold storage served as controls. Average germination for the three treatments are seen in Table 4.

Table 4. Spruce seed germination following R-55 solvent pre-treatments and nil treatment controls

Treatment	Days in germinator							
	7	10	12	13	16	20	22	26
a) seeds soaked in DSMO	0	0	0	0	0	0	0	0
b) Seeds soaked in acetone	6.4	15.0	23.2	27.0	30.2	31.4	32.8	33.2
c) Control - stock seed from cold storage	24.0	54.0	69.6	74.8	78.8	81.6	82.2	82.6

Dimethyl sulfoxide completely inhibited spruce seed germination.

Acetone reduced germination by almost 2/3. It would appear neither of these two solvents could be used as R-55 carriers.

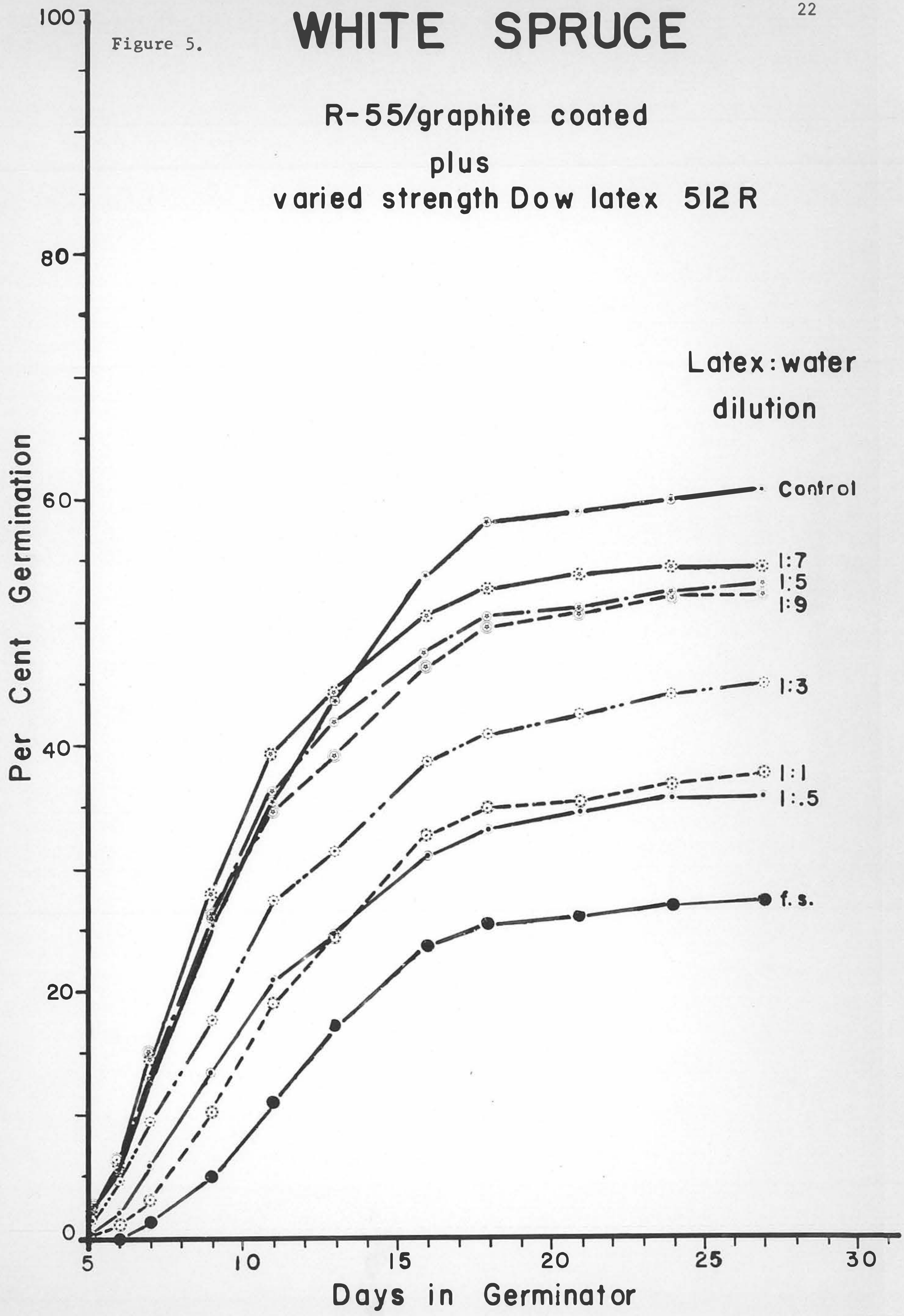
Latex studies

For almost two decades now, Dow latex 512R had been used in the conventional aluminum powder-endrin-arasan-latex coating treatment for coniferous seeds. While in most instances the latex was diluted 1:9 (latex:water) prior to use, some foresters have employed it in full strength concentration. Little scientific evidence appears to have been published for the choice of the 1:9 dilution factor. In the development of the new coating procedures using R-55, a slight advantage was shown in germination by acidifying the latex solution prior to use on white spruce seeds (Radvanyi 1970b).

Experiment 5. To test how latex dilution may influence germination of white spruce (5 replications of 100) were coated with 4:1 R-55-graphite preparation and acidified Dow latex 512R of seven dilution ratios (pH brought from 9.6 to 4.5 by adding HCl). Non-treated seeds from storage served as controls. The latex was obtained from the Alberta Tree Nursery at Oliver, Alberta, and as learned some time later, had been of fairly old stock. The rate of germination of the eight seed lots are shown graphically in Figure 5.

Except for the seed lots employing 1:7 and 1:5 latex dilutions (very slight differences occurred in germination of spruce seeds coated using 1:9, 1:7 and 1:5 dilution factor of latex) the higher the ratio of latex in the solution, the lower was the percentage of seed germinating. Germination of seeds coated using full strength latex was exactly 1/2 that of seeds coated with 1:7 dilution of the latex.

Figure 5.

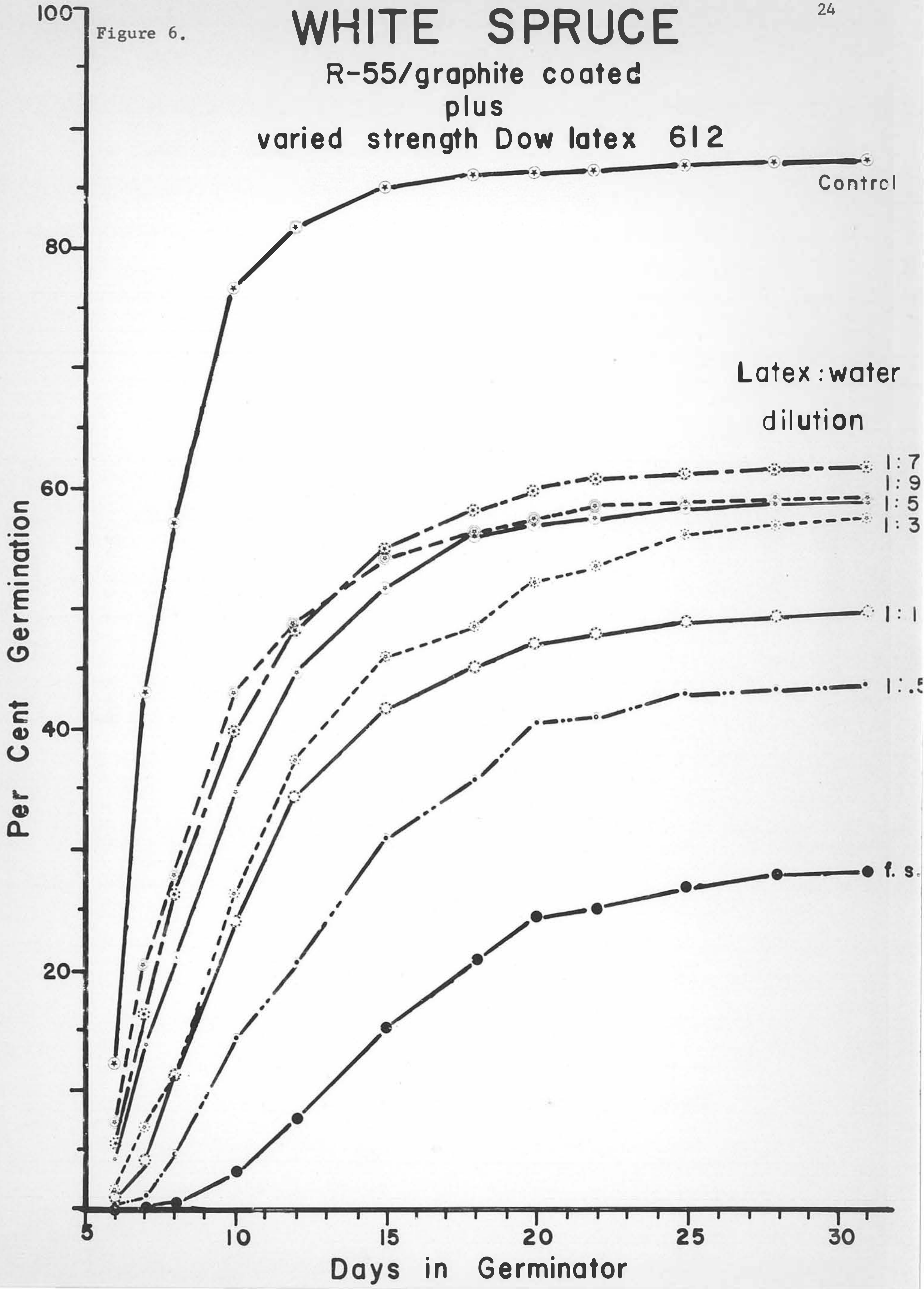

WHITE SPRUCE
R-55/graphite coated
plus
varied strength Dow latex 512 R
Latex:water
dilution
Control
1:7
1:5
1:9
1:3
1:1
1:.5
f. s.
Per Cent Germination
Days in Germinator
0
20
40
60
80
100
5
10
15
20
25
30

Experiment 6. Germination of seeds in the control lot of the previous experiment had been disappointingly low despite the fact that no coating treatment had been used on them. A repeat of the experiment was carried out a month later using a fresh batch of spruce seeds obtained supposedly from the same seed lot at the Tree Nursery and using fresh preparations of latex 612 obtained from Dow Chemical, Sarnia. (It was understood at the time latex 612 was a replacement of 512R but recently it has been learned 512R and 612 are the same.) As before, the latex was acidified (pH brought from 8.6 to 4.5) and seven dilution preparations made. Non-treated seeds served as controls. The rate of germination for the new test is shown in Figure 6.

As in the previous experiment, use of 1:7 dilution of the latex gave the highest total germination of coated seeds. In general, use of the latex in dilutions more concentrated than 1:3 ratio (latex: water) reduced germination markedly.

Experiment 7. Use of three different Dow Latex preparations on white spruce seed germination. Dow latex 512R has been used in coating coniferous seeds for nearly two decades. Would another latex give better germination results? Consultation with personnel at Dow Chemical at Sarnia, Ontario, revealed that while a wide variety of latex preparations were manufactured there, only the 512R had been used in coniferous seed germination studies. The company was most willing to supply gratis sample quantities of any other latex preparations we cared to test for our purposes. Three new latex preparations 612, 620 and 880 were obtained and used. Latex 612 (pH 8.2), 620

Figure 6.



WHITE SPRUCE
R-55/graphite coated
plus
varied strength Dow latex 612
Control
Latex : water
dilution
1 : 7
1 : 9
1 : 5
1 : 3
1 : 1
1 : .5
f. s.
Per Cent Germination
100
80
60
40
20
5
10
15
20
25
30
Days in Germinator

(pH 6.0) and 880 (pH 8.6) were diluted to ratios of 1:9 (latex:water), 1:3, 1:1 and full strength. They were then acidified to a pH 4.6 - 4.8 using HCl acid which had been diluted 1:1 (HCl:water). For the first time in our studies a problem was encountered in acidification of the latex solutions; adding even diluted HCl to latex 880 of 1:1 dilution, or to full strength latex, caused coagulation to occur. For the test, 880 latex in full strength concentration was therefore used non-acidified.

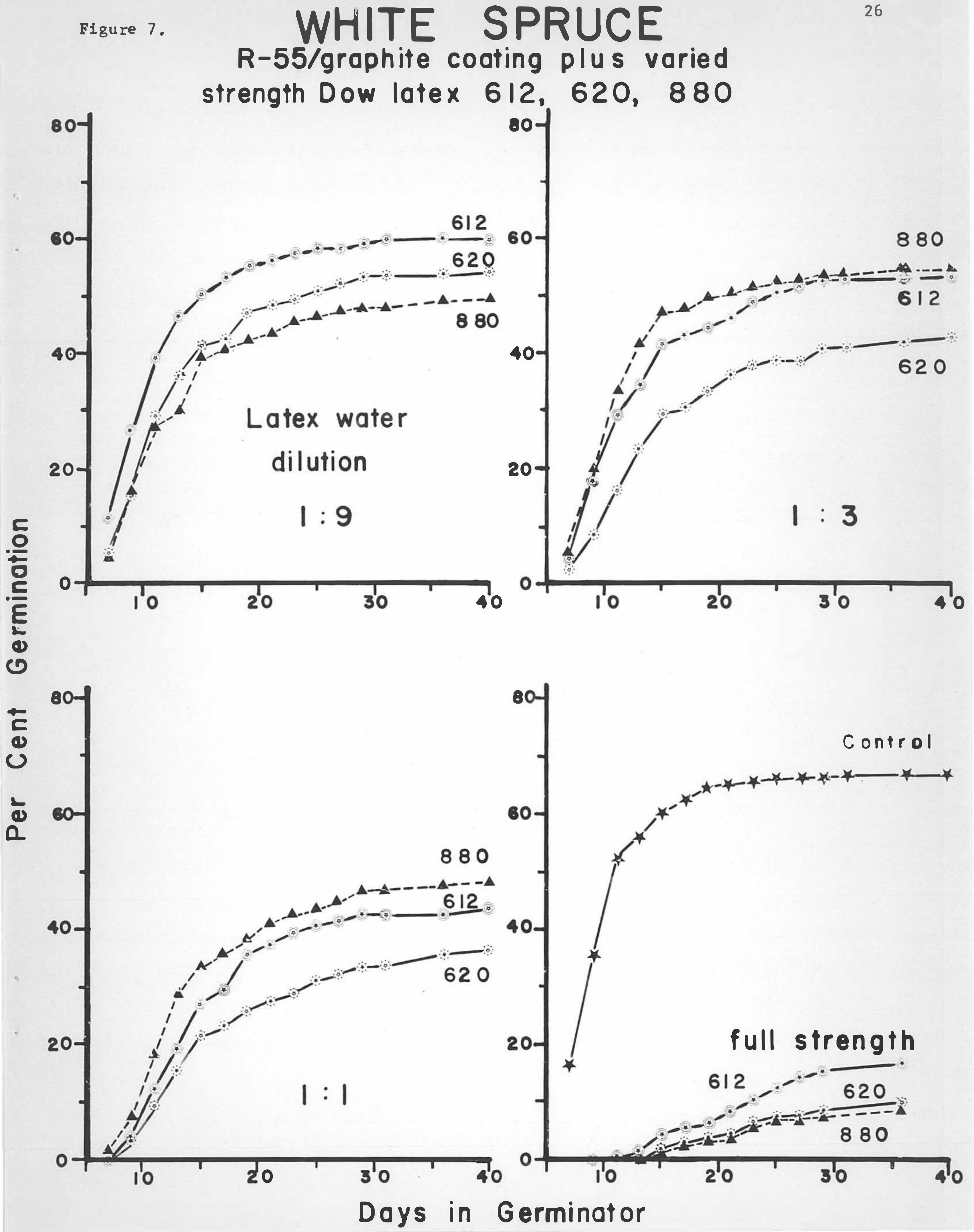
Germination of the 4500 R-55/graphite coated spruce seeds using the 3 latex types and 4 dilutions are shown in Figure 7. Non treated seeds served as controls.

For each latex and dilutions, except one, use of latex 612 gave higher germination results than the other two; 620 was better than 880. As before, the more concentrated was the latex used, the poorer were the germination results. The one exception occurred with the use of 880 latex where seeds coated using a 1:3 latex dilution factor resulted in higher germination values than when 1:9 dilution had been used.

Coating of other coniferous seed species - Black spruce

Experiment 8. While laboratory tests had indicated coating of white spruce seeds with the new R-55/graphite/latex preparation accorded excellent protection to the seeds when treated and non-treated seeds were made available to Peromyscus and yielded somewhat reduced but nonetheless acceptable germination results, no information was known on how well the coating treatment might work on other seed species. A species with which regeneration problems are being encountered similar

Figure 7.


WHITE SPRUCE
R-55/graphite coating plus varied strength Dow latex 612, 620, 880
Latex water dilution
1:9
612
620
880
1 : 3
880
612
620
1 : 1
880
612
620
Control
full strength
612
620
880
Per Cent Germination
Days in Germinator
0
20
40
60
80
10
20
30
40

in many respects to those of white spruce in Alberta is that of black spruce (Picea mariana) in Ontario. Discussions on these problems with forestry personnel from Ontario (Day 1971; Fraser 1971) led to our carrying out of coating and feeding tests on black spruce seeds as well.

In order to obtain a cursory judgement of the potential magnitude with which Peromyscus are capable to destroying seeds of black spruce, 3000 seeds of that species were presented to one mouse during each of three consecutive nights. The animal ate 2,096, 1,305, and 935 (average 1,444) seeds respectively. That Peromyscus have little aversion to destroying black spruce seed might well be expected.

To test how effective the new coating treatment might be when applied to black spruce seeds, a five-day alternate choice feeding trial was run using another adult male Peromyscus and methods similar to those used for white spruce as described under "Weathering tests". Three thousand non-treated and 3000 R-55/graphite/latex treated black spruce seeds were made available nightly on the floor of the test room. Each morning the seeds were swept up and a new lot of seeds scattered on the floor. The results of the feeding test and the calculation of percentage effectiveness of the coating on the seeds are shown in Table 5.

The feeding test was to run for five days. After four days, however, the mouse was found dead in its nest box. Post mortem examination indicated the animal starved to death despite the presence of many non-treated black spruce seeds still available on the floor.

A second animal was substituted and the test begun again. Results of the second feeding trial with black spruce seed are as shown in Table 6.

Table 5. Feeding trials on treated and non-treated black spruce seeds.

Day	# non-treated seeds eaten (out of 3000)	# treated seeds eaten (out of 3000)	% effectiveness of coating treatments
1	900	27	97.0
2	475	4	91.6
3	491	0	100.0
4	402	75	81.3
5			

Table 6. Repeat feeding trial on treated and non-treated black spruce seeds.

Day	# non-treated seeds eaten (out of 3000)	# treated seeds eaten (out of 3000)	% effectiveness of coating treatments
1	21	104	-79.8
2	25	0	100.0
3			
4			
5			

As in the previous experiment, the test animal was found dead after two days of the feeding trial despite the presence of many non-treated seeds still on the floor. Examination of the stomach revealed the presence of fragmented seed coat material. The paucity of this material suggests while Peromyscus will eat black spruce seeds, a diet consisting of only such seeds is not adequate to sustain the species. It is intended the experiment be re-run and an alternate food be permitted in the room.

Experiment 9. Black spruce germination tests.

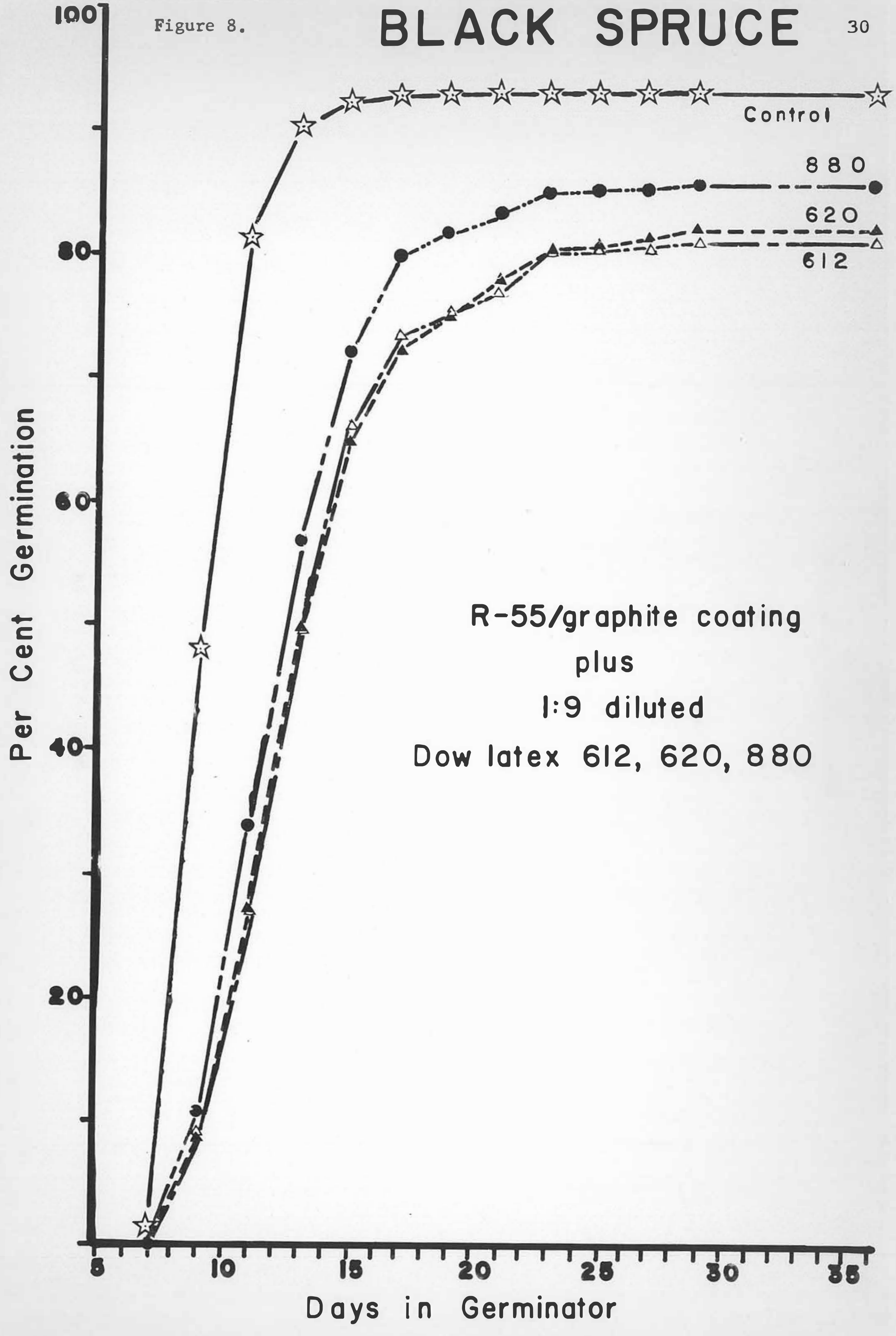
To check what germination of non-treated black spruce seeds drawn from cold storage facilities at the Alberta Tree Nursery might be and what phytotoxic or retardent influence coating such seeds with the new R-55/graphite/latex treatment may have on the seeds, germination tests were conducted in the departmental germinator. Using 1:9 dilution factors and 612, 620, and 880 latex solutions, 500 black spruce seeds were wetted with the three latex solutions and coated with R-55/graphite powder. Non-treated seeds served as controls. The results of the germination tests at the Alberta Tree Nursery in August 1970 gave 92.6 percent germination for this particular seed lot. The results of our test are shown in Figure 8.

The black spruce germination test indicated two interesting aspects. First, the germination of treated seeds were higher in relation to non-treated seeds than had been the situation with white spruce. Second, the influence of the three latex solutions used were in reverse order in the germination of the two seed species. With white spruce, best results had been obtained using 612 latex; with black spruce 880 gave the highest results. The differences in germination using the three latex solutions on black spruce were considerably smaller than had been the case with white spruce.

Experiment 10. Lodgepole pine seed coating.

To test the effectiveness of the new coating treatment on lodgepole pine seeds, seeds of this species too were coated with R-55/graphite/latex and presented along with non-treated seeds to an

Figure 8.


BLACK SPRUCE
Control
880
620
612
R-55/graphite coating
plus
1:9 diluted
Dow latex 612, 620, 880
Per Cent Germination
100
80
60
40
20
5
10
15
20
25
30
35
Days in Germinator

adult male Peromyscus. Two thousand treated and a similar number of non-treated seeds were scattered on the floor of the test room. The test ran for five consecutive nights and no alternate food was made available during the test. The numbers of seeds destroyed by the animal and the calculated percentage effectiveness of the coating treatment are shown in Table 7.

Table 7. Feeding trials on treated and non-treated lodgepole pine seeds.

Day	# non-treated seeds eaten (out of 2000)	# treated seeds eaten (out of 2000)	% effectiveness of coating treatment
1	876	15	99.9
2	1170	125	89.3
3	1175	14	98.8
4	1061	49	95.4
5	930	215	76.9

Experiment 11. Lodgepole pine germination tests.

a) To check what effect the coating may have on germination of lodgepole pine seeds, 500 seeds so treated were placed on pyrolite in the germinator. A similar number of non-treated seeds served as controls. Germination results are shown in Table 8. Germination of seeds from the same lot conducted at the Alberta Tree Nursery in 1970 had been 83%.

The germination of lodgepole pine seeds coated with the R-55/ graphite/latex treatment appear to be markedly slow. The tests indicate that more studies and formular modifications will be needed in applying the new coating method to lodgepole pine.

b) All germination tests in our germinator had been conducted on inert pyrolite material. The inert aspect of this material may be of advantage in that its use would permit comparisons on germination tests more readily than if tests had been conducted on soil, the quality of which could conceivably vary greatly.

A germination test was set up to check whether germination of lodgepole pine seeds could be hastened by supplying plant food to the seed. Five hundred non-treated pine seeds were placed on pyrolite and wetted using distilled water. A similar number of seeds also non-treated and mounted on pyrolite, were wetted using R_x-15 plant food in solution (1 tablespoon full dissolved in 1 quart distilled water). The germination results were as shown in Table 9.

While supplying of the plant food solution appeared to have a slight beneficial influence on germination of lodgepole pine seed at first, the results were not conclusive. More experimentation should be done using different concentrations and different plant foods, preferably one with less nitrogen content. If a beneficial result can be shown, the next step would be to experiment with inclusion of the plant food in powdered form in the R-55 and graphite mixture.

Responses to the new coating and bulk treatment

Publication of the paper outlining the method of the new coating treatment for coniferous seeds (Radvanyi 1970a) brought immediate response from foresters, tree nursery personnel, logging companies, and researchers from Alaska to Louisiana and from coast to coast. With the ban on further use of endrin for seed coating purposes,

Table 8. Germination of R-55/graphite treated lodgepole pine seeds and non-treated controls.

Treatment	Days in germinator									
	6	7	8	9	10	11	12	13	14	15
R-55/graphite	2.0	7.4	10.4	14.4	16.8	19.0	22.0	24.0	27.2	29.8
Control	7.2	27.2	39.6	49.6	52.8	56.8	60.4	63.0	64.4	66.4

Treatment	Days in germinator									
	16	17	18	19	20	21	23	25	27	30
R-55/graphite	31.8	33.8	35.4	36.8	37.8	39.0	40.4	42.2	43.8	45.0
Control	67.0	68.2	69.4	70.0	70.4	70.6	70.8	71.2	71.4	71.6

Table 9. Germination of lodgepole pine seed with and without Rx-15 plant food.

Treatment	Days in germinator 6	7	8	9	10	11	12	13	14	15
Watered with Rx15 soln	7.2	21.8	33.8	43.0	48.4	54.4	59.2	60.4	61.8	62.6
Control	7.2	19.6	30.6	39.0	45.0	51.2	57.2	59.8	62.0	63.2

Treatment	Days in germinator 16	17	18	19	20	21	23	25	27	30
Watered with Rx15 soln	62.8	63.2	63.4	63.6	63.7	63.7	64.0	64.0	64.0	64.0
Control	64.8	66.0	67.8	68.2	68.4	69.2	70.6	71.0	71.0	72.2

foresters have become hard pressed to find a means of protecting seeds used in broadcast seeding operations. A two-day seminar held at the Olympia Research Laboratory, Olympia, Washington, Oct. 1970 at which the writer attended, revealed that to find a replacement for endrin was of top priority in the Pacific northwest. The search had yielded no promising and acceptable results. The use of R-55 in the seed coating formulation may serve a triple function: 1) being of low mammalian toxicity it could negate the use of long lasting, lethal, and hazardous pesticides; 2) being an effective repellent, the small mammals are not killed and continue to exert some beneficial influence in the realm of insect population control and 3) it is also a fungicide.

In almost every letter received expressing interest in the new coating treatment the questions of quantities of ingredients needed to coat, say, 20 pounds of seeds i.e. use in bulk treatment of seeds -- and costs factors, were raised. In all of the tests leading up to the development of the coating treatment, seed lots of only 1000 spruce seeds or less had been used. Seed treatment had been carried out on small squares of fine wire mesh. The seeds had been wetted with latex solution, sprinkled with the prepared R-55/graphite mixture in excess and stirred with a glass rod until a uniform coating was achieved and the seeds had been separated. No attempt had been made to calculate how much of each ingredient was actually adhering to the seeds and/or how much had passed through the fine wire mesh. Before the new coating treatment could be applied to bulk treatment, further experimentation would have to be carried out to ascertain how much of the ingredients are actually being used.

Following consultation with personnel with previous experience in seed coating work with the Alberta Forest Service and the Alberta Tree Nursery, it was agreed seed coating was not a simple task. Even after the coating mixture such as R-55 and graphite, had been prepared in the proper weight ratio of mixture ingredients, eight or more variables could conceivably enter the picture in the way the coating was applied to the seeds. These variables would act singly or in combination with other variables. Those considered most important -- and doubtless there are other -- include: 1) Species of seeds being used - white spruce, black spruce, lodgepole pine, Douglas-fir; 2) Number of seeds per pound - would vary between and within species and would affect the seed coat area to be protected; 3) Latex type - Dow latex 612, 620, 880 - their degree of usefulness appears to vary with seed species to which it is being applied; 4) Dilution factor for each latex - 1:1 (latex:water) 1:5, 1:9, 1:12;5) Rate of latex application -- light, medium, heavy; 6) Rate of R-55/graphite mixture application - light, medium, heavy or excess; 7) Amount of seed being treated at one time; a twenty pound lot of seeds would have a different tumbling and abrassive action than would occur in treatment of a one-pound lot; 8) The number of minutes and rate of rotation the mixer is kept going in treating any one batch of seeds.

Other factors which could affect coating quality could include, the shape and tilt of the mixer, whether the latex and powder ingredients are applied all at once or in small allottments, and the length of time allowed to elapse between application of the latex and the powders. To remove subjectivity from the decision of what constitutes a "good" coating, germination tests should be conducted to check out the permutation and combination influences of each of the mentioned variables. To do so and allowing 3 or 4 degrees of variability within each factor, would necessitate carrying out in excess of 4000 germination tests. To test the repellency effectiveness of the coating, a similar number of feeding experiments should be done. As one has no way of knowing whether all the possible variables are being considered, the end results would continue to be of questionable value.

With the above variables in mind and the impossibility of equating them with the time, man-hours, and funds available to carry out such tests, it was decided if the data on how much of the ingredients would be required was to be obtained, it would have to be done on a trial and error basis and using both subjective and experimental measures for a "good" coating.

Using a hand driven gallon-sized cement mixer type of apparatus bulk treatmentswere carried out to ascertain what quantity of coating ingredients would be required to coat coniferous seeds "properly". One-quarter pound lots of white spruce seed were used in the initial trials. Measured quantities of acidified diluted Dow latex 612 were used to wet the seeds and then R-55/graphite powder added until a more or less uniform coating had been applied. By subtracting the weight of the stock supply of R-55/graphite remaining following the coating treatment from the known weight of the supply before the treatment, the amount applied to the seeds could readily be established. Six coating trials on white spruce seed used the following quantities of coating materials:

Test	Quantity of Seed	Diluted acidified latex	4:1 R-55:graphite mixture
1	1/4 lb.	20 cc	49.0 gms
2	1/4 lb.	30 cc	87.0 gms
3	1/4 lb.	25 cc	54.5 gms
4	1/4 lb.	30 cc	79.3 gms
5	1/4 lb.	40 cc	96.0 gms
6	1/4 lb.	30 cc	80.0 gms (measured)

Thirty cc of diluted acidified latex and 80.0 grams 4:1 R-55: graphite powder applied to 1/4 pound of seed appeared to give the most uniform coating for white spruce seed. The coating trials revealed the importance of two of the considered variables, namely, a) the length of time allowed to lapse between application of the latex and powder, and b) the manner of applying the latex and powder. If the R-55/graphite mixture was applied too soon, and in one large does, there was a tendency for large balls of coating materials to form. Should these be allowed to persist, they could clog the apparatus used to disperse seeds in broadcast seeding operations. A more uniform coating for white spruce was obtained when the drum was revolved for three to four minutes tumbling the latex wetted seeds before the powder mixture was applied. Uniformity of coating application was enhanced by adding the powder mixture in multiple small quantity allottments rather than as one large application. Following coating, the seeds were allowed to dry over night and then shaken in a fine mesh soil sieve to remove excess coating.

A crude test for adequacy of coating used in the past by Alberta Forest Service consisted of placing treated seeds under running tap water for two minutes. If at the end of that time, at least two-thirds of the seed surfaces were still coated, the coating was deemed as being adequate. No indication was given, however, as to the force of the water flow to be used in such a test. Spruce seeds coated with the new coating treatment as described in trial 6 above and allowed to dry were subjected to the flowing water test. The force of the flow was adjusted so that seeds tumbled freely in the wire mesh container. Once washed and allowed to dry, these seeds could be distinguished only with difficulty from seeds not receiving the wash test. It would appear an adequate coating was being accomplished.

With preliminary data on coating of 1/4 pound lots of white spruce worked out, two questions naturally follow -- 1) if 20 cc latex and 80 grams R-55/graphite mixture are suitable quantities to coat 1/4 pound of white spruce seed, would 80 times these quantities be the proper amounts of ingredients needed to coat a 20 pound sample of seed in a conventional cement mixer - seed treatment procedures?, and 2) if the quantities are acceptable for 1/4 pound spruce seed, how would they differ for a similar weight of black spruce, lodgepole pine, or Douglas-fir seeds?

Treatment of one twenty-pound lot of white spruce seed for the Alberta Forest Service using the 80X multiple factor of coating ingredients derived in the 1/4 pound seed tests and using the conventional cement-mixer type of coating apparatus suggested that a fairly acceptable coating can be achieved using these amounts. If and when the treatment becomes used on large scale broadcast seeding operations, minor adjustments in ingredient quantities and application procedures can be made.

To answer in part question 2), three coating trials were run on 1/4 pound lots of lodgepole pine seed. The quantities of ingredients used were as follows:

Test	Quantity of Seed	1:9 Diluted acidified Dow latex 612	4:1 R-55:graphite mixture
1	1/4 lb.	30 cc	80 grams
2	1/4 lb.	40 cc	100 grams
3	1/4 lb.	35 cc	90 grams

The test indicates the quantity of ingredients needed to coat the same weight of seeds would differ with seed species. Large scale coating trials on 20 pound seed lots of various seed species are yet to be done. It is anticipated tumbling action of the larger seed quantity could necessitate some further adjustment of the 80 x multiple factor. The Alberta Forest Service has indicated white spruce and lodgepole pine seeds in adequate quantities will be made available for multiple 20 pound lot coating trials. Arrangements are being made for "borrowing" adequate seed for similar trials on black spruce seed from Ontario and Douglas-fir seed from British Columbia.

A two pound sample of black spruce seed was received from Ontario for preliminary coating trials using the R-55/graphite mixture. In five test runs the following quantities of seed and coating ingredients were used:

Test	Quantity of seed	1:9 diluted acidified Dow latex 612	4:1 R-55/graphite mixture
1	1/4 lb. (113 grams)	25 cc	75 grams
2	1/4 lb.	25 cc	75 grams
3	1/4 lb.	30 cc	75 grams
4	1/4 lb.	20 cc	75 grams
5	1/4 lb.	20 cc	75 grams

Coating in Test 1 was irregular. In Test 2 the number of minutes the wet seeds were tumbled before application of the powder mixture was increased from 3 to 4. The coating still appeared patchy and not uniform. Similar results were obtained when the quantity of latex was increased in Test 3. In Test 4 the amount of latex was reduced and the resultant coating appeared more uniform when observed under a binocular microscope. In Test 5, the latex was applied to the seeds using a fine pointed pipette and the seeds were kept tumbling as the latex was added. The resultant coating was more uniform than in the previous tests and fewer lumps of R-55/graphite formed among the seeds. Procedures used in Test 5 would probably be most suitable for treatment of larger quantities of black spruce seed.

Discussion

For more than half a century Man has been aware of the role of small mammals in destruction of natural and artificial seed supplies intended for regeneration of cutover coniferous forest lands (Willis 1914). For almost as long a period, foresters have sought measures to protect the valuable seed supply against depredation by small mammals, birds and insects. Use of various mechanical barriers such as cans, paper, and wire screens to protect seed spots and seedlings have frequently proven ineffective or too costly (Krauch, 1938, Keyes and Smith 1943, Roy and Schubert 1953, Tevis 1953, and Campbell 1969). Attempts at protecting seeds by coating them with numerous poisonous compounds, and repellents had over several decades proven equally futile (Moore 1940, Garman and Orr-Ewing, 1949, Radwan 1963) and for years hopes for regeneration by direct seeding methods were almost abandoned. Most foresters concluded that seed destruction by animals, primarily rodents, was the limiting factor in reforestation by direct seeding and until means were found to control these populations, there was no more certain way of wasting large quantities of valuable seed and accomplishing nothing than to broadcast onto unprepared sites.

Several new developments within the past two decades have been instrumental in reviving hopes for greater success by direct seeding methods. With the introduction of the aluminum powder-endrin-arasan-latex seed coating method in the 1950's (Spencer 1957), many foresters accepted the technique as a panacea which would solve much of their reforestation problems. Secondly, the radiotracer techniques by Lawrence and Rediske (1959) proved to be a very useful method for evaluating fate of individual coniferous seeds in the natural environment. Prior to development and use of the radiotracer method, what had actually happened to individual seeds in the field was largely guesswork. While patterns of coniferous seed destructions have been described by Moore (1940, 1942), Garman and Orr-Ewing (1949), Kangur (1954), Lawrence, Kverno and Hartwell (1961), Lawrence and Rediske (1962), and in our studies - Radvanyi (1966b, 1971) - seeds placed into the natural environment are frequently moved and lost from subsequent observation. Only the radiotracer method has enabled recoveries of a large portion of such wandering seeds from within the natural environment.

Poisoning programs using Tetramine, 1080, and endrin and prescribed burning have not proven successful means of eliminating or effectively reducing the influence of small mammal populations long enough for reforestation by direct seeding (Hooven, 1955a, 1955b, 1956, 1958; Dimock 1957; Dick and Lawrence 1957; Dick, Finnis, Hunt and Kverno 1958). The hazards of secondary poisoning and in handling these poisons have led to their being used less and less. Tevis (1956) and Hooven (1969) have shown that even severe burns do not completely eliminate populations of small mammals and re-invasion from surrounding areas may be rapid. As Ahlgren (1966) and Hooven (op cit) both note, burning, instead of eliminating small mammal populations, may create habitat and food conditions conducive to increases in seed-eating mouse species.

Setbacks in the success being achieved by direct seeding methods during the '60's caused foresters to seek other avenues of approach to regeneration problems. One such alternate has been the development of the "bullet" or container seedlings as intended originally for use in the Walter tree-planting gun designed in British Columbia. The status of container planting has been reviewed by Stefansson (1969) Crossley, White, Adams, Dick, Kinghorn (1969), MacKinnon (1970) and

Kinghorn (1970). While container planting has shown temporal, spatial, and mechanization advantages over conventional bare root planting methods, the technique is not without its share of problems. The tree planting gun as well as the "bullets" have passed through many modifications and continue to be modified in an endless search for improvements. While seedlings can be grown in greenhouses in increasingly large numbers almost around the calendar year, field problems continue to occur with root strangulation, and malformation, dessication, flooding, snow, insect, and bird damage and frost heaving of either "bullets" or "plugs". The necessity of selecting the best microsite possible, when planting, is essential to maximum survival and growth of the seedlings and is frequently the weak link in the container technique, particularly if inexperienced individuals are employed to plant trees on a piece-work arrangement. While appreciable success with the technique has been achieved in the mild and moist coastal regions of British Columbia, the container method is still in the developmental stage and it is still too early to assess the full potential value of the approach. For the present it is a useful addition to the other regeneration techniques.

Regeneration of cutover areas by natural seed fall from residual stands have not proven reliable in the case of spruce and within the time table of dollar-driven Man. In white spruce, good cone crops may occur as long as six to seven years apart and are unpredictable. As seen in our early studies (Radvanyi 1962) and in studies by Alexander (1969), by far the larger portion of natural seed fall in spruce are scattered over only 1.5 to 2.0 chains downwind across the cutover area. Yet the trend in many forestry operations today is toward clear cutting strictly for the sake of dollars and cents economics in larger and larger blocks. Is there a supply of viable coniferous seed in the forest floor for natural regeneration? Studies by Frank and Safford (1970) suggest seeds of northern conifers do not retain viability in the forest floor longer than one year and that forest managers should not rely on this source for regeneration following clear cutting operations. Artificial seed supplies will have to be provided for direct seeding operations on large clear cut areas.

The radiotagging studies have indicated a large percentage of the artificial seed supply could, however, be destroyed by small mammal populations despite the fact that the seeds had previously been coated with the aluminum powder-endrin-arasan-latex treatment and such losses could occur within a matter of two to three months following late spring seeding. Further studies have indicated such losses could be reduced and germination percentages improved by late winter seeding into snow. Similar advantages to late fall or winter seeding of conifers have been noted by Cayford (1961), Graber (1969) Horton and Wang (1969). Radwan, Couch and Ellis (1970) suggest doubling the endrin concentration increases the effectiveness of the coating treatment but at the same time they question the approach in view of the potential hazards involved. A similar appreciation of the hazards both to humans and animals has led to refusal on the part of individuals involved in seed coating work in Ontario to refuse to handle this deadly pesticide. A subsequent ban by governments in both Canada and the U. S. on further use of endrin for forest regeneration work has left foresters empty handed and with no effective means of protecting seed supplies from predators. Currently I understand Ontario is conducting direct seeding operations using seeds coated only with aluminum powder, arasan and latex (R. J. Day, personal communication) and in Alberta seeding is being done with no prior coating treatment. In our studies, no protection against Peromyscus was seen in the use of Thiram or arasan (Radvanyi 1969, Expt. 21 and 22) and very little hope is held for use of non-treated seed in the natural environment.

Our studies on coniferous seed fate using the radiotracer technique indicated the widely accepted coating treatment of aluminum powder-endrin-arasan and latex was not fulfilling the purpose intended for it. Our attention was directed at assessing critically how well each component of the coating mixture was serving the intended function and in what ways the method might be improved. The new coating treatment which resulted from these studies has proven under laboratory conditions and under limited field trials to be superior to the old method. Studies during the past year have sought ways of improving even more the new coating procedures and in adapting it to bulk treatment of seeds as will be required by foresters.

Most of the experiments carried out during the past year were of a probing nature. The results of some tests were of value only from a negative aspect. Others served only to open up whole new areas of approach and by answering in part one question, have raised many more.

No new and startling pre-treatment procedure was found to vastly improve spruce seed germination. Neither prechilling, preheating, or both, gave germination percentages significantly different from seeds taken directly from cold storage. Nor was a successful means found to impregnate the R-55 rodent repellent into the seed coat and thus increase the duration of seed protection.

The examination of various latex solutions has pointed out the marked deleterious effect on germination which can be brought about by inadequate dilution of the latex concentrate. While dilutions of 1 part latex to 9 parts water had been widely used in the past, no experimental data for this particular dilution factor appears to have been published. Similarly no basis appears to have been available for use of full strength latex by others. Our germination tests on white spruce using Dow latex 512R and 612 as adhesives for applying the R-55/graphite coating treatment suggest a slight advantage in using 1:7 dilution of the latex over the 1:9 dilution. All our tests showed notable reductions in germination of treated white spruce seed using latex solutions with 1:3 dilution ratio or less.

Comparison tests using Dow latex 612, 620 and 880 in dilutions of 1:9, 1:3, 1:1 and full strength showed usually, but not in every case, the same decrease in germination with increasing concentration of latex used in applying the new coating. For 1:9 dilution of the latex, use of DL 612 gave the best germination; for 1:3 and 1:1 dilutions, however, 880 was superior to 612 or 620.

Use of the same latex solutions and same dilution factor can give different results when different coniferous seed species are being used. For white spruce using a 1:9 dilution factor, best germination results were obtained using latex 612, then 620 and 880.

With the same treatment, but on black spruce, the order of superiority was completely reversed - 880, 620 and 612. The experiments serve to exemplify the hazards of accepting that what is favourable for germination of one coniferous seed species will be of equal value to other species.

Nor should the formulation of the new coating treatment be regarded as final and equally acceptable for all coniferous seeds. Much more basic testing research will have to be conducted in both the laboratory and field and undoubtedly numerous adjustments will have to be made in its application. Results of germination tests in the laboratory and of seed exposure trials as outlined in our weathering tests are not the conditions to which broadcast seeds will ultimately be exposed in the field. The value of the new coating treatment will be seen only when one will some day be able to point to trees resulting from seeds so coated and these will be ready for cutting.

Needs for further research

Considerably more research is needed in evaluating the influence of small mammals on forest regeneration and in developing ways in which these influences may be rendered less harmful to Man. That small mammals can have a deleterious influence on not only natural and artificial seed supplies but also on the resultant seedlings and young trees is no longer the question of interest to foresters. The major problem now is how best to cope with the situation in the most effective manner and in the shortest period of time. With those who would assert that no regeneration problems exist,-(and surprisingly this is the view being expressed by the very individuals who requested initiation of this study)- I would agree. There never did exist a problem, - until

Man came along. The problem today is not in regeneration but in Man's mismanagement of his environment.

While field trials comparing fate of seeds receiving nil, old and the new coating treatment and the radiotracer method are currently underway at Rocky Mtn. House, Alberta, the results of the tests are very prone to many factors which may not only be uncontrollable but also unknown to the experimenters. A fair evaluation requires more than one year of testing. If the positive response to the publication of the new coating treatment is an indication of the degree of interest in the method, the technique will undoubtedly be tried in many other areas and under diverse conditions. As much more study should be done, perhaps some of these evaluations from elsewhere may be premature, cautionary, or rewarding.

1. Of paramount interest at the present time is standardization of details on coating procedures using the R-55/graphite/latex formulation. With recognition of the numerous variables that can influence application of any coating, perhaps no detailed instructions are possible which would give precisely repeatable results. Any set of instructions will have to be used with acceptance of a degree of variability in results. Before the new coating procedure can be applied to any large scale direct seeding operation, the quantity of coating ingredients required to treat large batches of seed (20 pounds or more) will have to be ascertained and done so for each coniferous species to be used.
2. The evaluation of the effectiveness of the new seed coating treatment in repelling and thus preventing destruction of seeds has to this point been carried out under laboratory studies using only one

small mammal species - Peromyscus. No data whatever is available on how other small mammal, insect or bird species react to seeds so treated. Similar feeding trials should be carried out encompassing at least those other species found to occur on our study areas or on any area where broadcast seeding is to be carried out. These responses toward treated seeds may vary with the presence and availability of alternate foods and thus with different seasons of the year.

3. The question of effects of storage of R-55/graphite treated seeds has not been investigated at all. Frequently foresters in the past have treated seeds in bulk only to find that for diverse reasons the seeding operation had to be suspended sometimes for days, months, or even until the following year, thus necessitating the treated seed be returned to storage. Storage has repeatedly shown to have deleterious influences on germination of seeds treated with the aluminum powder-endrin-arasan-latex treatment. Whether or not the same influences may affect germination of seeds treated with R-55/graphite is not known. While it would undoubtedly be most advisable to treat only seeds which can most assuredly be placed into the field, within a few days after coating such is not always possible. Even to know for how short a period treated seeds can be stored before the effectiveness of the treatment falls or a decline in germination sets in would be of considerable value in order that foresters might have some measure of time within which the seeds could still be used. Periodic germination testing of treated and stored seed as well as feeding trials should provide this information.

4. More studies are needed in the area of optimal latex type and dilution factors. These appear to differ with seed species and blanket use of one formula for all species is not advisable. Further germination testing, feeding trials and weathering tests need to be carried out to determine whether or not seed germination can be improved by use of even more dilute latex solutions, say 1:12, 1:15 or 1:20 dilution. If germination is improved by greater dilution of the latex, what effect would this have on retention of the coating on the seed? Would sufficient repellent stay on the seed long enough to permit germination?
5. If a greater degree of protection against small mammals is provided by the new coating procedure, what then will be the proper or adequate amount of seed which should be braodcast per acre of cutover forest land? Seeding at a rate of one pound of white spruce seed coated with the aluminum powder-endrin-arasan, latex treatment (per acre) had not yielded adequate regeneration. Would the same number of seeds bearing the new treatment be sufficient? With a greater degree of protection, would a lesser amount of seed suffice?
6. At the time the Canadian Wildlife Service took on this research project, the one and only question being raised was "What happens to broadcast coniferous seed in the environment when 220,000 seeds fail to produce 300 - 400 trees?" No forethough appears to have been made along the lines that should the possible fate of seeds be determined, the next logical question would be 'What can be done about it?' It is in seeking answers to <u>this</u> unasked question that the study had turned toward involvement in seed coating procedures. Another question still exists and should be considered

soon. Suppose the new coating treatment functions adequately and many more seedlings result - which are then promptly chewed off by small mammals, birds and insects. Should this occur, what will have been accomplished? The radiotracer method enables determination of seed fate only up to the point of germination. The resultant seedling is non-radioactive and hence the fate of it cannot be ascertained using the same techniques. To verify possible benefits of the new coating treatment, a subsequent study should be planned to follow the fate of coniferous seedlings. Without such a follow-up, the studies we have carried out to date will be incomplete.

Our studies over the past years have yielded considerable data on the potential influence of small mammals on forest regeneration in western Alberta and in particular how this influence may affect the fate of individual coniferous seeds in the natural environment. While the new seed coating procedure holds considerable promise for success in broadcast seeding, a complete or final solution is still far from having been attained. An adequate field evaluation of the method could and should involve a minimum of five years of testing, possibly even more. It is high time that those who stand to benefit most from the method become more directly involved in both costs and physical participation in the future evaluation work. The forest industry can ill affort to sit back and wait for others to solve problems for them and there is more involved in forestry than just cutting trees. Trees are a crop which should be harvested but no farmer has remained long in the trade without learning to solve his seeding problems. Nor will our forest industry remain viable unless greater priority is placed on replacing that which we excell in removing. Is a crisis needed to drive home the point?

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