Winter Coloration and Growth of Jack Pine in the Nursery as Affected by Seed Source

By J. H. STOECKELER and PAUL O. RUDOLF

Lake States Forest Experiment Station*), Forest Service, U. S. Department of Agriculture

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A serious impediment to progress in forest tree improvement is the need to wait many years before significant genetic differences between trees or groups of trees can be distinguished. Any criteria for making such distinctions in the juvenile stage would, therefore, be of great value.

It has long been noted that young seedlings of several conifers undergo a change in foliage color at the onset of cold weather. Jack pine, *Pinus banksiana,* is such a species. Therefore, special observations of autumn foliage color and size were made on jack pine seedlings of 29 different Lake States seed origins in the Hugo Sauer State Nursery near Rhinelander in northeastern Wisconsin. The results of these observations are reported here.

Past Evidence

Fall color changes in seedling foliage have been observed in such species as Scotch pine *(P. sylvestris),* ponderosa pine (P. *ponderosa),* and eastern redcedar *(Juniperus virginiana),* in addition to jack pine. In a few instances reports have indicated differences in foliage coloration within a species according to origin.

BÜSGEN and MÜNCH (1931) attribute the autumnal change in the color of evergreens to the combined action of sunlight and low temperature, which causes hardening of cells and the transport of assimilates out of the cells. The red coloring matter in the cell sap gives the needles a reddish tint.

KIENITZ (1922) noted that 1-0 Scotch pine grown in a nursery near Chorin, Germany, had winter foliage which was a strong violet-brown color in East Prussian and Latvian seed sources, while the lots of Scottish or French origin retained their blue-green summer color. Eleven years after planting, the lots from the East Prussian and Latvian seed showed marked superiority in height and survival over those from Scotland and France.

LANGLET (1936), in summarizing results of a comprehensive provenience study of Scotch pine in Sweden, found that 1—0 plants from southern France and Spain retained bluish-green foliage but trees from all other sources assumed a more or less violet-red to mahogany-brown color. Plants from southern Swedish provinces became colored only at the tips. The most intense color occurred in extreme northern proveniences such as those from Siberia and from the high plateau east of Lake Baikal in the eastern part of the U.S.S.R. Stock of these showed foliage coloration soon after the first frost.

KALELA (1937) cites a trial of Scotch pine coducted at Tharandt, Germany, in which foliage of the 1-0 stock of Finnish origin turned violet after the first frost. He also describes tests in Finland of seed sources obtained from the entire range of Scotch pine within the country in which the strongest winter foliage coloration occurred in trees from the colder northern interior areas with a continental type of climate. The 1–0 stock from the northern areas turned reddish to mahogany brown; older stock tended to turn yellow.

In 1935 to 1937, the senior author observed at the Towner Nursery in north central North Dakota that 1–0 ponderosa pine stock showed marked purple coloration in the autumn foliage among those lots of western North Dakota and eastern Montana origin as compared to mild purple-green coloring in a lot of Nebraska origin.

How the Study was made

In 1950 and 1951, jack pine seed was collected from 29 localities in the Lake States with the cooperation of various state, federal, university, county, and private foresters (fig. 1 and table 1). The project is part of a regionwide test in which some 17 separate field plantings were made over the Lake States area in the spring of 1954 to test the long-range adaptability, survival, growth, resistance to enemies, and form of the various seed sources in each planting area. The area of seed collection lies between latitude 44 and 48 degrees north and between longitude 83 and 96 degrees west. The nursery site at Rhinelander, in Oneida County, Wisconsin, was rather centrally located in the range, lying at latitude 45.6 degrees north and longitude 89.4 degrees west.

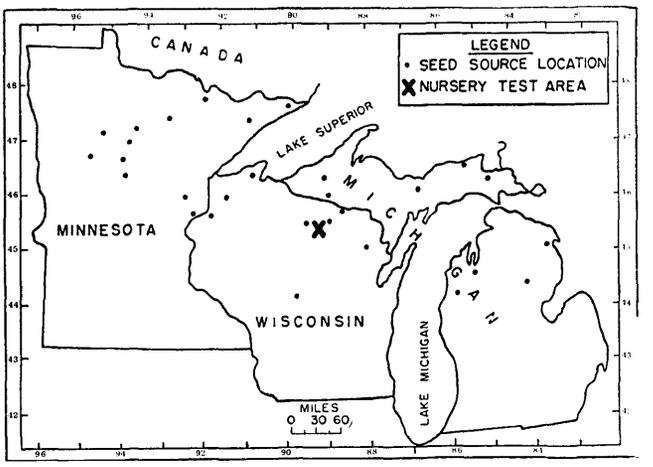

Fig. 1. — Location of the 29 jack pine seed collection ereas and the nursery test area at Hugo Sauer Nursery, Rhinelander, Wisconsin.

Nursery sowings were made in the spring of 1952 with each seed source replicated twice, and in the spring of 1953 with each seed source replicated four times. The seed was sown by hand in drills (10 drills per 4-foot-wide bed) to obtain stands of about 25 to 30 trees per square foot, using precisely weighed amounts of seed for each individual seeding. Germination occurred promptly and uniformly in both seedings, and thereafter the beds were given standard watering and weeding care.

*) Maintained at St. Paul 1, Minnesota, in cooperation with the University of Minnesota. Credit is due Mrs. L. P. OLSEN of the Lake States Forest Experiment Station for aid in the statistical analysis of the data.

Table 1. — *Latitude and climate of the 29 seed-source areas*

Collection number	State	County	Latitude	Average annual precipitation	Degree days over 50° F.[1])	Frostfree days per year	Average January temperature	Average July temperature
			Degrees	*Inches*	*Number*		*Degrees F*	
1589	Minn.	Cass	47.00	24	9,200	125	5	68
1590	Minn.	Cass	47.34	24	9,380	130	7	68
1591	Minn.	Itasca	47.55	24	9,100	120	5	68
1592	Minn.	Lake	47.75	28	7,400	115	10	64
1593	Minn.	Cook	48.00	30	6.700	125	14	60
1594	Minn.	St. Louis	48.03	26	8,500	105	5	64
1595	Minn.	Pine	45.95	27	9,500	130	10	69
1596	Minn.	Pine	46.30	26	9,000	125	9	66
1597	Minn.	Becker	47.08	24	8,900	110	4	68
1600	Minn.	Cass	46.75	26	9,400	130	6	68
1601	Minn.	Beltrami	47.48	22	8,600	115	5	68
1602	Minn.	Itasca	47.75	24	8,800	105	6	67
1604	Wis.	Douglas	46.34	28	9,700	120	10	67
1605	Wis.	Bayfield	46.75	28	9,000	130	13	66
1606	Wis.	Forest	46.02	31	8,500	95	12	65
1607	Wis.	Oneida	45.82	31	8,500	105	11	66
1608	Wis.	Burnett	45.92	28	10,000	125	10	69
1609	Wis.	Marinette	45.28	30	9,630	125	14	68
1610[2])	Wis.	Oneida	45.75	31	8,970	125	10	66
1611	Wis.	Wood	44.45	32	10,000	130	13	70
1612	Mich.	Gogebic	46.22	32	8,480	80	12	65
1613	Mich.	Ontonagon	46.56	32	8,800	85	15	65
1614	Mich.	Alger	46.24	32	8,070	90	15	64
1615	Mich.	Chippewa	46.26	30	8,000	140	15	64
1616	Mich.	Manistee	44.26	30	10,100	145	22	68
1617	Mich.	Ogemaw	44.34	28	9,600	95	19	68
1618	Mich.	Alpena	45.00	30	9,000	135	19	66
1620	Mich.	Grand Traverse	44.62	28	9,700	145	18	68
1621	Mich.	Luce	46.60	30	7,900	140	16	62

[1]) The normal annual sum of average daily temperatures of 50° F. or higher.

[2]) Climate at Hugo Sauer Nursery is quite similar to that given for this collection.

Results

Foliage Color

On October 20, 1953, a considerable variation was noted in the needle color of 2—0 jack pine at the Hugo Sauer Nursery near Rhinelander, Wisconsin, involving the 29 different sources. The color change was from a normal green to a purple or purplish bronze. The percent of the visible needle surface which had changed color from the normal green was estimated in each bed. The results (fig. 2), when plotted as percent of color change over latitude of the source, showed a correlation coefficient of 0.819, significant at statistical odds of 99 out of 100, often referred to as the 1-percent level. Stock from the northern part of the range of jack pine in the Lake States (latitude around 47.5 to 48.0 degrees) had an average color change of around 80 percent. Stock from the southern end of the range of the species, latitude of 44 to 45 degrees, was still very green, with only 0 to 10 percent of these lots showing any color change in the needles. This change starts at the ends of the needles on the tip of the tree.

By November 4, 1953, about 25 percent more of the needle surface had changed color compared with the October data, with an especially marked upward trend in lots which came from latitudes of 46° or further north. However, those from a latitude of 44 to 45 degrees north, largely from the Lower Peninsula of Michigan and central Wisconsin, were still essentially green, showing only a very slight color change (fig. 3). The results were also

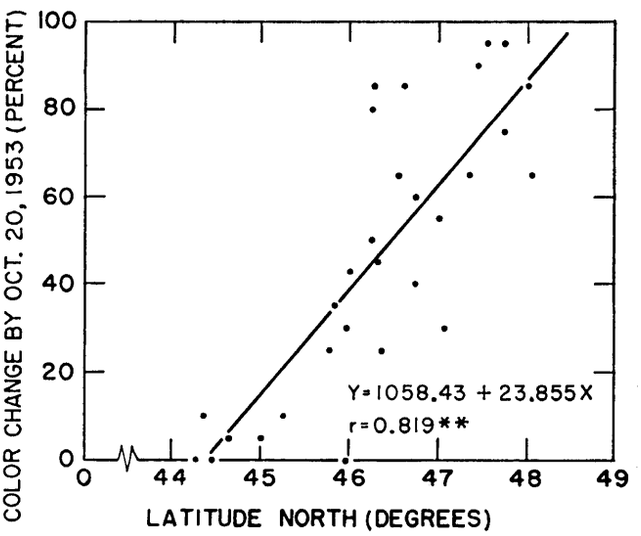

Fig. 2. — Color change in needles of 29 lots of 2-0 jack pine as of October 20, 1953, related to latitude of the seed source. The equation for the regression, the correlation coefficient (*r*), and statistical significance are also given. (** means significant at the 1-percent level.)

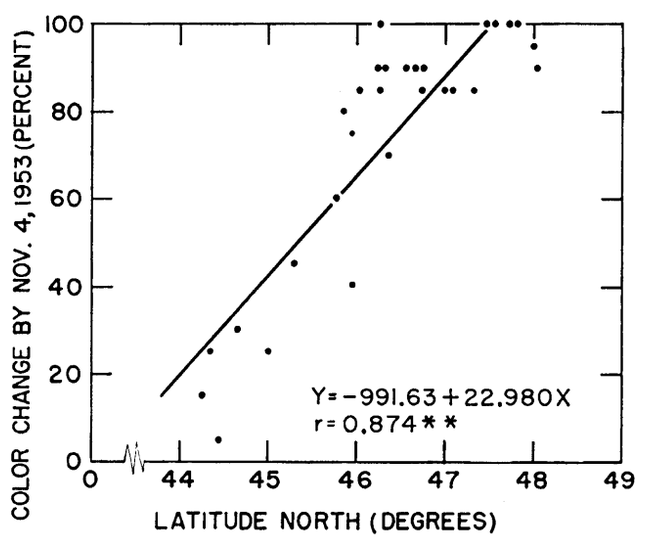

Fig. 3. — Color change in needles of 29 lots of 2-0 jack pine as of November 4, 1953, related to latitude of the seed source. The equation for the regression, the correlation coefficient (*r*), and statistical significance are also given. (**means significant at the 1-percent level.)

highly significant, yielding a correlation coefficient of 0.874, significant at the 1-percent level.

Minimum air temperatures in September, 1953, ranged from 33° to 40° F. on nine occasions. The first freeze (28°) occurred on October 26 and the second (29°) on October 27; minima ranged from 26 to 29 for each day of the last 5 days of October. From November 1 to 4, the minima were 25, 36, 32, and 24 respectively. Apparently the temperatures were low enough to cause the color changes observed.

When these lots were examined on April 19, 1954, no additional color change was observed from that for November 4, 1953. The averaging line was practically identical with that for the November 4 observation (fig.3). The correlation coefficient for the April 19 values was 0.800, significant at the 1-percent level. The equation was $y = -865.54 + 20.177X$.

When the data for the November 4, 1953, color change were plotted over length of frost-free period, the results were not significant statistically, yielding a correlation coefficient of only 0.334.

The lack of significance of this criterion, compared with latitude, leads to the conclusion that the phenomenon of color change is more directly associated with factors such as photoperiod and frequency and intensity of frosts in autumn, than with length of the frost-free period expressed in days; the last factor may be markedly affected by the presence of large bodies of water such as the Great Lakes.

The color change in 1—0 jack pine stock was substantially higher by November 4, 1953, than in the 2—0 which was growing in a nursery plot alongside it (fig. 4). The color was a more intense purple in the 1—0 stock, the change was more complete, and it was fairly strong even in the lots from southern latitudes. The correlation coefficient was 0.684, significant at the 1-percent level.

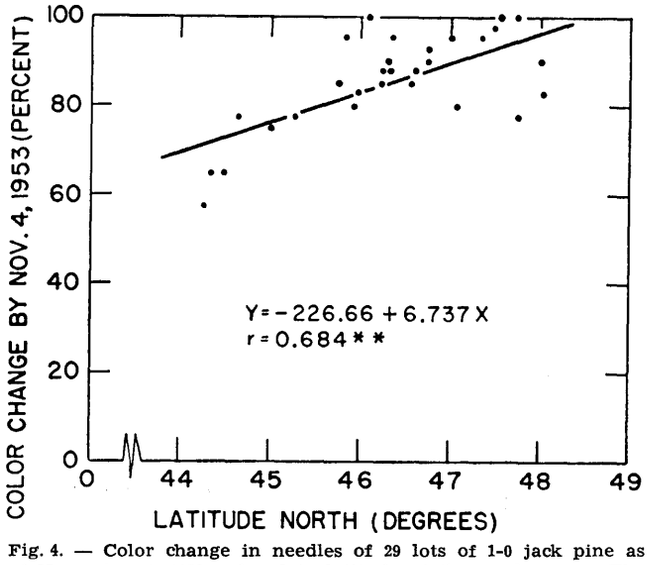

Fig. 4. — Color change in needles of 29 lots of 1-0 jack pine as of November 4, 1953, related to latitude of the seed source. The equation for the regression, the correlation coefficient (*r*), and statistical significance are also given. (** means significant at the 1-percent level.)

The more intense color change in 1—0 as compared to 2—0 or older stock in jack pine agrees with the European observations on Scotch pine.

Some 24 lots of the 2—0 beds of jack pine were left to the 3—0 age and again observed for color change on November 8, 1954. At this time there was substantial color change in the lots from latitude 47° to 48° (fig. 5). The correlation coefficient was 0.830, significant at the 1-percent level. However, the averaging line for the 3—0 was substantially lower, by about 25 or 30 percent of coloration, than the 2—0 on approximately equivalent dates a year apart.

When the data on color change of the 3—0 stock were plotted over average January temperature of the seed source, a correlation coefficient of —0.511 was obtained, significant at the 5-percent level (fig 6). This is a considerably poorer criterion than latitude of the seed source with its correlation coefficient of 0.830, significant at the 1-percent level. The same data when related to number of frost-free days of the seed source were non-significant, with a correlation coefficient of −0.094.

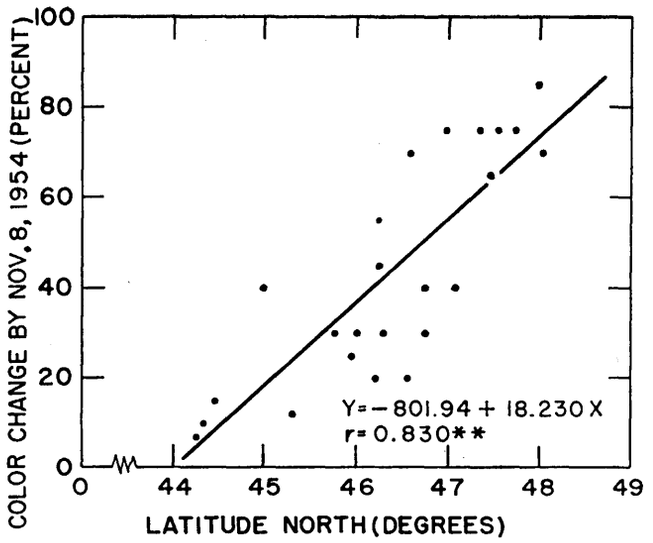

Fig. 5. — Color change in needles of 24 lots of 3-0 jack pine as of November 8, 1954, related to latitude of the seed source. The equation for the regression, the correlation coefficient (*r*), and statistical significance are given. (** means significant at the 1-percent level.)

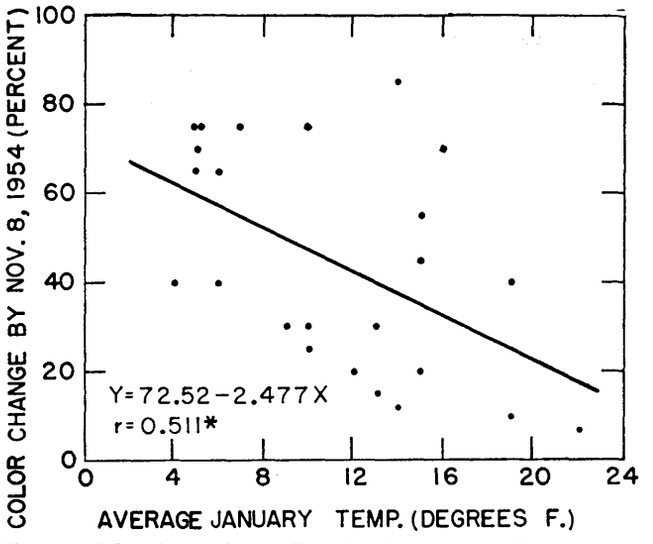

Fig. 6. — Color change in needles of 24 lots of 3-0 jack pine as of November 4, 1954, related to the average January temperature of the seed source. The equation for the regression, the correlation coefficient (*r*), and statistical significance are given. (* means significant at the 5-percent level.)

For comparison, six different averaging lines of color change in four age classes of jack pine observed in a 2-year period were drawn (fig. 7). The most marked and complete color change occurred in 1—0 jack pine. The 2—0 stock observed on October 20, 1953, and again on November 4, 1953, showed about 25-percent color change in that 2-week period, but even on November 4 was substantially less than in the 1—0 stock. The averaging line for 2—0 stock on April 19, 1954, was practically identical to that for November 4, 1953, and hence was not plotted on the graph. In October and November 1954 observations were made on 2—1 and 3—0 stock. Examination of needle color on October 6, 1954, of 2—1 and 3—0 stock showed no change in the 2—1 stock and only a slight touch of color on the ends of the needles of the 3—0 stock. The 2—1 stock showed no color change in any lots on October 18, and a moderate change by November 8, 1954, ranging from

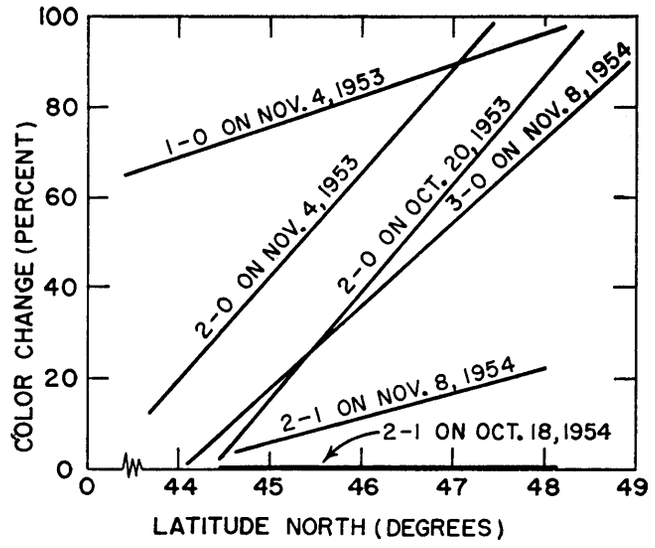

Fig. 7. — Color change in needles of four age classes of nursery-grown jack pine, related to latitude of the seed source and date of observation. The 1-0 and 2-0 ages are represented by 29 lots, the 3-0 by 24 lots, and the 2-1 by 9 lots.

5 to 20 percent. The 3—0 stock on the latter date showed substantially more color change than the 2—1 age class, with a color change of 60 percent or more in the more northern lots.

Apparently, color change is greatest in 1—0 stock, somewhat less in 2—0 or 3—0 stock, and least in transplants.

The weather records for the fall of 1954 indicate the first freeze (31°) occurred on September 23; on 4 other days in September the minimum temperature was in the range of 34° to 40° F. In October the minimum dropped below 32° F. on 8 different days, ranging from 20° to 31° and averaging 24.5° F.

In the period November 1 to 8, inclusive, the minimum was below freezing each day, ranging from 24° to 31° and averaging 27.2° F. for all eight minima.

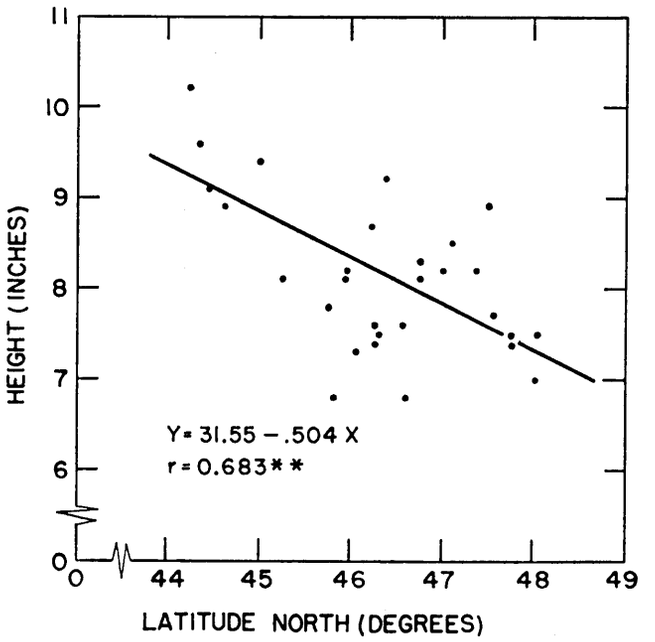

Fig. 8. — Average height of 29 lots of 2-0 jack pine in October 1954, related to latitude of the seed source. The equation for the regression, the correlation coefficient (*r*), and statistical significance are given. (** means significant at the 1-percent level.)

Height Development

A considerable difference in average height of the stock at the 2—0 stage was observed in the fall of 1954, with the stock of more northern latitudes being shorter than that from southern latitudes (fig. 8). The correlation coefficient was −0.683, significant at the 1-percent level.

When height was related to the number of degree days over 50° F. for the area of seed source (fig. 9), the correlation was 0.682, significant at the 1-percent level. This was almost identical in magnitude to that for latitude. The latter criterion would seem to have some advantage in statistical analysis because it can be determined more precisely and does not require a weather record of 10 to 20 years' duration from a nearby station.

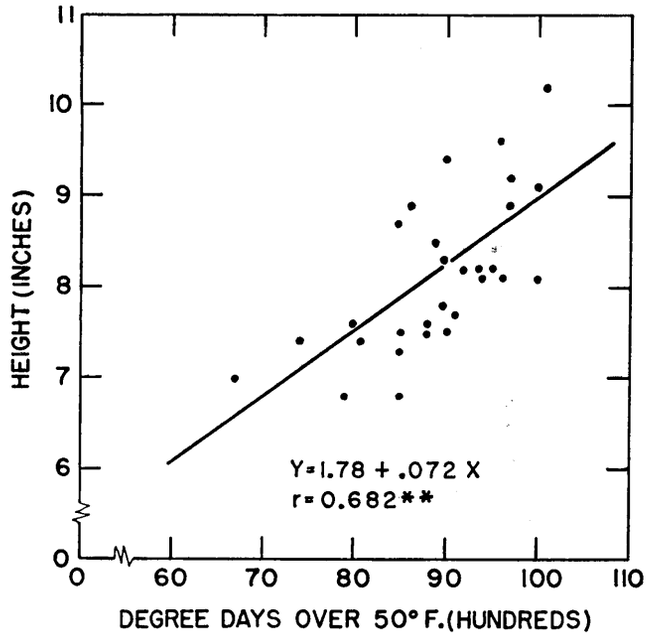

Fig. 9. — Average height of trees in 29 lots of 2-0 jack pine in October 1954, related to the number of degree days over 50° F. The equation for the regression, the correlation coefficient (*r*), and statistical significance are given. (** means significant at the 1-percent level.)

Two other criteria were also used on analysis of the fall 1954 height data. When related to the average January temperature, the correlation coefficient was —0.342. It was not significant. When related to the number of frost-free days, the results were also nonsignificant statistically, with a correlation coefficient of 0.093.

Discussion

The results observed on the degree of color change in jack pine nursery stock lead to the conclusion that color change as such is not an infallible criterion of the relative status of physiological hardening-off of the stock and its suitability for lifting and field shipment. Lots of southern origin tended to retain a green needle color even after repeated exposure to temperatures below freezing. These same lots withstood exposure to freezing weather during the planting period and for several weeks thereafter and came through with excellent first-year survival.

The tendency for jack pine seedling stock of more northern seed sources to be shorter than stock from southern seed sources offers a partial explanation of why northern nurseries, using locally collected seed, have more

difficulty than do southern nurseries in getting stock of adequate height to meet grading standards.

It might be inferred, therefore, that somewhat less rigid standards on acceptable minimum height growth might be permitted in northern nurseries if the stock is suitable in other respects.

Summary

Observations made over a 2-year period of 29 different seed sources of jack pine grown at the Hugo Sauer Nursery, Rhinelander, Wisconsin, revealed that fall foliage color changes are associated with the latitude of the seed source. The more northerly the seed source, the more purplish did the needles become during cold weather.

Color change occurs earliest, is most intense, and is most complete in 1—0 stock. Color change is progressively less complete in stock of 2—0 and 3—0 age classes, and is the least in 2—1 stock.

Color change also was found to be correlated with the average January temperture of the original seed source area, but the correlation was not as good as with latitude. There was no correlation with the length of frost-free period, expressed in days.

Height growth of 2—0 stock proved to be positively correlated with latitude of the seed source and the number of degree days over 50° F. per annum of the original area of seed collection.

Résumé

Titre de l'article: *Influence de l'origine des graines sur la coloration hivernale et la croissance du Pin de Banks (Pinus banksiana) en pépinière.* —

Des observations faites au cours de 2 années sur 29 origines différentes de Pin de Banks à la pépinière Hugo Sauer à Rhinelander, Wisconsin, montrent que le changement de coloration des aiguilles en automne est lié à la latitude de l'origine des graines: la coloration pourpre hivernale est d'autant plus accentuée que les graines proviennent d'une région plus septentrionale.

Le changement de couleur est le plus précoce, le plus intense et le plus complet pour les semis 1—0; il l'est moins pour les semis 2—0 et 3—0 et le minimum est atteint pour les plants 2—1.

Une corrélation, moins nette cependant que pour la latitude, existe entre le changement de couleur et la température moyenne de janvier du lieu d'origine des graines. Il n'y a aucune corrélation entre la longueur de la période de végétation, exprimée en jours.

Une corrélation existe entre la hauteur des semis 2—0 et, d'une part la latitude, d'autre part le nombre de jours où la température est supérieure à 50° F (+ 10° C) au lieu d'origine des graines.

Zusammenfassung

Titel der Arbeit: *Provenienzbedingte Unterschiede in Winterfärbung und Wachstum bei Bankskiefer-Sämlingen.* —

Das Verhalten von Bankskiefer-Sämlingen 29 verschiedener Herkünfte wurde 2 Jahre lang in Hugo Sauer Nursery, Rhinelander, Wisconsin, beobachtet. Der herbstliche Farbwechsel der Nadeln hängt mit der geographischen Breite der Provenienz zusammen. Je nördlicher die Herkunft, umso rötlicher (purpurn) werden die Nadeln bei kalter Witterung.

Am frühesten, intensivsten und verbreitetsten ist die Verfärbung bei 1j. Sämlingen. Weniger ausgeprägt ist sie bei 2j. und 3j. und am geringsten bei 3j. v. Pflanzen. Außerdem stellte sich heraus, daß auch zwischen der mittleren Januar-Temperatur des Herkunftsortes und dem Grad der Farbveränderung gewisse Beziehungen bestehen, wenngleich sie auch nicht so deutlich sind wie die zwischen Verfärbung und geographischer Breite. Ohne jeden Einfluß erwies sich die Länge der frostfreien Jahreszeit.

Das Höhenwachstum der untersuchten 2j. *P. Banksiana*-Sämlinge korreliert mit der geographischen Breite der Herkunft und mit der Anzahl der Tage über 50° F (+ 10° C) im Jahr am Herkunftsort.

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