8. La plupart des Pins que nous avons testés manifestent a l'encontre de leur propre pollen une discrimination faible a forte; nous pouvons donc nous attendre, dans les vergers a graines, a une quantité relativement faible de graines viables resultant d'autofécondation. Le danger de consanguinite et de la réduction de vigueur correspondantes peut être encore réduit en éliminant completement du verger a graines les arbres completement autofertiles.

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A Provenance Study of Jack Pine Seedlings

By M. M. GIERTYCH and J. L. FARRAR[1])

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Introduction

With the increasing use of planting as a method of forest regeneration, it is important to have information about the genetic quality of the materials used. In a species like jack pine (*Pinus banksiana* LAMB.) with a nearly transcontinental distribution (*Fig. 1),* the variation between different provenances is likely to be considerable. A number of investigations of such variability in jack pine have been reported. SCHANTZ-HANSEN and JENSEN (10) described a test of 32 provenances of jack pine from localities in the United States and Canada grown in plantations in Minnesota. Large differences in size and form of the plants were evident; northern provenances were slower growing than southern. STOECKELER and RUDOLF (12) in Wisconsin found that foliage of seedlings of the more northerly provenances showed increased tendency to turn bronze-coloured in the cold season. Also the height growth of 2-year-old seedlings was correlated directly with the number of degree-days (base 50° F, 10° C) of the locality of origin and inversely with latitude. HOLST and YEATMAN (5) found for Ontario provenances grown in a nursery near Chalk River, Ontario, that height growth of transplants was correlated with the length of the growing season (base 42° F, 5,5° C) and the mean temperature for June, July, and August of the locality of origin. VAARTAJA (13 and 14) using greenhouse tests found that in jack pine, among other species, the more northerly provenances showed a greater response to variations in photoperiodic treatments.

CRITCHFIELD (3) found substantial variation in lodgepole pine (*Pinus contorta* DOUGL.) of various origins. NIENSTAEDT and OLSON (8) working with eastern hemlock (*Tsuga canadensis* [L.] CARR.) have shown the usefulness of provenance tests of seedlings grown under controlled conditions in growth chambers.

The present report deals with an experiment conducted in growth chambers where the effect of photoperiod and nitrogen supply on seedlings of jack pine was studied. Physiological results, averaged for all provenances, have been reported (4); presently, variations between the provenances are dealt with.

Materials and Methods

The experiment has been described in a previous paper (4). Materials consisted of nine provenances of jack pine (*Pinus banksiana* LAMB.) and one of lodgepole pine or western jack pine (*P. contorta* var. *latifolia* ENGELM.). Approximate locations of the parent stands are shown in *Fig. 1,* and relevant data are given in *Table 1.*

Each seed-lot was part of a larger seed-lot collected by the Department of Forestry, Ottawa, Canada and currently being used by that organization for provenance studies.

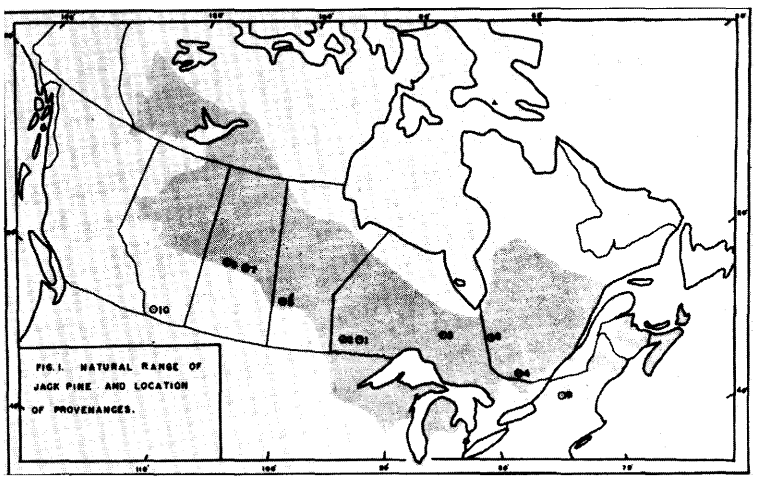

Fig. 1. — Map of Canada showing the range of jack pine and localities from which the seed were obtained. The numbers correspond with those in *Tables 1* and 2. Based on RUDOLF (9).

The seedlings were grown for 115 days after sowing the seed. The root medium was a porous form of silica in steel-plated vessels 10 cm. tall and 6 cm. in diameter. The number of seedlings per vessel was reduced to five after germination was complete. The temperature was held near 20° C and relative humidity averaged about 75%. Light was provided by incandescent lamps; intensity was about

[1]) The authors are respectively: graduate student in the Department of Botany, and Abitibi Professor of Forest Biology, Faculty of Forestry; University of Toronto, Toronto, Canada.

Table 1. — Data concerning the various localities where the seedlots were collected. — Degrees and hours are in the decimal system; jP is jack pine, lP is lodgepole pine.

Serial No. and Species	Proximate Named Locality	North Lat.	West Long.	Altitude	Day Length	Deg.-Days (base 42° F)
		deg.	*deg.*	*m.*	*hours*	*no.*
1-jP	Vermillion Bay, Ont.	49.9	93.3	300	16.37	2750
2-jP	Kenora, Ont.	49.8	94.4	300	16.35	2850
3-jP	Stevens, Ont.	49.6	85 8	300	16.32	1950
4-jP	Chapeau, Que.	45.9	77.0	150	15.74	3150
5-jP	Big River, Sask.	53.8	107.0	450	17.11	2600
6-jP	Louvicourt, Que.	48.7	79.2	300	16.16	2350
7-jP	Candle Lake, Sask.	53.8	105.2	450	17.11	2550
8-jP	Cowan, Man.	52.0	100.6	300	16.73	2700
9-jP	Upper Jay, N. Y., USA	44.3	74.2	600	15.52	3600
10-lP	Crowsnest Forest, Alta.	49.7	114.7	1200	16.33	2250

7500 lux at plant level. There were two photoperiods; a long night (10 hours light and 14 hours dark) and a broken night (9.5 hours light, 7 hours dark, 0.5 hours light and 7 hours dark). Nitrogen was supplied at five levels: zero, 51, 102, 203, and 406 parts per million in a standard HOAGLAND solution. Preliminary experiments had suggested that optimum nitrogen concentration was around 200 ppm.

Each plant was measured for height and scored for presence of a dormant terminal bud and secondary leaves (needle bundles). The stems, leaves, and roots of each treatment-group were ovendried, weighed separately, and analysed jointly for nitrogen by the KJELDAHL method

Two parameters were selected to characterize the climate of the localities of origin. The first was the latitude or the number of hours of daylight on the longest day. This is considered to be an index of photoperiodic conditions. The second was the number of growing degree-days (base 42° F, 5.5° C) per year. The values were interpolated from the isolines on a map prepared by BOUGHNER and KENDALL (1). In the case of lodgepole pine (No. 10), degree-days were estimated from meteorological data for Cowley A., Alberta (7). The number of degree-days is taken as an index of growing conditions which integrates temperatures and indicates the duration of the growing season.

To investigate variation between provenances, climatic information about localities of origin was correlated with the growth data gathered about the provenances and also with the responsiveness of the provenances to the photoperiodic stimuli. The ratio of the total dry weight under the broken night photoperiod to the total dry weight under the long night photoperiod was taken as a measure of that responsiveness.

Data were analysed by standard statistical procedures (11). Calculations of regression coefficients and averages were based on data for *Pinus banksiana* only.

Results

As noted previously (4), all provenances responded favourably to increasing concentration of nitrogen and to the light break during the dark period. There were no significant interactions between jack pine provenances and nitrogen concentration.

Fig. 2 shows the relation between total dry weight per seedling and growing degree-days at the place of origin. As the number of growing degree-days increased at the place of origin, the larger were the seedlings in the growth chamber. A number of other parameters showed a similar positive correlation with growing degree-days; these included height, dry weights of foliage and roots, and dry weight of seed *(Table 2)*. Also positively correlated with the growing degree-days was the dry weight per unit of nitrogen content (reciprocal of nitrogen concentration) *(Fig. 3)*.

The relation between the ratio of the dry weight under broken night photoperiod to the weight under long night photoperiod to the latitude or the length of the longest day is shown in *Fig. 4*. Seed from localities with longer days showed a marked response to change in photoperiod. For example, seedlings from Big River (No. 7), where the longest day is more than 17 hours, trebled their dry weight as a result of the light break during the night, whereas seedlings from Upper Jay (No. 9), where the longest day is about 15.5 hours, increased their dry weight by only 37%.

Lodgepole pine seedlings were dissimilar to jack pine seedlings in several ways *(Table 2)*. They were heavier than jack pine seedlings from regions with a similar number of growing degree-days, and this despite the fact they were shorter. The shortness was due partly to the greater frequency of dormant buds; the greater weight was due partly to the greater frequency of secondary foliage (needle bundles). The response of lodgepole pine seedlings to the light break during the dark period was similar to the response of the least responsive jack pine seedlings *(Fig. 4)*.

Table 2. — Some characteristics of the seed and seedlings of the various provenances. Figures are averages over all levels of nitrogen and both photoperiods. — L is long-night photoperiod, B is broken-night photoperiod; jP is jack pine, lP is lodgepole pine.

No.	Spec.	Seed Weight	Seedling Height	Foliage Weight		Root Weight		Percentage of Plants with Winter Buds		Percentage of Plants with Secondary Needles	
				L	B	L	B	L	B	L	B
		mg	*mm*	*mg*	*mg*	*mg*	*mg*	*%*	*%*	*%*	*%*
1	jP	3.2	41	28	65	45	44	51	0	30	0
2	jP	3.1	42	37	75	50	50	86	0	34	0
3	jP	3.2	39	26	74	36	52	51	4	48	0
4	jP	3.6	45	35	84	50	57	24	0	24	0
5	jP	3.8	39	20	74	32	62	30	8	26	0
6	jP	3.3	40	29	75	36	52	44	2	50	0
7	jP	3.2	37	19	71	25	54	30	16	44	0
8	jP	3.3	41	20	78	36	56	32	0	16	0
9	jP	4.2	44	44	85	64	53	20	0	34	0
Aver.	jP	3.4	41	28	76	42	53	41	3	34	0
10	lP	3.5	32	43	59	43	60	72	78	54	0

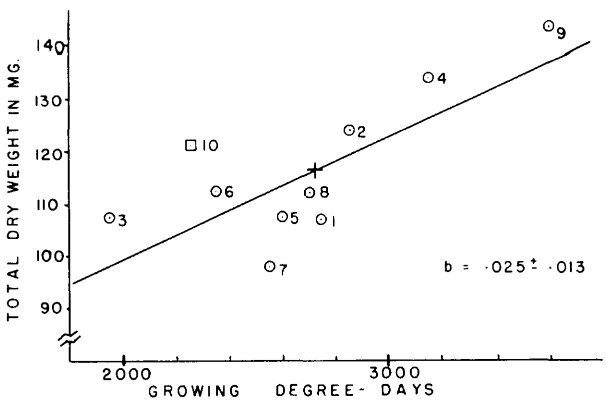

Fig. 2. — The relation between average dry weight per seedling and the number of growing degree-days (base 42° F, 5.5° C) at place of origin of the seed.

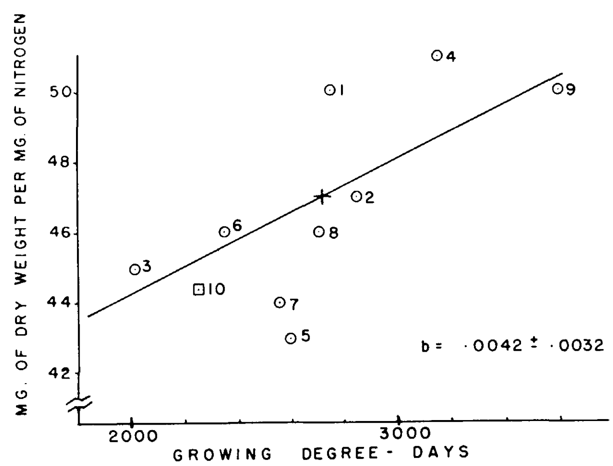

Fig. 3. — The relation between dry weight per unit of nitrogen content and growing degree-days.

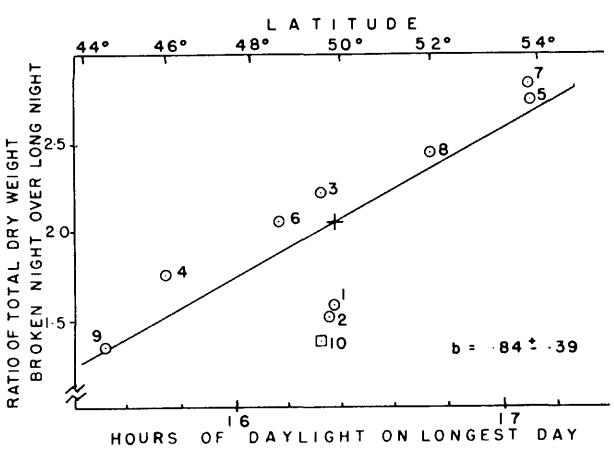

Fig. 4. — The response to change in photoperiod in relation to the photoperiod and latitude of the place of origin. The response is expressed as the ratio of the dry weight under broken-night photoperiod to the dry weight under long-night photoperiod.

Discussion

The results serve to amplify certain conclusions reported earlier. Differences due to provenance showed up clearly in the early months of the trees' life. While the provenance with the largest seed, Upper Jay (No. 9), produced the biggest plants, there did not seem to be a consistent relationship between seed weight and the plant size, probably because of the favourable environment. Hence the differences between provenances can be assumed to be largely genetic.

The marked response of the northern provenances to photoperiod supports VAARTAJA's contention (14) that the more severe the climatic conditions are, the more essential is an adaptation to a photoperiodic stimulus which prepares the plant for drought or cold. However such an adaptation also prevents the plant from making full use of favourable growing conditions (8).

The better growth of provenances from the warmer localities indicates that these plants made more efficient use of the available light under the experimental conditions. This is in line with the findings of others (5, 10, 12, 13, 14). These provenances also produced more organic material for each milligram of nitrogen absorbed — possibly an adaptation to more severe competition for nitrogen which might be expected in warmer localities.

While conclusions drawn from growth chamber experiments must be applied with caution to the growing of jack pine under field conditions, some suggestions are offered which seem to follow from the results. Seedlings moved from cooler localities might be expected to stop growing earlier in the season than those native to the area, and hence put on less growth. Seedlings moved from southerly localities would grow faster than the native ones, and hence would be more desirable in that regard. However, they must be tested for frost hardiness (5), snow damage, and native pests.

The climate of eastern North America has been warming for some decades (2). The seed used comes from trees which probably had their youth at the beginning of the century, and therefore are adapted to the conditions which existed then. Since then, the average annual temperature of North America has gone up by about 2° C (2). This corresponds to a shift northwards of about 3° Lat., or a difference of about 500 growing degree-days. As seen in *Fig. 2*, this is about one-third of the dry weight scale. Assuming that the climatic trend will continue, a considerable northward transfer of seed would seem worthwhile and justifiable. Also promising are breeding experiments aimed at joining the fast growth rate, which may be present in southern races, to the resistance found in northern races to frost and other unfavourable factors.

The results of this experiment will be more significant when the results of the larger investigations by the Department of Forestry become available.

Acknowledgements

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Summary

Seedlings of nine provenances of *Pinus banksiana* LAMB. demonstrated statistically significant regressions with climatic factors. The more northern provenances were more responsive to the photoperiodic treatments. The total dry weight, height, dry weights of leaves and roots, and dry weight per unit of nitrogen content, all are positively correlated with the number of growing degree-days (base 42° F, 5.5° C) in the locality of origin. It is suggested that northward transfers of seed may result in increased growth compared with native stock, provided that resi-

stance to frost is already present or can be obtained by breeding. The former is not unlikely in view of the warming trend in the climate.

Zusammenfassung

Titel der Arbeit: *Eine Provenienzuntersuchung an Bankskiefer-Sämlingen.*

Sämlinge von neun *Pinus banksiana*-Herkünften zeigten statistisch signifikante Regressionen mit Klimafaktoren. Die nördlicheren Provenienzen sprachen besser auf photoperiodische Behandlungen an. Gesamt-Trockengewicht, Höhe, Trockengewicht der Blätter und Wurzeln und das Trockengewicht je Einheit des Stickstoffgehaltes sind positiv korreliert mit dem steigenden Wert für das Verhältnis Temperaturgrad je Tag am Herkunftsort (Basis 42° F, 5.5° C). Es wird angenommen, daß eine Saatgutübertragung nach dem Norden eine Wachstumssteigerung ergibt, verglichen mit dem heimischen Bestand, vorausgesetzt daß Frostresistenz bereits vorhanden ist oder durch Züchtung noch erreicht werden kann. Diese Verhaltensweise ist zugleich dem Erwärmungstrend beim Klima nicht unähnlich.

Résumé

Titre de l'article: *Etude des provenances sur des semis de Pinus banksiana Lamb.*

L'étude des semis de neuf provenances de *Pinus banksiana* Lamb. a permis de mettre en évidence des régressions significatives avec les facteurs climatiques. La réponse photopériodique est la plus forte pour les provenances septentrionales. Le poids sec total, la hauteur, les poids secs des feuilles et des racines et le poids sec rapporté à la teneur en azote présentent une corrélation positive avec le nombre de jours où la température moyenne excède 5.5° C dans la station d'origine. On pense qu'un transfert des graines vers le nord permettrait d'augmenter la croissance par rapport aux provenances locales pourvu que la résistance au froid soit suffisante ou qu'elle puisse être améliorée. La première hypothèse n'est pas improbable en raison de la tendance au réchauffement du climat.

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Controlling the Moisture Content of Conifer Pollen

By Ronald M. Lanner

Research Forester, Institute of Forest Genetics,
Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture

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The feasibility of storing pine pollen in a domestic deepfreezer has been demonstrated by Duffield and Callaham (1959) and by recent unpublished work. Research currently underway at the Institute of Forest Genetics deals with the influence of moisture content on the viability of deepfrozen pollen. To facilitate this study, a method has been developed to bring pollen samples to predetermined moisture contents.

Procedure

Standard dessicators were used as controlled-humidity chambers. Relative humidities (R. H.) were attained by sulfuric acid solutions of appropriate density (Handbook of Chemistry and Physics, 1949) as follows:

Percent relative humidity	Acid density
5	1.67
20	1.58
47	1.35
70	1.25
89	1.15
100	1.00

Half a liter of solution was poured into the flatbottomed basin of each dessicator. Earlier trials had shown the need for a large dessicant surface area. The chambers usually stood for several days before pollen samples were placed inside.

Pollen of five ponderosa pines (*Pinus ponderosa* Laws.) was collected and extracted 8 weeks prior to these tests. Small samples (0.2—0.4 g.) were put in weighing bottles provided with ground-glass stoppers. They were weighed to the nearest 0.0001 g., placed in the chambers, and removed at various intervals before re-weighing. Then they were oven-dried for at least 5 hours at 90—95° C. and weighed once again. The weighing bottles were left unstoppered only while in the chambers and drying oven. Initial and terminal moisture contents were computed and expressed as percent of dry weight for each sample. Throughout the test, the air temperature in the laboratory was 70° F. ± 5°.

To compare the hygroscopicity of dead and live pollen, several samples of oven-dried pollen were placed in the 100 percent R. H. chamber.