EFFECTS OF ARASAN AND R-55 ON GERMINATION OF BLACK SPRUCE AND JACK PINE SEEDS

J.W. FRASER

GREAT LAKES FOREST RESEARCH CENTRE

SAULT STE. MARIE, ONTARIO

REPORT O-X-320

CANADIAN FORESTRY SERVICE

DEAPRTMENT OF THE ENVIRONMENT

SEPTEMBER 1980

Copies of this report may be obtained from:

Information Office
Great Lakes Forest Research Centre
Canadian Forestry Service
Department of the Environment
Box 490
Sault Ste. Marie, Ontario
P6A 5M7

ABSTRACT

Experiments to determine the effect of two reputed rodent-repellent coatings, Arasan and R-55, on germination of black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.) seeds are documented and evaluated. Neither coating had any appreciable adverse effect on germination of black spruce seeds, except at low temperature (10C) where R-55 depressed germination slightly below that from untreated seeds. Coating jack pine seeds with Arasan invariably depressed germination but appreciably so only at low temperature (10C). Length of storage had no practical effect on germination of black spruce coated with either Arasan or R-55, but did depress germination of Arasan-coated jack pine seeds at low temperature (10C).

RÉSUMÉ

Documentation et évaluation d'expériences en vue de déterminer les effets de deux enrobages réputés pour repousser les rongeurs, Arasan et R-55, sur la germination des graines d'Épinette noire (*Picea mariana* [Mill.] B.S.P.) et de Pin gris (*Pinus banksiana* Lamb.). Aucun des deux enrobages n'a eu d'effet adverse appréciable sur la germination des graines d'Épinette noire, sauf à basse température (10°C) où la germination des graines traitées au R-55 était légèrement inférieure à celle des graines non traitées. L'enrobage des graines de Pin gris avec Arasan a invariablement diminué la germination mais de façon appréciable à basse température (10°C) seulement. La durée d'entreposage n'a eu aucune influence pratique sur la germination des graines d'Épinette noire enrobées avec Arasan ou R-55, mais a diminué la germination des graines de Pin gris enrobées d'Arasan à basse température (10°C).

ACKNOWLEDGMENTS

I am indebted to former forest research technician, J.M. Shoup, for his assistance with the Arasan and R-55 experiments and to forest research technician, M.J. Adams, who conducted the supplementary experiment with Latex 636 and prepared the numerous histograms in this report. I am also indebted to A. Radvanyi, research scientist, Canadian Wildlife Service, for applying the R-55 treatments, and to the Ontario Ministry of Natural Resources for applying the Arasan treatment.

TABLE OF CONTENTS

INTRODUCTION

This report deals with the influence of two reputed rodent-repellent seed coatings, Arasan, and R-55, on germination[1] of black spruce (*Picea mariana* [Mill.] B.S.P.) seeds. It also deals with the influence of the Arasan coating on germination of jack pine (*Pinus banksiana* Lamb.) seeds. The report is based on a series of germination tests in constant-temperature incubators over a period of several years, and documents the germination response of coated and of untreated seeds to different temperatures in relation to how long the coated seeds were stored before they were tested.

For the rationale behind the experiments reported here and for a comprehensive review of literature on these and other seed treatments readers are referred to Fraser's (1974) paper at the Timmins symposium on direct seeding. Preliminary results presented then were updated, as was the literature review, at the Thunder Bay symposium on black spruce (Fraser 1975). The end results of these experiments, since completed, are documented in this report.

When these trials were initiated there was a widespread controversy concerning 1) the need for rodent-repellent coatings on black spruce and jack pine seeds sown on boreal forest cutovers, 2) the efficacy of the established Arasan and recently developed R-55 coatings (Radvanyi 1970) as rodent repellents, and 3) the adverse effect, if any, of either coating on germination of black spruce.

In any event, by the time the experiments initiated to help resolve the third of these controversies were completed, Phillips Petroleum had discontinued manufacturing R-55, Arasan 42S was no longer available, and Dow Chemical had stopped producing latex 512R, the binder in the Arasan coating. Hence, the results of these particular experiments now have no practical significance whatever. However, latex, the "binder" used in both these coatings, will probably continue to be used as such (in one form or another) unless or until there is documented evidence that there is no need for lubricants such as aluminum flakes or graphite to facilitate passage of black spruce or jack pine seeds through mechanical seeders. Also, operational direct seedings using Arasan-coated seeds are still being assessed and the influence of Arasan on germination should be considered in evaluating the results. For these reasons, if for no others, the results of these experiments warrant documentation.

---

[1] In this report germination refers only to germination under specified conditions in growth chambers or incubators, as opposed to field germination.

METHODS AND MATERIALS

The Ontario Ministry of Natural Resources provided the seeds used in these tests and also applied the Arasan coatings (Arasan + latex + aluminum) (Appendix I). The Canadian Wildlife Service provided and applied the R-55 coatings (Appendix I).

Arasan Tests

Germination of coated and untreated (control) seeds of both species, stored in sealed containers at 2C-4C, was tested in controlled-temperature cabinets at 10C, 21C and 32C (constant temperatures) 0, 2, 4, 8, 10, 12, 14 and 18 months after the coatings were applied.[2] The scheduled 2-month-interval storage tests were interrupted, inadvertently, at 6 and 16 months. For each of the storage-period tests, seeds were sown onto the surface of saturated, short-grain, black germination paper over saturated Kimpak[3] in sterile petri dishes. There were four dishes (replicates) of 100 seeds each for each treatment (control, coated) per temperature. The seeded dishes were covered and allocated randomly to temperature treatments. Moisture of the germination medium was maintained by adding measured amounts of distilled water if there was any indication of drying. Germination was tallied daily for 28 days: seeds were tallied as germinants when radicles were at least 2 mm long, or longer than the long dimensions of the seeds.

R-55 Tests

Germination tests of five different R-55 coatings on black spruce seeds paralleled the Arasan tests in all other respects, i.e., the same three temperatures and the same eight storage periods. Subsequently, germination of untreated and coated seeds stored for approximately 4 years (47 months) and for 6 years was tested at 21C. Shortage of seed precluded testing at 10C and 32C.

All data from these tests were analyzed by the Chi-square method. Treatment means, standard deviations and coefficients of variation based on cumulative germination data were calculated for individual storage treatments and for all storages combined 7, 14, 21 and 28 days after seeding.

---

[2]Shortage of seed precluded the 14- and 18-month tests with jack pine.

[3]Mention of companies and/or products in this report does not constitute endorsement of either by the Great Lakes Forest Research Centre.

RESULTS

Arasan Tests (Black Spruce)

For all storage periods combined (Fig. 1) it is evident that, although germination at 21C was better than at 32C and at 10C, in that order, throughout the test, i.e., at weekly intervals, there were no appreciable differences among the responses from coated and untreated seeds at any temperature at any time. The coefficients of variation (Appendix II, Table A1) confirm this and indicate that germination occurred uniformly at 21C, less so at 32C and least so at 10C. Although the differences in germination from coated and from untreated seeds are minimal, germination at 21C obviously was not only better than at 32C and 10C, but was effectively complete only one week after seeding. At 32C, although germination increased with time, the increase was minimal after the second week, whereas, although there was no germination at 10C until the third week, it was at least as good as it was at 32C by the end of the test.

Do these temperature/germination responses of coated and untreated seeds vary appreciably with the length of time seeds are stored prior to testing? As cumulative percent germination obviously must increase with time until germination is complete, treatments among which there is no significant difference have been averaged to simplify graphical presentation of the data (Fig. 2). For example, for the 10-month storage test with untreated seeds at 32C (Appendix II, Table A2), germination at 7, 14, 21 and 28 days was 67, 92, 94 and 95%, respectively. Since there was no statistically significant difference among 92%, 94% and 95%, the mean value, 94%, is plotted for 14, 21 and 28 days in Figure 2.

It is obvious (Fig. 2) that at 21C, length of storage had no effect on resultant germination of either untreated or coated seeds. It is equally obvious that length of storage had no appreciable effect on the pattern revealed when all storage treatments were combined, i.e., more and faster germination at 21C than at 32C or at 10C.

No supportable hypothesis has been advanced for the abnormally poor germination response from both untreated and freshly coated seeds (0 months' storage) at 10C and 32C relative to the response at 21C in the same test and to those at the same temperatures as storage periods increased.

Even if allowance is made for the above-mentioned anomalous response from untreated and freshly coated seeds (0 months' storage) at 10C and 32C, Figure 2, while confirming that germination was better and faster at 21C than at 32C and 10C, clearly illustrates the lack of any adverse effect of storage on coated seeds.

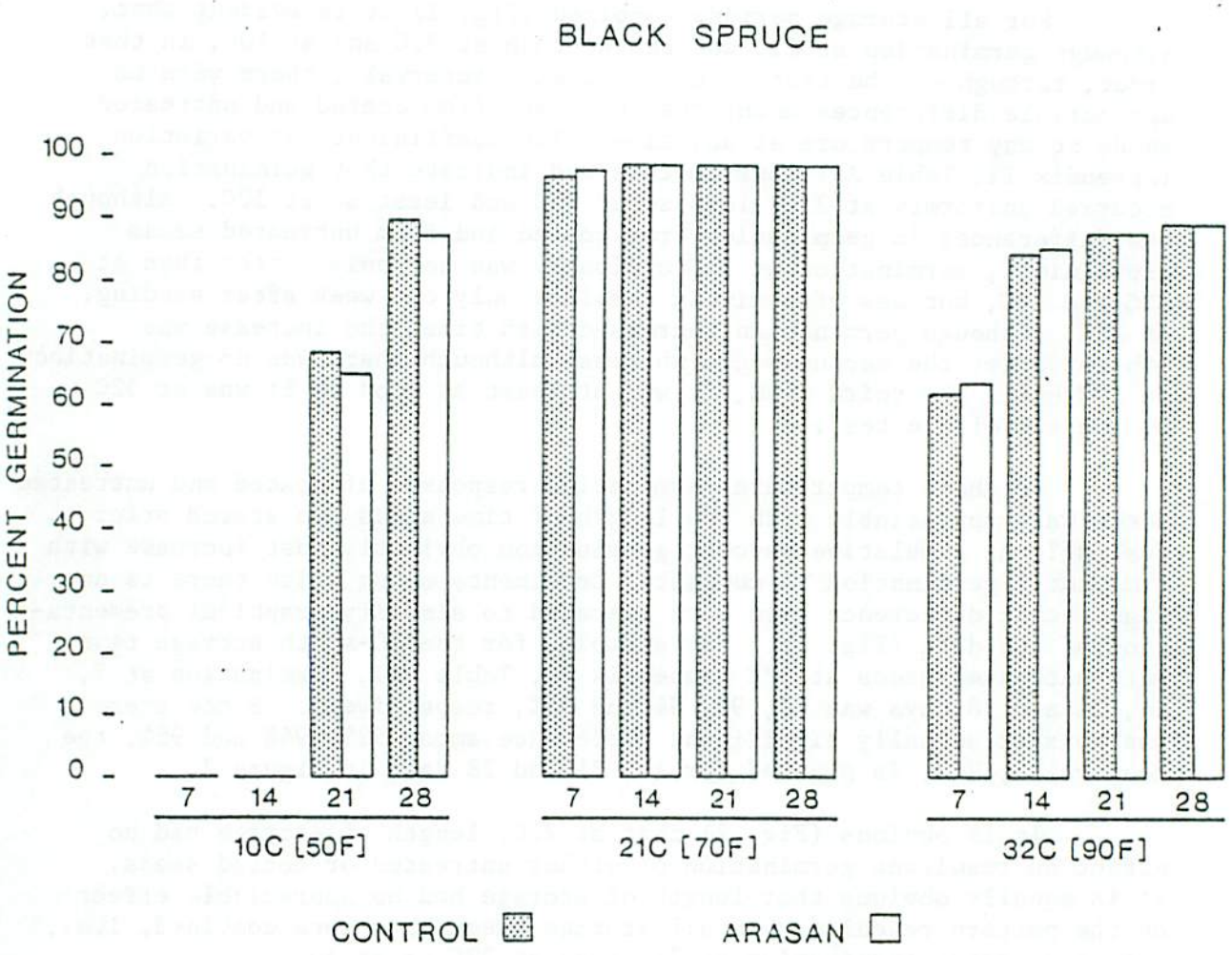

Figure 1. Cumulative percent germination of black spruce seeds (all storage periods combined) 7, 14, 21 and 28 days after seeding at 10C, 21C and 32C.

Figure 2. Mean cumulative percent germination of black spruce seeds by temperature and seed treatment 7, 14, 21 and 28 days after sowing seeds stored for 0, 2, 4, 8, 10, 12, 14 and 18 months.

Arasan Tests (Jack Pine)

For all storage periods combined it is evident from Figure 3 that jack pine germination, like black spruce germination (cf. Fig. 1), was consistently better at 21C than it was at 32C and at 10C throughout the test, but unlike black spruce germination, it was invariably better from untreated (control) seeds than it was from coated seeds. As indicated by the coefficients of variation (Table A3), jack pine germination was more uniform at 21C than at 32C and 10C (similar to black spruce). Unlike black spruce germination, it was more uniform from untreated than from coated seeds even at the best germination temperature, i.e., 21C.

For jack pine a somewhat different pattern emerged than for black spruce (cf. Fig. 1). Although germination of jack pine seeds at 10C was delayed until the third week, as was the case with black spruce seeds, germination from coated seeds was consistently poorer than from untreated seeds. Given time, i.e., 28 days, untreated seeds germinated almost as well at 10C and at 32C but coated seeds did not. Germination of jack pine seeds at 32C began as soon as germination of black spruce at that temperature, but unlike black spruce germination, it was complete by the seventh day. However, it was considerably poorer relative to germination at 21C than was the case with black spruce, and unlike black spruce germination, it was consistently poorer from coated than from untreated seeds. Coefficients of variation (Table A3) indicate more uniform germination from untreated seeds (except perhaps at 32C) than from coated seeds and also more uniform germination at 21C than at either 10C or 32C, regardless of seed treatment.

The length of time seeds were stored had little, if any, effect on the germination/temperature responses of either untreated or coated seeds (Fig. 4, Table A4). Only at 10C, where the apparently increasing but irregular, depressant effect of storage on germination was more pronounced on coated than on untreated seeds, did storage appear to have any effect on the germination response of untreated or of coated seeds.

R-55 Tests (Black Spruce)

For all storage periods combined (Fig. 5) the pattern of germination response is quite similar to that established for Arasan-coated black spruce, i.e., consistently better germination at 21C than at 32C and 10C, in that order, for both untreated and coated seeds. In this instance, however, although coated seeds never germinated as well as untreated seeds at 21C or 10C, there was no appreciable difference in germination from coated versus untreated seeds at 32C (except for treatments 2 and 3 where germination was inexplicably low). Coefficients of variation (Table A5) indicate that here, as with Arasan-coated seeds, germination occurred more uniformly at 21C than at 32C and at 10C, and that untreated seeds usually germinated more uniformly than coated seeds.

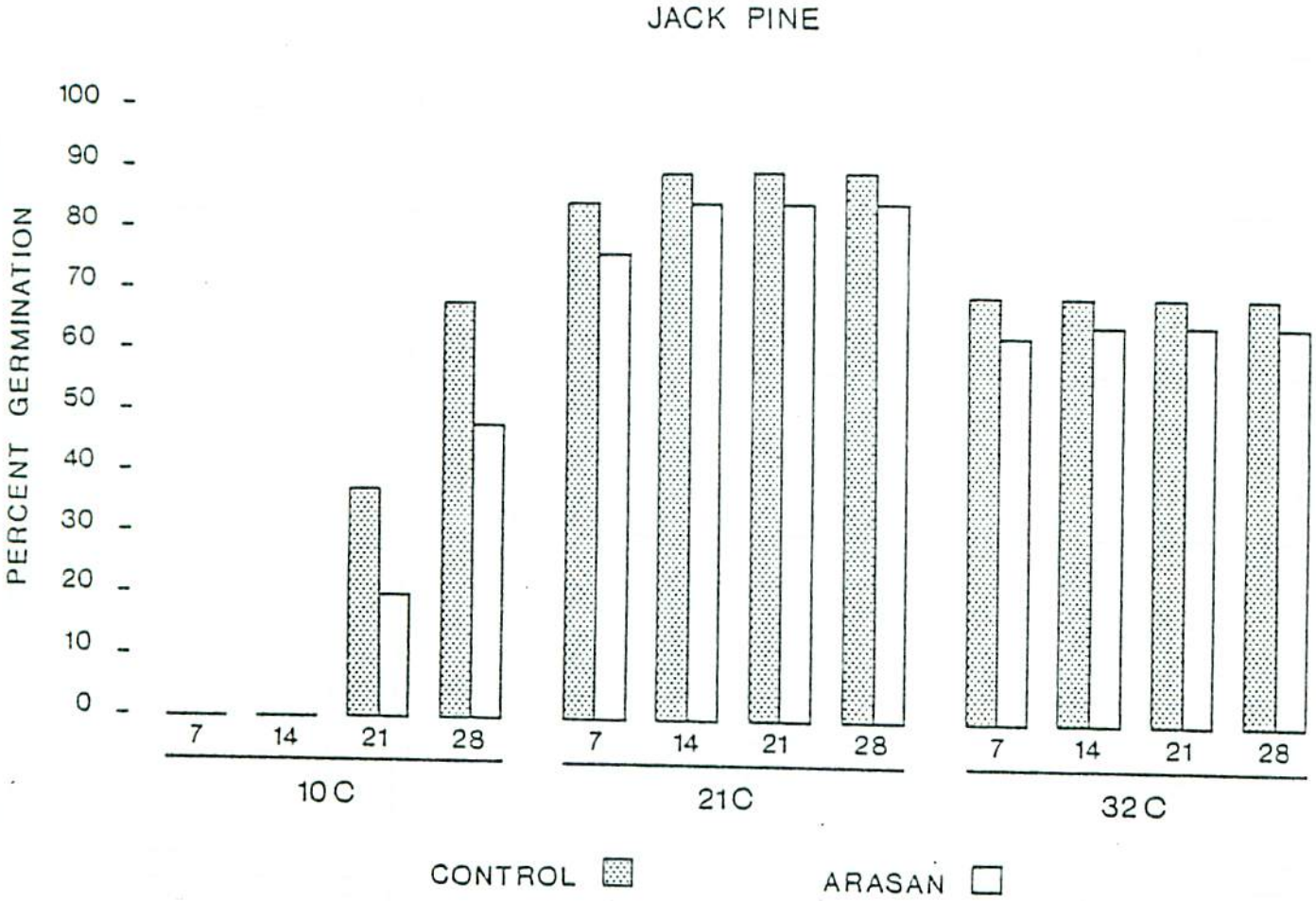

Figure 3. Cumulative percent germination of jack pine seeds (all storage periods combined) 7, 14, 21 and 28 days after seeding at 10C, 21C and 32C.

Figure 4. Mean cumulative percent germination of jack pine seeds by temperature and seed treatment 7, 14, 21 and 28 days after sowing seeds stored for 0, 2, 4, 8, 10 and 12 months.

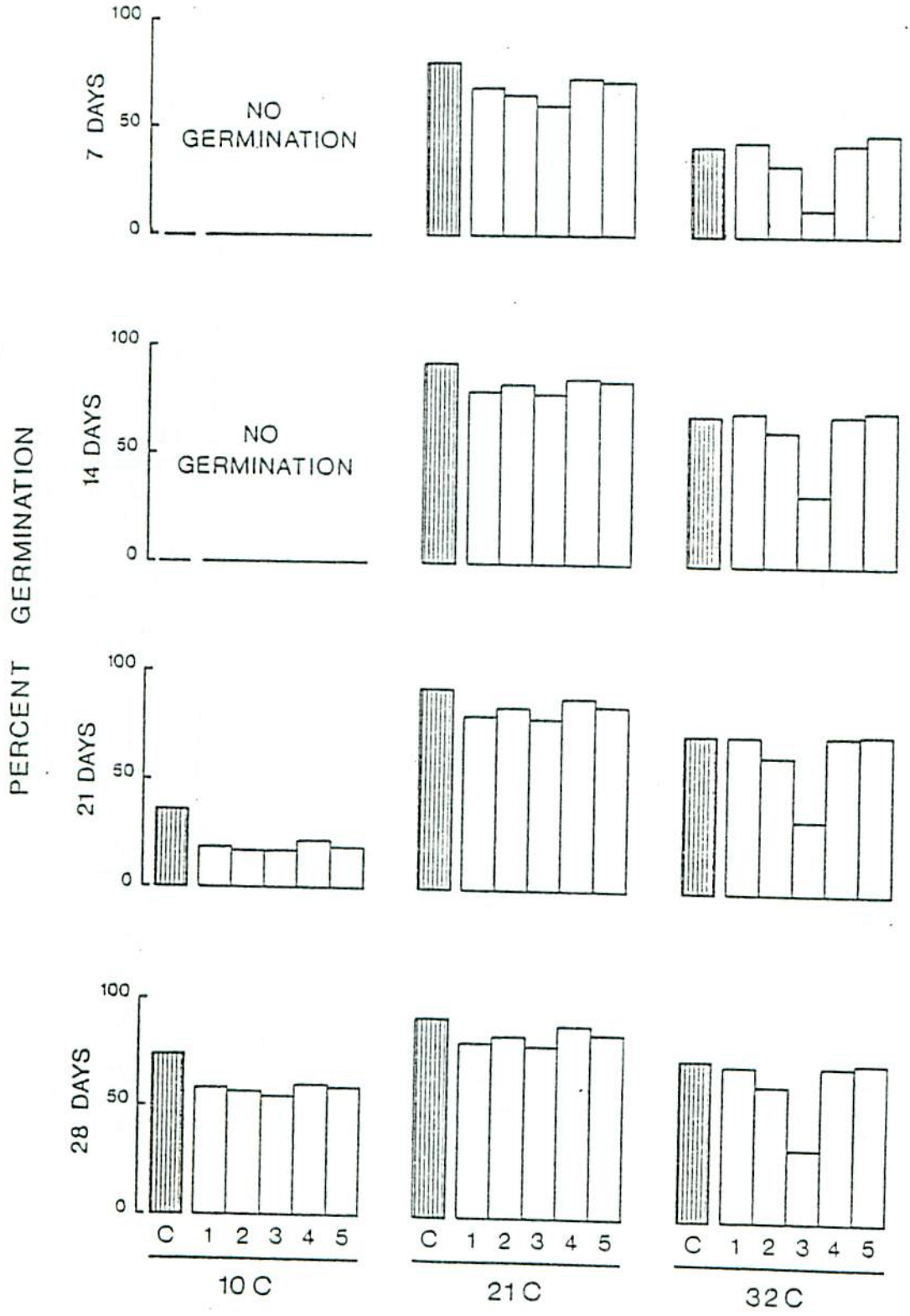

Figure 5. Mean cumulative percent germination of black spruce seeds (all storage periods cominbed) by seed treatment and temperature 7, 14, 21 and 28 days after seeding.

If allowance is made for the different amount of germination at 21C, 32C and 10C, in that order, germination began earlier at 21C and at 32C (7 days) than at 10C (14+ days) and was effectively complete sooner (14 days) at 21C and 32C than at 10C (28 days). Note that these patterns were maintained for coated as well as for untreated seeds.

If one considers the effects of storage (Fig. 6, Table A6), the almost complete lack of germination from freshly coated seeds at 10C and at 32C suggests a possible initially toxic effect of R-55 which is not operative at 21C. However, this hypothesis is untenable as germination was almost equally non-existent from untreated seeds. During the second test, i.e., seeds (untreated as well as coated) stored for 2 months, germination was still effectively nil from coated seeds at 10C, but normal from untreated seeds. In this test, paradoxically, coated seeds germinated as well as untreated seeds (except from treatment 3), but germination from coated seeds at 21C was noticeably out of character in comparison with germination in the previous and all subsequent storage-period tests. Although no satisfactory explanation has been found for these anomalies, it is interesting to note that only germination from R-55 treatment 3 was consistently and abnormally poor relative to all others regardless of the length of storage, and this accounts for the treatment 3 pattern in Figures 5 and 6.

Otherwise, length of storage had no appreciable effect on germination of either coated or untreated seeds at any given temperature (Fig. 6), nor on the pattern revealed when all storage treatments were combined (Fig. 5).

Aside from somewhat slower germination during the first week after seeding (< 10% over all) and perhaps slightly less uniform germination during that initial period (Fig. 7, Table A7) there was no appreciable difference in the germination pattern of coated seeds stored for approximately 4 years and those stored for only 1½ years.

After 6 years of storage, germination during the first week after seeding was 28% lower from untreated seeds and 32% lower from coated seeds (mean of all five R-55 treatments) than it was after 4 years of storage. However, by the end of the second week it was only 6% and 3% lower from uncoated and coated seeds, respectively, than it was after 4 years of storage.

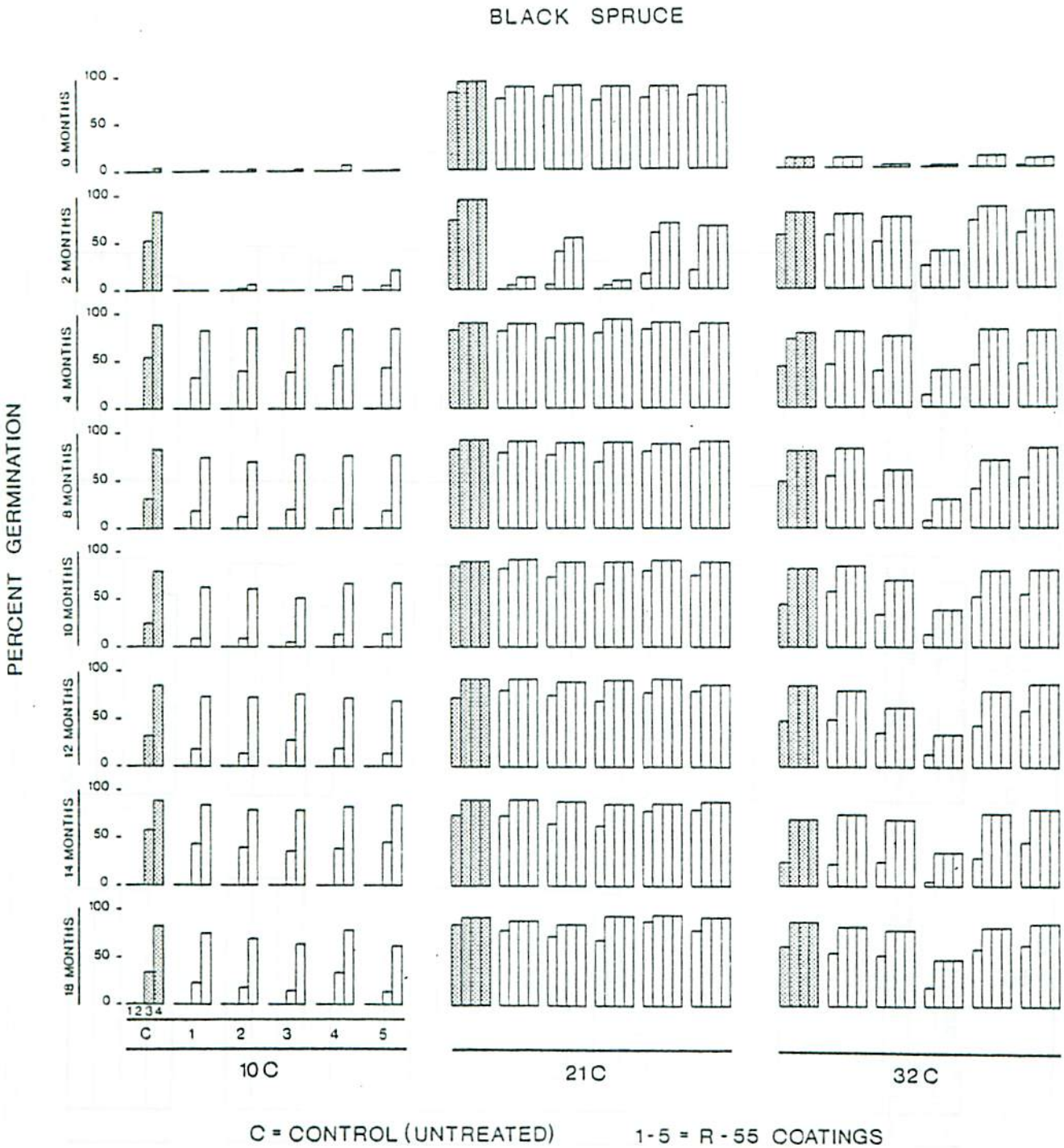

Figure 6. Mean cumulative percent germination of black spruce seeds by temperature and seed treatment 1, 2, 3 and 4 weeks after sowing seeds stored for 0, 2, 4, 8, 10, 12, 14 and 18 months.

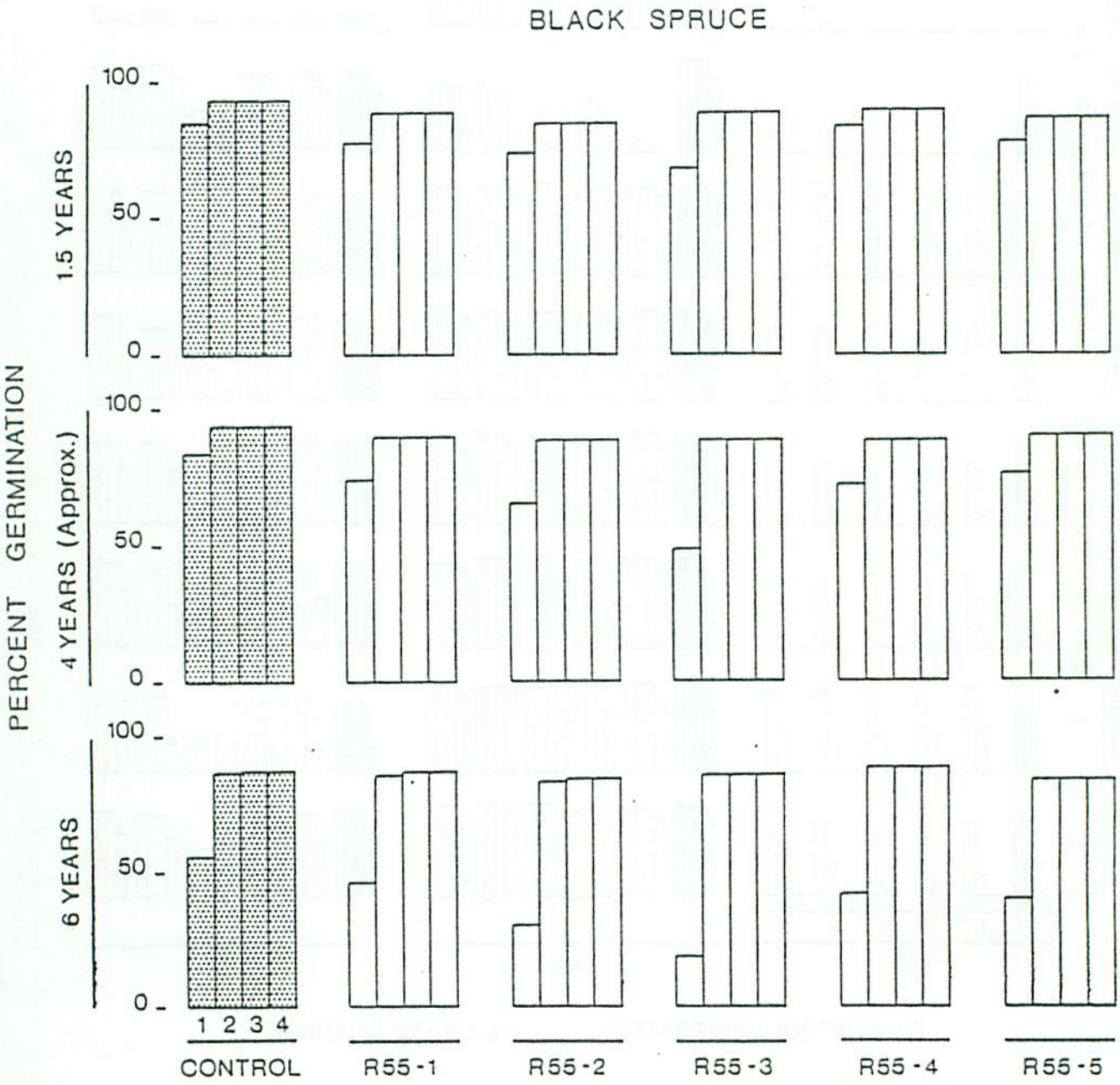

Figure 7. Mean cumulative percent germination of black spruce seeds at 21C after 1½, 4 and 6 years of storage.

DISCUSSION AND CONCLUSIONS

Results of the tests with Arasan-coated black spruce seeds appear to support the premise behind the province of Ontario's Arasan-latex-aluminum treatment[4] of black spruce seeds for direct seeding, namely, that Arasan has no adverse effect on germination of black spruce seeds. The germination response of better, faster germination at 21C, 32C and 10C (in that order) is equally true for Arasan-coated and untreated seeds. The evidence indicates that coated seeds germinate as uniformly as untreated seeds and that stored coated seeds germinate as well as stored untreated seeds up to and including 18 months of storage.

Arasan-coated jack pine seeds exhibit a somewhat different germination pattern. Although germination from Arasan-coated jack pine, like that from Arasan-coated black spruce, is better at 21C than at 32C and 10C, coated jack pine seeds never germinate as well or as uniformly as untreated seeds. Storage had no effect on untreated or on coated seeds except, perhaps, at 10C where germination from coated seeds was somewhat poorer and more irregular than from untreated seeds.

The germination responses and patterns of R-55 coated black spruce are quite similar to those of Arasan-coated black spruce, so that, aside from the apparent anomalies at 10C and 32C with freshly coated seeds and at 10C and 21C with seeds stored for only 2 months, neither the R-55 coating nor the length of time coated seeds were stored (up to and including 18 months) had any practical adverse effect on germination. This conflicts rather markedly with Radvanyi's (1975) finding. He reported that germination from R-55-coated black spruce seeds, which equalled that from untreated seeds to begin with (92%), dropped to 62% and 8% after 1 and 2 years storage, respectively.

The general similarities in the black spruce germination/temperature/storage responses between the Arasan and R-55 coatings, whose only common ingredient is the latex binder, suggests that it may be this component that is responsible for any subtle effects the coatings do exert on germination rather than any toxic effect of the Arasan or R-55.

Although it is now irrelevant because the product is no longer manufactured, except for the anomalies at the 0-month and 2-month storage tests (Fig. 6), there is little to choose among the five R-55 treatments at 10C, and even less at 21C, insofar as their effect on germination is concerned. However, the consistently poor germination response from treatment 3 and the irregular response from treatment 2 at 32C appears to favor the selection of treatments 1, 4 and 5.

---

[4]See Appendix III for résumé of supplementary study (unpublished) of latex-aluminum coating currently used by the province of Ontario.

In conclusion, neither Arasan nor R-55 have any appreciable adverse effect on germination of black spruce seeds except at low temperatures (10C) where R-55 depresses germination slightly below that obtained from untreated seeds.

Coating jack pine seeds with Arasan invariably depressed germination but only appreciably so at low temperatures (10C).

Length of storage -- up to 18 months -- had no practical effect on germination of Arasan-coated black spruce seeds, but storing Arasan-coated jack pine seeds depressed germination at low temperatures (10C).

Length of storage -- up to 18 months -- had no practical effect on germination of R-55-coated black spruce at any of the test temperatures. Even longer storage (approximately 4 years) had no more adverse effect on germination of R-55-coated seeds at the optimum germination temperature (21C) for this species than it did on untreated seeds.

LITERATURE CITED

FRASER, J.W. 1974. Seed treatments (including repellents). p. 77-90 *in* J.H. Cayford, Ed. Direct seeding symposium. Dep. Environ., Can. For. Serv., Ottawa, Ont. Publ. 1339. 178 p.

FRASER, J.W. 1975. Direct seeding black spruce - is it feasible? p. 140-155 *in* Black spruce symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Symp. Proc. O-P-4. 15 p.

RADVANYI, A. 1970. A new coating for coniferous seeds. For. Chron. 46(5). 3 p.

RADVANYI, A. 1975. Germination of black spruce seeds: how storage affects seeds treated with R-55. J. For. 73(3):165.

APPENDICES

APPENDIX I

R-55 Seed-coating Treatments (Black Spruce)

Seeds coated with R-55 were treated by the Canadian Wildlife Service, Western Region, as follows (A. Radvanyi, Canadian Wildlife Service, Edmonton, Alberta, personal communication): coatings contained (a) a 4:1 R-55:graphite mixture, (b) Dow latex 612, diluted 1:9 latex: water acidified with HCl to bring the pH from 8.2 to 4.8.

Coating 1.
- 25 cu. cm latex solution applied in one lot
- gallon-size mixer rotated 2-3 min before R-55/ graphite applied
- 75 g R-55/graphite powder applied in three small portions
- seeds tumbled approximately 3 min more, then emptied and shaken in a fine mesh sieve to remove surplus powder
- coating was irregular under microscope.

Coating 2.
- same as 1 except for 4 min tumbling after seeds wetted with latex and before powder added
- coating was still somewhat irregular.

Coating 3.
- latex increased to 30 cu. cm
- 75 g R-55/graphite powder
- coating was still patchy.

Coating 4.
- latex decreased to 20 cu. cm
- 75 g R-55/graphite powder
- coating improved but some lumping of powder still occurred.

Coating 5.
- 20 cu. cm latex
- 75 g R-55/graphite powder
- 4 min between latex and powder application; latex added using a pipette, giving a very fine stream applied while mixer in motion
- coating more uniform.

Arasan Seed-coating Treatments (Black Spruce, Jack Pine)

Seeds coated with Arasan were treated by the Ontario Ministry of Natural Resources, Tree Seed Plant (C.H. Lane, Ontario Ministry of Natural Resources, Toronto, Ontario, personal communication) using the following formulation for 10-lb (4.5 kg) seed lots:

Arasan 42S	6.6 fl oz	(187.4 ml)
Dow latex 512R	1.0 fl oz	(28.4 ml)
Distilled water	9.0 fl oz	(255.6 ml)
Aluminum flakes	1.0 oz	(28.3 g)

APPENDIX II

Table A1. Mean cumulative percent germination of black spruce seeds (all storage periods combined) 7, 14, 21 and 28 days after seeding at 10C, 21C and 32C.

Temp. (°C)	Days since seeding	Untreated Seeds (control)		Arasan-coated Seeds	
		Percent germination	Coefficient of variation	Percent germination	Coefficient of variation
10	7	0	-	0	-
	14	0	-	0	-
	21	68	45	65	45
	28	90	27	87	32
21	7	97	3	98	2
	14	99	1	99	1
	21	99	1	99	1
	28	99	1	99	1
32	7	62	41	64	40
	14	85	30	86	26
	21	88	27	88	23
	28	88	26	90	23

Table A2. Mean cumulative percent germination of black spruce seeds by seed treatment and temperature 7, 14, 21 and 28 days after seeding for each storage period.

Months of storage	Days since seeding	Black Spruce - Percent Germination[a]					
		Control			Arasan		
		10C	21C	32C	10C	21C	32C
0	7	0	96	1	0	99	2
	14	0	99	19	0	99	29
	21	0	99	27	0	99	35
	28	29 a	99	29 a	15	99	37
2	7	0	98	80	0	97	76
	14	0	98	94	0	98	95
	21	91	98 a	96 a	75	98 a	96 a
	28	100	98 a	97 a	98 a	98 a	98 a
4	7	0	99	72	0	99	74
	14	0	100	95	0	99	94
	21	90	100	96	90	99	96
	28	100 a	100 a	96	100 a	99 a	96
8	7	0	98	69	0	98	71
	14	0	100	94	0	98	94
	21	74	100	96	63	98	96
	28	100 a	100 a	96	96 a	98 b	97 a b
10	7	0	98	67	0	98	77
	14	1	99	92	4	100	95
	21	81	99	94	90	100	96
	28	97 a	99	95 a	99 a b	100 a	97 b
12	7	0	98	75	0	99	77
	14	0	98	96	0	99 a	97 a
	21	40	98 a	98 a	54	99 a	98 a
	28	96	98 a	98 a	96	99 a	99 a
14	7	0	95	52	0	99	52
	14	0	98	90	0	100	90
	21	92	98	95	88	100	94
	28	97 a	98 a	96 a	98	100	96
18	7	0	97	79	0	97	78
	14	0	98 a	96 a	0	99	95
	21	75	98 a	98 a	62	99	96
	28	97 a	98 a	99 a	97 a	99	96 a

[a]There is no significant difference (p = 0.05) between values joined by the same vertical line or between those within the same treatment with the same lower case letter(s) in the same horizontal line.

Table A3. Mean cumulative percent germination of jack pine seeds (all storage periods combined) 7, 14, 21 and 28 days after seeding at 10C, 21C and 32C.

Temp. (°C)	Days since seeding	Untreated Seeds (Control)		Arasan-coated Seeds	
		Percent germination	Coefficient of variation	Percent germination	Coefficient of variation
10	7	0	-	0	-
	14	0	-	0	-
	21	37	46	20	66
	28	67	20	47	39
21	7	84	6	76	11
	14	88	4	84	7
	21	88	4	84	7
	28	88	4	84	7
32	7	68	46	62	47
	14	68	46	64	47
	21	68	46	64	47
	28	68	46	64	47

Table A4. Mean cumulative percent germination[a] of jack pine seeds by seed treatment and temperature 7, 14, 21 and 28 days after seeding for each storage period.

Months of storage	Days since seeding	Control			Arasan		
		10C	21C	32C	10C	21C	32C
0	7	0	86	0	0	82	0
	14	0	91	0	0	88	0
	21	55	91	0	42	88	0
	28	86	91	0	77	89	0
2	7	0	86 a	81 a	0	78 a	78 a
	14	0	89	82	0	86	80
	21	48	89	82	24	86	80
	28	75	89	83	57	86	80
4	7	0	80 a	77 a	0	71 a	65 a
	14	0	86	78	0	79	66
	21	45	86	78	18	80	68
	28	62	87	78	34	80	69
8	7	0	80	80	0	65	76
	14	0	86	81	0	78 a	77 a
	21	22	86	81	8	78 a	78 a
	28	54	87	81	29	78 a	78 a
10	7	0	82 a.	84 a	0	74 a	79 a
	14	0	86 a	85 a	0	83 a	81 a
	21	39	86 a	85 a	24	83 a	81 a
	28	58	86 a	85 a	37	83 a	81
12	7	0	89	82	0	86	76
	14	0	90	82	0	90	78
	21	15	90	82	6	90	78
	28	65	90	82	46	90	78

[a]There is no significant difference (p = 0.05) between values joined by the same vertical line or between those with the same lower case letter(s) in the same horizontal line.

Table A5. Mean cumulative percent germination of black spruce seeds (all storage periods combined) at 10C, 21C and 32C at weekly intervals.

Days since seeding	Seed[a] treatment	10C		21C		32C	
		Percent germination	Coefficient of variation	Percent germination	Coefficient of variation	Percent germination	Coefficient of variation
7	C	No germination		80	15	41	48
	1			68	39	43	48
	2			65	36	33	50
	3			60	40	12	72
	4			72	30	43	49
	5			71	28	47	42
14	C	No germination		91	3	68	35
	1			79	36	70	33
	2			82	20	61	38
	3			78	37	32	47
	4			85	13	69	33
	5			84	11	71	34
21	C	36	57	92	3	72	33
	1	18	101	80	33	72	33
	2	17	98	83	15	62	38
	3	17	92	79	31	34	46
	4	22	82	86	10	72	32
	5	19	99	85	9	74	32
28	C	74	37	92	3	74	33
	1	57	61	81	31	72	33
	2	56	55	84	13	62	39
	3	54	61	79	34	34	46
	4	60	50	88	8	72	32
	5	58	51	85	9	74	34

[a] C = Control (untreated seeds). 1-5 = Five R-55 treatments.

Table A6. Mean cumulative percent germination of black spruce seeds by seed treatment 7, 14, 21 and 28 days after seeding for each storage period.

Months of storage	Temp. (°C)	No. of days	Percent germination[a] - Black Spruce					
			Control	R-55-1	R-55-2	R-55-3	R-55-4	R-55-5
0	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	0	0	0	0	0	0
		28	4 b c	1 a	3 a b c	2 a b	6 c	1 a
	21	7	82 b	75 a b	77 a b	72 a	75 a b	77 a b
		14	94	87 a	88 a	88 a	88 a	87 a
		21	94	88 a	89 a	88 a	88 a	88 a
		28	94	88 a	89 a	88 a	88 a	88 a
	32	7	0	0	0	0	0	1
		14	9 b	10 b	3 a	2 a	12 b	10 b
		21	12 b	11 b	3 a	2 a	15 b	10 b
		28	12 b	11 b	3 a	2 a	15 b	10 b
2	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	52	0	1	0	4 a	5 a
		28	83	0	6	0	15	21
	21	7	73	0	5	0	16 a	20 a
		14	94	5 a	40	4 a	59 b	62 b
		21	94	11 a	52	8 a	66 b	67 b
		28	94	15	56	10	70 a	68 a
	32	7	56 a	56 a	49 a	24	70	56 a
		14	75 a	74 a	73 a	38	83	76 a
		21	79 a	76 a	74 a	38	85	78 a
		28	81 a b	78 a b	74 a	38	85 b	80 a b

[a]There is no significant difference (p = 0.05) between values joined by the same vertical line, or between those with the same lower case letter(s) in the same horizontal line.

(continued)

Table A6. Mean cumulative percent germination of black spruce seeds by seed treatment 7, 14, 21 and 28 days after seeding for each storage period (continued).

Months of storage	Temp. (°C)	No. of days	Percent germination[a] - Black Spruce					
			Control	R-55-1	R-55-2	R-55-3	R-55-4	R-55-5
4	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	54	35 a	40 a b	38 a b	45 b	43 a b
		28	88 a	82 a	85 a	85 a	84 a	84 a
	21	7	83 b	81 a b	74 a	79 a b	83 b	80 a b
		14	90 a	89 a	89 a	92 a	90 a	87 a
		21	90 a	89 a	89 a	92 a	90 a	88 a
		28	90 a	90 a	89 a	92 a	90 a	88 a
	32	7	43 a	46 a	39 a	12	44 a	46 a
		14	72 a	80 b	72 a	36	78 a b	79 a b
		21	78 a	81 a b	75 a	38	82 b	82 b
		28	80 a	82 a	76 a	43	82 a	82 a
8	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	31	18	12	20	21	18
		28	83 b	75 a b	70 a	77 a b	76 a b	76 a b
	21	7	83 a	79 a	76 a	68	80 a	83 a
		14	91 a	90 a	88 a	88 a	87 a	90 a
		21	91 a	90 a	88 a	89 a	87 a	90 a
		28	91 a	90 a	88 a	89 a	87 a	90 a
	32	7	48 a b	54 b	28	7	41 a	52 b
		14	78 a	82 a	60	27	68	81 a
		21	81 a	84 a	62	31	71	84 a
		28	82 a	84 a	62	31	72	85 a

[a]There is no difference (p = 0.05) between values joined by the same vertical line, or between those with the same lower case letter(s) in the same horizontal line.

(continued)

Table A6. Mean cumulative percent germination of black spruce seeds by seed treatment 7, 14, 21 and 28 days after seeding for each storage period (continued).

Months of storage	Temp. (°C)	No. of days	Percent germination[a] - Black Spruce					
			Control	R-55-1	R-55-2	R-55-3	R-55-4	R-55-5
10	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	25	9 a	9 a	5	12 a	12 a
		28	80	63 a	61 a	51	66 a	66 a
	21	7	85 b	82 b	74 a	66	80 a b	75 a
		14	90 a	92 a	88 a	88 a	91 a	87 a
		21	90 a	93 a	89 a	89 a	91 a	88 a
		28	90 a	93 a	89 a	89 a	91 a	88 a
	32	7	45	58 a	34	13	52 a	55 a
		14	81 a	84 a	70	38	79 a	79 a
		21	84 a	86 a	70	40	81 a	81 a
		28	85 a	86 a	70	40	81 a	82 a
12	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	32 b	18 a	14 a	27 b	18 a	14 a
		28	85	74 a	72 a	76 a	72 a	68 a
	21	7	72 a b	80 b	75 a b	68 a	77 b	78 b
		14	91 a	91 a	88 a	90 a	91 a	86 a
		21	91 a	91 a	88 a	90 a	91 a	86 a
		28	91 a	91 a	88 a	90 a	91 a	87 a
	32	7	48 a	49 a	36	14	44 a	59
		14	82 a b	78 a b	61	34	77 a	84 b
		21	86 b	80 a	62	34	80 a	86 b
		28	86 b	80 a	62	34	80 a	87 b

[a]There is no significant difference (p = 0.05) between values joined by the same vertical line, or between those with the same lower case letter(s) in the same horizontal line.

(continued)

Table A6. Mean cumulative percent germination of black spruce seeds by seed treatment 7, 14, 21 and 28 days after seeding for each storage period (concluded).

Months of storage	Temp. (°C)	No. of days	Percent germination[a] - Black Spruce					
			Control	R-55-1	R-55-2	R-55-3	R-55-4	R-55-5
14	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	57	42 a	39 a	36 a	38 a	45 a
		28	88 b	84 b	78 a	78 a	82 a b	84 b
	21	7	74 b	73 b	65 a	62 a	78 b c	80 c
		14	90 a	89 a	88 a	86 a	87 a	88 a
		21	91 a	90 a	88 a	86 a	87 a	88 a
		28	91 a	90 a	88 a	86 a	87 a	88 a
	32	7	25 a b	22 a	25 a b	5	30 b	46
		14	66 a	73 a b	68 a	34	72 a b	78 b
		21	72 a b	76 a b c	70 a	34	78 b c	81 c
		28	73 a b	76 a b c	70 a	36	78 b c	82 c
18	10	7	0	0	0	0	0	0
		14	0	0	0	0	0	0
		21	34 b	24	17 a	15 a	34 b	14 a
		28	82 b	75 b	69 a	64 a	78 b	62 a
	21	7	85 d	78 b c	73 a b	69 a	84 b	79 b c d
		14	92 a	88 a	85 a	89 a	90 a	87 a
		21	92 a	88 a	85 a	89 a	90 a	87 a
		28	92 a	88 a	85 a	89 a	90 a	87 a
	32	7	62 a b	56 a b	54 a	20	60 a b	64 b
		14	85 a	81 a	78 a	48	82 a	84 a
		21	87 b	82 a b	79 a	49	82 a b	86 a b
		28	88 b	82 a b	79 a	49	82 a b	86 a b

[a]There is no significant difference (p = 0.05) between values joined by the same vertical line, or between those with the same lower case letter(s) in the same horizontal line.

Table A7. Mean cumulative percent germination of black spruce seeds and coefficients of variation (CV) by seed treatment 7, 14, 21 and 28 days after seeding at 21C.

Years of storage	Days since seeding	Control		R-55-1		R-55-2		R-55-3		R-55-4		R-55-5	
		Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
$1\frac{1}{2}$	7	85	4	78	6	73	2	68	5	84	6	79	3
	14	92	4	88	4	85	4	89	6	90	4	87	3
	21	92	4	88	4	85	4	89	6	90	4	87	3
	28	92	4	88	4	85	4	89	6	90	4	87	3
4	7	84	1	74	3	66	8	49	13	72	7	76	4
	14	94	3	90	3	89	4	88	2	88	3	90	4
	21	94	3	90	3	89	5	88	2	88	3	90	4
	28	94	3	90	3	89	5	88	2	88	3	90	4
6	7	56	6	46	17	30	9	19	19	41	14	40	14
	14	87	2	86	3	83	2	86	4	89	6	84	5
	21	88	3	87	2	84	2	86	4	89	6	84	5
	28	88	3	87	2	84	2	86	4	89	6	84	5

APPENDIX III

Influence of Latex 636 on Germination of White Spruce, Black Spruce and Jack Pine Seeds

By the time the studies presented in this report were completed, Arasan had been dropped from the Ontario Ministry of Natural Resources (OMNR) Arasan + latex + aluminum seedcoating treatment, and seeds were coated only with latex and aluminum flakes. Presumably, the rationale was that seeds had to be "lubricated" (aluminum flakes) in order to pass through mechanical seeders undamaged, and latex was used to "bind" the aluminum flakes to the seedcoat. Although the premise that such lubrication was essential was never, to my knowledge, substantiated and/or documented, seeds for direct seeding were still being coated with latex and aluminum in 1979.

Early in 1979, because Dow Latex 612R was no longer available, OMNR began using Dow Latex 636 as the binder in latex + aluminum seedcoating. They tested the effect of this new latex on germination of conifer seeds with no untoward results (personal communication from C.H. Lane) under their test conditions, i.e., alternating temperatures, both of which are within the optimum germination/temperature range for the species tested.

In addition, with untreated seeds as controls, the effect of the new treatment on germination of black spruce, white spruce (*Picea glauca* [Moench] Voss) and jack pine seeds was tested at the Great Lakes Forest Research Centre. Apart from the effects of storage, these tests paralleled those for testing the previous Arasan coating and the second series of R55 coatings.

Mean cumulative percent germination of black spruce seeds by temperature and seed treatment at weekly intervals after seeding.

No. of days	Black Spruce - Percent Germination[a]					
	10C		21C		32C	
	Control	Latex	Control	Latex	Control	Latex
7	0	0	90	80	39 a	35 a
14	0	0	99 a	99 a	91 a	92 a
21	56	33	99 a	99 a	95 a	97 a
28	96 a	94 a	99 a	99 a	96 a	97 a

[a]There is no significant difference between percentages joined by the same vertical line, nor between those with the same lower case letter in any horizontal line.

Results at the optimum temperature (21C) indicate that, other than delaying germination slightly during the first week after seeding, the new latex treatment had no adverse effect on germination of black spruce seeds. Even at the upper end of the range of optimum germination temperatures for this species (32C), where germination was somewhat slower than at 21C, the latex treatment did not affect germination adversely.

At the opposite end of the optimum temperature range (10C), germination from latex-coated seeds, three weeks after seeding, was significantly lower than from untreated seeds, but was no longer so by the end of the fourth week.

Germination from coated jack pine seeds was significantly lower than from untreated seeds at all three temperatures at all times up to and including 28 days after seeding. This indicates that the new coating does inhibit germination of jack pine seeds. It is debatable whether the statistical differences at 21C beyond the 14th day have any practical significance, but those at 10C and 32C certainly do.

Mean cumulative percent germination of jack pine seeds by temperature and seed treatment at weekly intervals after seeding.

No. of days	Jack Pine - Percent Germination[a]					
	10C		21C		32C	
	Control	Latex	Control	Latex	Control	Latex
7	0	0	87	72	74	50
14	0	0	92	86	76	52
21	31	8	92	87	77	54
28	72	35	93	87	78	56

[a]See footnote to black spruce tabulation for indications of statistical significance.

Mean cumulative percent germination of white spruce seeds by temperature and seed treatment at weekly intervals after seeding.

No. of days	White Spruce - Percent Germination[a]					
	10C		21C		32C	
	Control	Latex	Control	Latex	Control	Latex
7	0	0	35 a	33 a	0	0
14	0	0	81 a	83 a	2 a	2 a
21	12	8	84 a	85 a	5 a	5 a
28	47	8	84 a	85 a	8 a	9 a

[a]See footnote to black spruce tabulation for indications of statistical significance.

The new coating had no significant effect on germination of white spruce seeds at the optimum germination temperature (21C) nor at 32C where it was < 10% even from untreated seeds, but it did inhibit germination significantly at 10C.

If one considers only the results at 21C there is no evidence here that the new latex 636 + aluminum coating has any adverse effect on germination of black spruce, white spruce, or jack pine seeds. However, such ideal temperature conditions never occur in the field. Therefore, the results at 10C and/or 32C are interpreted as indicating that the coating probably will have *some* adverse effect on germination under field conditions, particularly on germination of white spruce and jack pine seeds. Hence, some consideration might be given to whether lubricating the seeds by coating them with latex 636 + aluminum to facilitate seeding them mechanically -- which is presumably the only reason for the coating -- is a worthwhile trade-off against a potentially adverse effect on germination, depending upon the seedbed temperature conditions during and following the seeding.