somenzahlenbestimmungen unter Einzelkeimlingen festgestellt (auf 283 Keimlinge 4, d. h. 1,4% Abweicher). Es kann somit kein Zusammenhang zwischen Mehrlingsauftreten und dem Vorkommen chromosomaler Abweicher angenommen werden. Darauf deuten auch bereits die früher veröffentlichten Ergebnisse an gleichzeitig durchgeführten anderen Kreuzungen hin (ILLIES 1958), die zeigten, daß abweichende Chromosomenzahlen fast regelmäßig nur in Nachkommenschaften solcher Baume vorkamen, in denen auch gehäuft verdickte Keimlinge auftraten, die bei den Mehrlingen nicht beobachtet werden konnten.

Zusammenfassung

Es werden Untersuchungsergebnisse an Nachkommenschaften von Testkreuzungen und frei abgeblühten Bäumen von ***Picea abies***, die sich durch einen verschieden hohen Anteil von Mehrlingssamen auszeichneten, mitgeteilt. Danach ist der Einfluß der Mutter für die Ausbildung von Mehrlingen von entscheidender Bedeutung, was auch durch die Auffindung morphologisch charakteristischer Mehrlingstypen bei der Verwendung bestimmter Mütter unterstrichen wird. Ein Einfluß des Vaters sowie der Umwelt war nicht nachweisbar. Ebenso besteht kein Zusammenhang zwischen dem Auftreten chromosomal abweichender Keimlinge und dem Mehrlingsanteil, so daß dieser. für die Auslese Polyploider kein Interesse besitzen dürfte.

Summary

Title of the paper: ***Further investigations into polyembryony in Picea abies (L.) Karst.***

This paper records the results of investigations carried out on the progenies derived from controlled crossings and free pollination of trees of ***Picea abies*** which are characterized by a varying production of polyembryonic seeds. According to that the influence of the mother tree on the development of polyembryony is strong. Moreover this factor is stressed by the development of morphologically different types of polyembryos in different mother trees used in the crossings. No influence of the father or of the environment could be demonstrated. Likewise there could not be found any connection between the occurrence of seedlings with aberrant chromosome numbers and the degree of polyembryony. Therefore the latter character has no interest for the selection of polyploids for breeding purposes.

Résumé

Titre de l'article: ***Nouvelles recherches sur la polyembryonie chez Picea abies (L.) Karst.***

Cet article rend compte des resultats des recherches entreprises sur les descendances issues par croisements contrôlés ou pollinisation libre de ***Picea abies*** caractérisés par une production a des taux variables de graines présentant plusieurs embryons. On note que l'influence de l'arbre mere sur le développement des embryons multiples est élevée. De plus, ce facteur est renforcé par le fait que les differents arbres mères employés dans les eroisements ont donné des types d'embryons multiples morphologiquement differents. Ni l'influence du père, ni celle du inilieu n'ont pu être mises en évidence, de même aucune relation n'a pu être trouvée entre la presence de semis avec des nombres chromosomiques aberrants et le taux de polyembryonie.

En conséquence, ce caractère n'a pas d'intérêt pratique pour la selection de polyploides en vue de l'amelioration des arbres.

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Seasonal Variation of Chloroplast Pigments and Nutrient Elements in the Needles of Geographic Races of Scotch Pine

By **H. D. GERHOLD**[1])

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Unusual coloration in plant leaves is widely recognized as a possible indication that a nutrient element is lacking in the soil. A number of nutrient deficiencies and their corresponding symptoms have been reported for pines (WILDE and VOIGT, 1952). The appearance of some of the symptoms is similar to Scotch pine discoloration during the winter. Thus it is not unreasonable to postulate that the seasonal discoloration of Scotch pine needles might result from some type of nutrient deficiency.

The nature of the seasonal yellowing has been described previously in relation to the effects of microclimatic factors (GERHOLD, 1959). If one should seek to interpret it as indicative of a nutrient deficiency, two peculiar features would have to be explained. First, the discoloration is limited to the dormant season; needles are completely normal in color and size during the summer. Second, geographic races of Scotch pine growing on the same site differ in degree of discoloration; the foliage of some appears to remain green and upon close inspection exhibits only a slight hint of yellow, while others have been portrayed as "golden yellow" (BALDWIN, 1955).

Attempts have been made to prevent or correct the yellowing of Scotch pine trees in the winter by means of fertilizers. These were successful only in those cases where nutrient elements were found to be lacking in the soil. In

[1]) The author is Instructor in Forestry at The Pennsylvania State University. This paper is part of a dissertation prepared under the guidance of Dr. FRANÇOIS MERGEN and submitted in 1958 to the Graduate School of Yale University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. It was authorized for publication on Dec. 18, 1958, as Paper No. 2328 in the Journal Series of the Pennsylvania Agricultural Experiment Station. Portions of this study were conducted as part of a Northeast Regional Project (NE 27); a cooperative study involving agricultural experiment stations in the Northeastern Region and supported in part by regional funds of the United States Department of Agriculture.

many other cases fertilizers supplying a variety of elements have failed to improve the needle color (LUNNUM, 1956).

This study attempts to ascertain if a nutrient deficiency is responsible for the seasonal discoloration of Scotch pine needles. Quantitative determinations were made of chloroplast pigments and nine nutrient elements in the needles of six races of Scotch pine in the summer and winter. If a deficit of one of the elements is responsible for the discoloration, it should be correlated with a decrease in chlorophyll relative to carotenoids. Foliar analysis should reveal that the quantity of this element decreases in a parallel relationship with chlorophyll from summer to winter, and is lowest in those races which discolor the most.

Review of Literature

Racial Color Differences

Provenance tests are the source of most of our knowledge about differences in the inherent winter color of Scotch pine races. Little has been added to ENGLER's (1908; 1913) excellent description of the pattern of geographic variation. He recognized that intensity and earliness of coloration is correlated with latitude and altitude of the seed source: "the more continental the native climate, the earlier and more intense is the winter discoloration of the needles."[2]) Variation is continuous in two directions: from south to north, and from central European lowlands to the timberline in the Alps. Reports by KIENITZ (1911; 1922), LANGLET (1936), DENGLER (1938), and BALDWIN (1955; 1956) have confirmed these findings and have provided additional details.

KÖNIG (1925) tabulated characteristics of eleven European races and used needle color in the winter as a means of identifying them. But DENGLER (1938) has cautioned that individuals of a given provenance vary in hue, and occasional trees differ markedly from the average color. LANGLET (1936) presented figures that showed the percentage of trees in each of three color classes for various provenances.

ENGLER (1913) interpreted the pronounced discoloration of trees of Swedish and Russian origin in Switzerland as a specific racial characteristic developed under native environmental influences, which is transmitted to the progeny as a residual effect, and will disappear in time. His Lamarckian diagnosis has been modified on the basis of subsequent experiments that showed that the pattern of discoloration is fixed and does not change as trees get older (KIENITZ, 1911; 1922). The characteristic needle color of races is inherited by second generation progeny on a foreign site (DENGLER, 1938; MÜNCH, 1924), but site factors do exert some influence on phenotypic needle color (SCHMIDT, 1930; STONE, 1954).

Chloroplast Pigments

ASKENASY (1867) investigated the absorption spectra of chloroplast pigments, and suggested that these are the primary contributors to the needle color of Scotch pine. A red pigment has also been observed in conifer needles (SCHIMPER, 1885), which might be rhodoxanthin (STRAIN, 1958). The chloroplast pigments of pine needles have been identified as chlorophylls a and b, beta-carotene, and lutein, with smaller amounts of alpha-carotene and other unidentified xanthophylls (STRAIN, 1938; 1958).

Analytical data of several investigations indicate that rather large fluctuations occur in the chloroplast pigment content of Scotch pine, even after allowing for differences due to techniques. Racial and seasonal differences have been demonstrated by LANGLET (1942), who found that carotenoids increased gradually from July to January, while chlorophylls reached a peak in September and declined until January. Races from the far north had high chlorophyll contents in the summer, but in January there was an inverse relationship between latitude of seed source and total chlorophyll, with a decrease in chlorophyll content as high as 50 percent from the summer levels in northern races. Figures of STANKOVIĆ, et al. (1953) and STANKOVIĆ and KARAPANDZVIĆ (1954) support these conclusions. On the other hand, STÅLFELT (1927) and ZACHAROWA (1929), using green weight rather than dry weight as a basis, reported that chlorophyll content increased to a winter maximum in December or January, then dropped sharply until March, reached another peak in June, and decreased again until August. In the mild winters of Aachen, Germany, chlorophyll content in one-year-old needles increased continually from July to March (LAURS, 1935). Other factors which may influence chlorophyll content are elevation (ZELLER, 1935), shading (STÅLFELT, 1921), daylength, temperature, soil moisture (SIRONVAL, 1954), and nutrition (DEUBER, 1926; SCHERTZ, 1929).

Nutrient Elements

MERGEN (1953) reported a highly significant relationship between nitrogen and chlorophyll contents in the needles of Scotch pine and other conifers. Other possible relationships may be intimated from descriptions of chlorotic symptoms resulting from deficiencies of magnesium, calcium, copper, iron, potassium, and sulphur (WILDE and VOIGT, 1952.)

Numerous experiments have demonstrated that the availability of elements in the soil is reflected by their levels in conifer needles, and can be correlated with height growth. Included in this category are nitrogen, phosphorus, potassium, calcium, magnesium, and boron (BECKER-DILLINGEN, 1937; GAST, 1937; NĚMEC, 1942; HEIBERG and WHITE, 1950; STONE, 1953; LEYTON and ARMSON, 1955; WALKER, 1955; STONE and BAIRD, 1956; VAN GOOR, 1956; LEYTON, 1957). THOMAS, et al. (1953) have discussed the validity of foliar diagnosis for determining nutrient deficiencies in horticultural crops.

Variations in nitrogen, potassium, and phosphorus within tree crowns have been studied by LEYTON and ARMSON (1955), and WHITE (1954). Levels decreased from top to bottom, and maximum differences among trees could be detected near the top. SAYRE (1957) found that boron, silicon, manganese, aluminum, iron, and copper accumulate in needle tips; phosphorus, magnesium, lead, calcium, silver, and zinc are uniformly distributed; and potassium is low in the tips and high at the bases of red and white pine needles. Chloroplasts of tobacco, tomato, and oat leaves contained from 30 to 40 percent of the total leaf nitrogen, 10 percent of which is in chlorophyll and 80 percent in proteins (GRANICK, 1938; GALSTON, 1943). Iron and copper are concentrated in the chloroplasts of sugar beets and chard (WHATLEY, et al., 1951).

Seasonal variations have also been reported in Scotch pine, although apparently in some cases a given element can either increase or decrease. DULK (1875) found increases in calcium, magnesium, potassium, iron, manganese and silicon from July to October, while phosphorus and sulfur decreased. TAMM (1955) stated that nitrogen, potassium, and calcium increased from August to January, and that phosphorus decreased. In other pines nitrogen, phosphorus, and potassium decreased from summer to winter (WHITE, 1954).

[2]) Translated from German by H. D. GERHOLD.

Fertilizer Trials

Attempts to improve the winter color of Scotch pine (BYRNES, 1953; FOX, 1955; DENUYL 1956; HACSKAYLO and GOSLIN, 1957) and other conifers (MCDERMOTT and FLETCHER, 1955) with fertilizers have been unsuccessful. LUNNUM (1956) summarized the results of fertilizer trials conducted in many states. There was not a single instance of improvement in needle color unless a nutrient deficiency was involved. Numerous accounts, also involving other pine species, fall into the latter category (BECKER-DILLINGEN, 1937; NÉMEC, 1942; HEIBERG and WHITE, 1950; STONE, 1953; VAN GOOR, 1956; ROTH and COPELAND, 1957).

Experimental Procedures and Results

Collection of Needle Samples

Needle samples were obtained for analysis from a provenance test planting which had been established in cooperation with the International Union of Forest Research Organizations.[3]) Trees representing many geographic seed sources were planted in 1942 as 2-2 transplants on the Vincent State Forest near Deering, New Hampshire. The plantation is located at an elevation of 1,100 feet on a hilltop which is nearly level. The Paxton loam soil is virtually uniform, except for variations in depth to a hardpan layer. More detailed site descriptions have been recorded by WRIGHT and BALDWIN (1957), and by ECHOLS (1958).

Six races were selected solely on the basis of the color of their needles in the winter. Two of these discolored very noticeably, two discolored moderately, and two discolored almost imperceptibly *(Table 1)*. Needle samples were collected from six dominant or codominant trees of each race, with three chosen at random in each of two plots. The current year's needles were picked from leaders of lateral branches in the second and third whorls from the top on August 23-24, 1956, and February 27-28, 1957. The samples were picked into polyethylene bags, and were frozen immediately by placing them in an insulated container with dry ice. They were stored in a freezer at -10^0 C. until they were prepared for analysis.

[3]) The author is indebted to Dr. H. I. BALDWIN for making this plant material available.

Table 2. — Constants from regression of dry weight of needles (Y) on fresh weight of needles (X). Y = bX.

Race IUFRO No.	Constant "b" August	Constant "b" February
19	.4158	.4344
21	.4168	.4474
55	.4153	.4480
42	.4225	.4493
46	.4511	.4511
4	.4476	.4421

Chloroplast Pigment Determinations

The method of extraction and separation was adapted from that of SCHERTZ (1928), and is a modification of the WILLSTÄTTER and STOLL technique. Duplicate samples of randomly chosen needles weighing about 600 mg. were cleaned and weighed, then cut into small pieces and ground up thoroughly. Chloroplast pigments were extracted with 80 percent acetone, and chlorophylls a and b were estimated directly in this solution. Pigments in half of the acetone solution were transferred to ether to be further purified for the estimation of carotenoid pigments. Chromatographic analysis revealed that these consist largely of beta-carotene and lutein. Flavanoids were washed out with a 1 percent sodium carbonate solution, and chlorophyll was removed with methanolic potassium hydroxide.

The concentration of pigments in solution was determined from absorption measurements taken with a "Spectronic 20" colorimeter. Extinction coefficients given by MCKINNEY (1941) for chlorophylls a and b in 80 percent acetone, and by KAR (1937) for beta-carotene and lutein in ether, were used to derive the following formulas:

chlorophyll a, mg. per liter = 12.72(663)—2.59(645)
chlorophyll b, mg. per liter = 22.88(645)—4.67(663)
total carotenoids, mols per liter = (451)/132,590

Table 1. — Details of the origin and needle color of geographic races of Scotch pine planted at Deering, New Hampshire

IUFRO Number	Origin Country District Town	Latitude North	Longitude East	Altitude meters	Needle Color November 1955[2])	Needle Color February 1955[3])
19[1])	*Netherlands* Drente Diever	52° 51'	6° 21'	10	36.3 4/5	deep blue-green
21	*Germany* Hannover Göddenstedt	52° 58'	10° 47'	75	36.1 4/5	blue-green
55	*Poland (USSR)* Ukraina Luboml	51° 15'	24° 05'	180	34.1 4/5	pale yellow-green
42	*Czechoslovakia* Liberecky Kurivody	50° 36'	14° 43'	300	33.0 4/5	yellow-green
46	*Sweden* Vesterbottens Vindeln	64° 12'	19° 5C'	200	30.7 4/5	yellow to gold
4	*Norway* Hedmark Tynset	62° 18'	10° 44'	550	30.8 4/5	yellow to gold

[1]) Planted stand.
[2]) Munsell color notations, average values representing twelve trees. On the color scale 25.0 indicates yellow and 37.5 indicates green-yellow.
[3]) Groups of tree crowns classified visually by BALDWIN (1955), average of two plots.

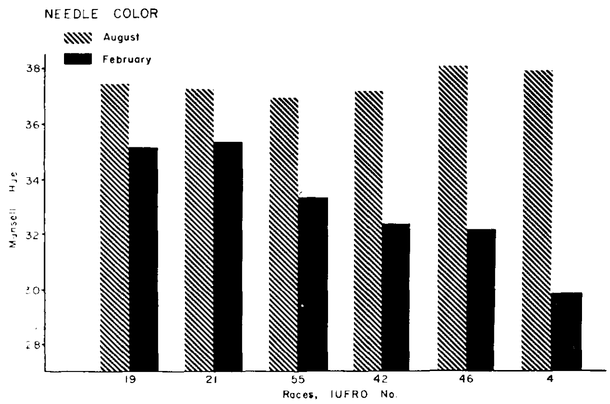

Fig. 1. — Needle colors of the six geographic races of Scotch pine in August and February.

(663), (645), and (451) are $\log_{10} I_0/I$ values of light passing through 1 cm. of solution at wavelengths of 663, 645, and 451 millimicrons, respectively.

Pigment contents were expressed on a dry weight basis to minimize seasonal fluctuations in moisture content. Constants in *Table 2* were used to convert the fresh weights of samples to dry weights. The constants were obtained by weighing needles before and after they were dried to a constant weight at 65^0 C., during their preparation for the analysis of nutrient elements. Needle colors were evaluated with Munsell Color Charts (1952) at the time of analysis.

Changes in needle color of the six races are illustrated in *Figure 1.*[4]) The two Scandinavian races were slightly greener in the summer, but discolored more in the winter than the others. In the other races, color changes were not as great as in those of northern origin, but they were still substantial.

Both total chlorophyll and total carotenoids underwent seasonal changes and both contributed to needle color. But because the carotenoids increased the same amount in all the races from August to February, while chlorophyll content closely paralleled changes in needle color, it is evident that a decrease in chlorophyll is the primary cause of discoloration *(Figures 2* and *3; Table 3).* The relationship of pigments to needle color can be expressed by the curvilinear regression equation:

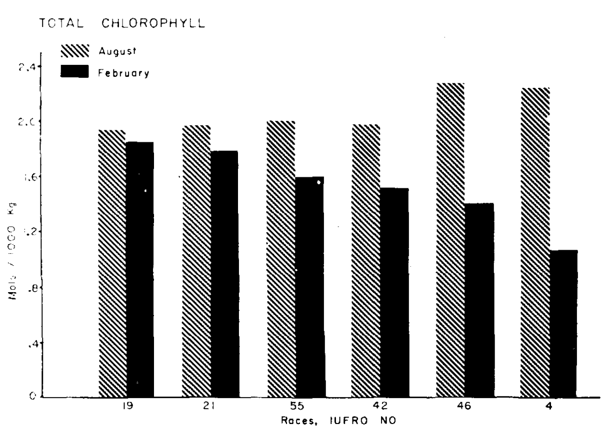

Fig. 2. — Concentration of total chlorophyll in the needles of the six geographic races of Scotch pine in August and February.

[4]) Bar graphs illustrate only those differences which are statistically significant, as determined by analyses of variance Figures for boron and manganese are exceptions; their respective F values approached but did not reach the 5 percent level of significance *(Table 6).*

$$Y = 26.68 + 2.7475\, X_1 - 9.4294\, X_2,$$

in which Y = needle color (Munsell hue),

X_1 = total chlorophyll (mols per 1000 kg), and

X_2 = log of (total carotenoids ÷ total chlorophyll) (both mols per 1000 kg).

Table 4 shows the relative contributions of X_1 and X_2. The equation accounts for 88 percent of the variability in needle color but the very nature of X_2 restricts its use to limits of the data, and makes extrapolation unreliable *(Figure 4).*

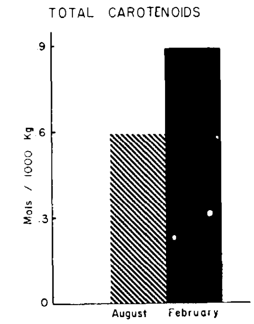

Fig. 3. — Concentration of total carotenoids in the needles of Scotch pine in August and February, average values for six races.

Nutrient Element Determinations

Spectro-chemical analysis of the needles involved two procedures.[5]) Phosphorus, potassium, calcium, magnesium, iron, manganese, copper, and boron were determined simul-

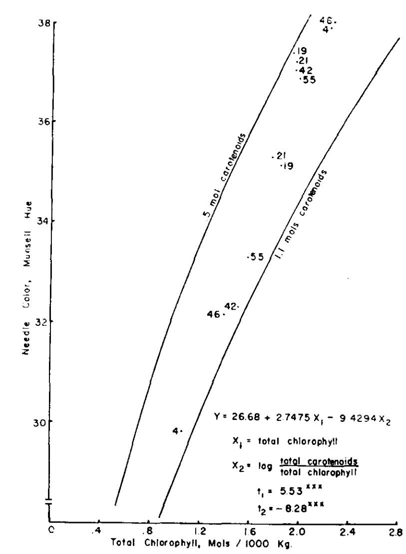

Fig. 4. — Regression of Scotch pine needle color on chloroplast pigment variables. Points between curves represent average values for races, as indicated by IUFRO numbers, in August *(upper group)* and February *(lower group).*

taneously by means of the spectrographic technique employed by C. B. Smith (French, et al., 1957), with several recent changes. A slightly modified Kjeldahl technique was used for the chemical determination of nitrogen. For both types of analysis, cleaned needles were dried at 65^0 C. and were ground to pass a 20-mesh screen in an intermediate Wiley mill, which had been adapted to prevent contamination.

[5]) The invaluable aid of Dr. C. B. Smith in performing this analysis is gratefully acknowledged.

Table 3. — Chloroplast pigment content and colors of current year's needles in geographic races of Scotch pine in August and February

Date	Race IUFRO No.	Tree No.	Chlorophylls		Total Carotenoids	Needle Color	Date	Race IUFRO No.	Tree No.	Chlorophylls		Total Carotenoids	Needle Color
			a	b						a	b		
			Mols. per 1000		*kilograms*	*Munsell Notation*				*Mols. per 1000*		*kilograms*	*Munsell Notation*
August 1956	19	8	1.02	.64	.44	37.0 4/3	February 1957	19	8	1.06	.58	.97	36.0 4/4
		43	1.20	.72	.60	38.0 4/3			43	1.19	.67	.80	36.5 4/4
		57	1.17	.69	.54	38.0 4/3			57	1.29	.72	.98	34.5 4/4
		61	1.28	.76	.57	37.5 4/3			61	1.08	.59	.91	34.5 4/3
		81	1.23	.74	.61	37.0 4/3			81	1.06	.61	.94	35.0 4/4
		117	1.30	.78	.54	37.0 4/3			117	1.41	.84	1.00	34.5 5/4
		Average	1.20	.72	.55	37.4			Average	1.18	.67	.93	35.5
August 1956	21	20	1.02	.61	.48	37.5 4/3	February 1957	21	20	1.07	.59	.89	35.0 4/4
		23	1.07	.62	.49	37.0 5/4			23	1.22	.72	.90	36.0 4/4
		59	1.42	.85	.70	37.0 4/3			59	.98	.56	.87	35.0 5/4
		64	1.22	.76	.52	37.5 4/3			64	1.12	.63	.99	35.0 4/3
		85	1.29	.80	.56	37.5 4/3			85	1.26	.66	1.03	35.5 4/3
		102	1.34	.83	.67	37.0 4/3			102	1.19	.65	1.04	35.5 4/3
		Average	1.23	.74	.57	37.2			Average	1.14	.63	.95	35.3
August 1956	55	8	1.23	.74	.64	36.5 4/3	February 1957	55	8	.98	.54	.73	34.0 4/3
		21	1.09	.70	.50	37.0 4/3			21	.86	.51	.83	32.5 5/4
		52	1.61	.99	.84	37.0 4/3			52	1.21	.66	.94	35.0 4/4
		71	1.20	.70	.61	37.0 4/3			71	.95	.52	.76	32.5 5/4
		79	1.16	.63	.51	37.0 4/3			79	.96	.50	.88	33.0 4/5
		94	1.26	.68	.65	37.0 4/3			94	1.18	.68	1.07	33.0 4/3
		Average	1.26	.74	.62	36.9			Average	1.02	.57	.97	33.3
August 1956	42	30	1.19	.74	.66	37.5 4/3	February 1957	42	30	1.20	.66	1.35	35.5 4/3
		41	1.03	.65	.55	36.5 4/4			41	1.00	.55	.88	31.5 4/5
		33	1.21	.75	.57	37.5 4/4			46	.88	.49	.85	31.0 5/5
		78	1.23	.75	.58	37.0 4/3			78	.92	.48	.84	32.0 4/5
		99	1.25	.71	.55	37.0 5/4			99	.88	.48	.74	33.0 5/4
		104	1.23	.78	.53	37.0 5/4			104	.97	.52	.89	31.0 5/4
		Average	1.19	.73	.57	37.1			Average	.97	.53	.92	32.3
August 1956	46	4	1.48	.85	.62	38.5 4/3	February 1957	46	4	1.03	.55	.92	32.5 5/4
		39	1.43	.84	.67	38.0 4/3			39	1.07	.59	.92	33.5 4/5
		51	1.49	.88	.68	38.0 4/3			51	.71	.36	.85	30.0 4/5
		85	1.14	.65	.49	37.5 4/4			85	.83	.45	.76	33.0 4/5
		103	1.54	.89	.51	38.0 4/3			103	1.00	.53	.98	32.0 4/5
		108	1.51	.90	.64	38.5 4/3			108	.84	.43	.95	32.0 5/4
		Average	1.43	.83	.60	38.1			Average	.91	.48	.90	32.1
August 1956	4	6	1.41	.85	.61	38.0 4/3	February 1957	4	6	.91	.52	.91	32.0 4/5
		40	1.47	.87	.62	38.0 4/3			40	.78	.38	.85	30.5 5/5
		52	1.32	.79	.61	37.5 4/3			52	.44	.21	.74	26.5 7/7
		88	1.54	.95	.71	38.0 4/4			88	.61	.29	.74	29.0 5/5
		97	1.30	.74	.58	38.0 4/3			97	.69	.38	.69	31.0 5/5
		117	1.37	.80	.63	38.0 4/3			117	.75	.38	.82	30.0 5/5
		Average	1.40	.83	.63	37.9			Average	.70	.36	.79	29.8

For the spectrographic analysis, duplicate 1 gram samples were re-dried at 100° C., ashed at 500° C., and mixed with a buffer that also contained the internal standards nickel, barium, and thallium. A 10 milligram portion of each duplicate sample was burned to completion in a 2 meter emission spectrograph, and its emission spectrum was recorded on a film. Each film contained exposures of 12 samples, as well as 3 synthetic standards, and 2 additional needle sample repeatedly used as referees. The concentrations of elements were computed from the densities of images recorded on the film at the following wavelengths: B-2496.8, P-2554.93, Mg-2781.4, Mn-4041.36, Ni-2992.6, Ca-3006.86, Fe-3059.1, Cu-3247.5, K-4047.2, Tl-3229.75, Ba-3071.59. The density of each line was read on a comparator-densitometer, corrected for variables in burning and for variations in film emulsion, and then converted to percent dry weight, or micrograms per gram dry weight.

For the determination of nitrogen, the improved Kjeldahl method was employed, as outlined in Section 2.24 of "Official Methods of Analysis" (A. O. A. C., 1955). Duplicate samples (1 gram) were analyzed.

Analytical results were subjected to analyses of variance. Possible correlations between pigment and element contents were explored graphically and further investigated by regression analyses when graphs indicated this procedure might have merit (Snedecor, 1956).

Table 4. — Test of each X after the effect of the other in the needle color regression has been removed

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
X_1 and X_2	2	474.31		
X_1 alone	*1*	*408.85*		
X_2 after X_1	1	65.46	65.46	69.6***
X_1 and X_2	2	474.31		
X_2 alone	*1*	*445.35*		
X_1 after X_2	1	28.96	28.96	30.8***
Error	69	65.18	.94	

Table 5. — Nutrient element content of current year's needles in geographic races of Scotch pine in August and February

Date	Race IUFRO No.	Tree No.	Concentration of Elements								
			Percent Dry Weight					Micrograms/Gram Dry Weight			
			N	P	K	Ca	Mg	Fe	Mn	Cu	B
August 1956	19	8	1.22	.060	.575	.30	.10	26.5	110	[1]	8.0
		43	1.40	.090	.79	.18	.115	33.0	185	7.0	10.0
		57	1.61	.075	.71	.22	.09	21.0	289	7.5	7.5
		61	1.49	.095	.80	.24	.095	38.0	232	[1]	9.0
		81	1.31	.105	.62	.19	.07	21.5	491	8.5	11.0
		117	1.38	.085	.74	.185	.035	28.0	500	8.75	13.0
		Average	1.40	.085	.706	.219	.084	28.0	301	7.94	9.8
August 1956	21	20	1.25	.100	.72	.205	.07	25.0	302	6.0	10.5
		23	1.26	.085	.74	.255	.075	15.0	165	6.5	7.5
		59	1.37	.065	.69	.185	.09	18.5	161	6.5 [2]	9.5
		64	1.37	.095	.71	.24	.12	24.0	125	7.25[2]	12.0
		85	1.39	.125	1.09	.13	.06	22.0	120	9.25	14.5
		102	1.55	.075	.695	.30	.10	21.0	93	6.25	10.0
		Average	1.37	.091	.774	.219	.086	20.9	161	7.00	10.7
August 1956	55	8	1.49	.090	.61	.30	.11	34.0	308	9.0	13.5
		21	1.39	.105	.65	.45	.145	24.0	365	10.5	17.5
		52	1.51	.125	.82	.315	.08	25.0	510	[1]	16.5
		71	1.28	.075	.70	.285	.115	22.0	153	7.25	12.5
		79	1.31	.105	.665	.27	.09	22.0	256	6.75	8.5
		94	1.39	.090	.785	.22	.07	24.0	131	[1]	9.5
		Average	1.40	.095	.705	.307	.102	25.2	287	8.38	13.0
August 1956	42	30	1.33	.095	.705	.20	.065	18.0	356	9.0 [2]	11.5
		41	1.28	.080	.63	.24	.095	21.0	308	10.5	7.0
		46	1.33	.995	.78	.245	.06	23.0	252	8.0	7.5
		78	1.39	.080	.70	.17	.045	27.0	490	8.25	12.0
		99	1.52	.100	.63	.235	.085	20.5	510	9.0 [2]	7.0
		104	1.44	.080	.64	.28	.075	28.0	402	8.75	12.5
		Average	1.38	.088	.681	.228	.071	22.9	386	8.88	9.6
August 1956	46	4	1.69	.095	.90	.265	.065	27.5	89	[1]	11.5
		39	1.74	.135	.77	.30	.105	24.0	129	9.5	17.0
		51	1.86	.125	.88	.445	.13	28.5	262	9.5	15.5
		85	1.59	.120	.715	.34	.08	20.5	720	7.75	17.5
		103	1.84	.105	.88	.26	.07	27.0	530	9.5	13.0
		108	1.60	.080	.69	.315	.085	28.0	470	[1]	14.5
		Average	1.72	.110	.806	.321	.089	25.9	367	9.06	14.8
August 1956	4	6	1.85	.095	.88	.22	.075	23.0	600	9.5	10.0
		40	1.60	.095	.78	.28	.07	28.5	690	9.5	9.0
		52	1.50	.110	.765	.30	.075	22.0	335	7.5 [2]	11.5
		88	1.64	.105	.63	.34	.08	25.0	179	8.25	10.0
		97	1.58	.070	.66	.335	.06	17.5	239	6.25	10.5
		117	1.73	.095	.815	.21	.09	21.0	149	[1]	14.0
		Average	1.65	0.95	.755	.281	.075	22.8	365	8.38	10.0
February 1957	19	8	1.65	.090	.63	.55	.12	36.0	179	6.5 [2]	11.0
		43	1.64	.110	.75	.23	.095	38.0	306	5.25	9.0
		57	1.76	.135	.68	.30	.075	35.5	530	6.75	9.5
		61	1.78	.135	.67	.365	.125	44.0	747	8.75[2]	13.0
		81	1.60	.105	.645	.36	.09	20.5	[3]	6.75	11.0
		117	1.87	.115	.81	.195	.045	34.5	[3]	7.0	16.5
		Average	1.72	.115	.698	.333	.092	34.7	627	6.44	11.7
February 1957	21	20	1.79	.105	.65	.345	.07	33.0	396	5.75	10.5
		23	1.73	.135	.665	.42	.07	25.5	310	7.25	7.5
		59	1.76	.085	.64	.27	.125	27.0	425	6.5 [2]	7.0
		64	1.75	.105	.68	.285	.145	42.5	231	4.5 [2]	10.5
		85	1.71	.135	.78	.26	.095	31.5	254	6.75	9.5
		102	1.83	.140	.64	.48	.08	34.5	192	5.0	15.0
		Average	1.76	.118	.676	.343	.098	32.3	301	6.19	10.0
February 1957	55	8	1.64	.110	.68	.335	.065	37.5	485	6.0	9.5
		21	1.58	.130	.74	.785	.145	40.5	680	6.5	14.0
		52	1.86	.130	.65	.72	.13	28.5	[3]	5.75[2]	16.5
		71	1.62	.110	.695	.455	.115	31.0	423	4.75	9.0
		79	1.73	.115	.605	.395	.110	27.0	419	5.5	10.5
		94	1.68	.095	.61	.35	.115	27.5	203	5.25[2]	8.5
		Average	1.69	.115	.663	.507	.113	32.0	535	5.69	11.3

Table 5. — (Continued)

Date	Race IUFRO No.	Tree No.	Concentration of Elements: Percent Dry Weight N	P	K	Ca	Mg	Micrograms/Gram Dry Weight Fe	Mn	Cu	B
February 1957	42	30	1.70	.140	.81	.27	.07	37.5	990	6.5 [2])	14.0
		41	1.32	.120	.61	.255	.07	25.5	450	5.75	10.0
		46	1.71	.105	.68	.375	.05	31.0	408	7.5	5.0
		78	1.69	.110	.555	.32	.04	31.5	980	7.25	9.5
		99	1.74	.110	.61	.345	.05	25.5	816	5.0 [2])	8.0
		104	1.59	.115	.61	.395	.08	46.5	920	5.0	11.5
		Average	1.63	.117	.646	.327	.060	32.9	761	6.38	9.7
February 1957	46	4	1.75	.095	.74	.335	.045	36.0	111	5.0 [2])	8.5
		39	1.76	.105	.61	.42	.13	19.0	249	3.75	17.0
		51	1.73	.105	.63	.66	.095	28.5	304	4.25	14.0
		85	1.85	.120	.57	.535	.075	22.0	[3])	6.0	13.5
		103	1.77	.100	.74	.395	.06	25.5	840	7.5	10.0
		108	1.80	.135	.65	.40	.065	23.5	[3])	6.25[2])	15.5
		Average	1.78	.110	.657	.458	.078	25.7	584	5.38	13.1
February 1957	4	6	1.67	.115	.69	.22	.045	15.0	750	8.5	13.5
		40	1.68	.120	.65	.37	.07	29.5	[3])	6.5	13.0
		52	1.66	.105	.69	.43	.055	25.0	485	8.5	11.5
		88	1.68	.110	.66	.425	.09	33.0	192	5.75[2])	13.0
		97	1.57	.110	.605	.52	.04	20.5	306	5.0	13.0
		117	1.71	.110	.64	.27	.055	17.5	191	5.75[2])	15.0
		Average	1.66	.112	.656	.373	.059	23.4	487	6.44	13.2

[1]) Missing copper values are due to contamination during grinding.
[2]) Values randomly eliminated from statistical analysis to restore orthogonality.
[3]) Missing manganese values were too high to read from calibration curve; probably are in vicinity of 1000 micrograms per gram.

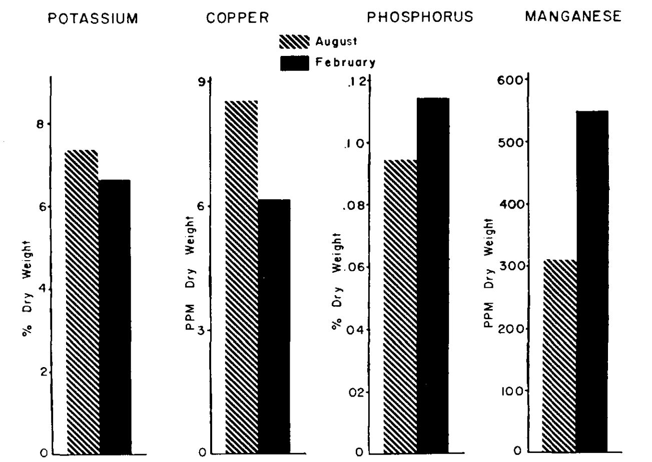

Fig. 5. — Concentration of potassium, copper, phosphorus, and manganese in Scotch pine needles in August and February, average values of six races.

Statistically significant differences in the concentrations of elements in the needles were found to exist among the various races, and between the two collection dates *(Tables 5 and 6)*. Numerous physiological inferences could be drawn from these seasonal and racial differences, but in this paper discussion will be restricted to possible effects of the elements on discoloration.

Potassium and copper were the only elements among the nine analyzed which were at a lower level in February than in August *(Figure 5)*. Magnesium contents differed among races *(Figure 6)*, but did not change significantly from August to February. Phosphorus showed an increase from August to February *(Figure 5)*. Concentrations of nitrogen, iron and calcium also increased from August to February, and these also differed among the races *(Figures 7, 8, and 9)*. In addition, there was an interaction effect of races and seasons on the content of nitrogen and iron, as there was little change from August to February

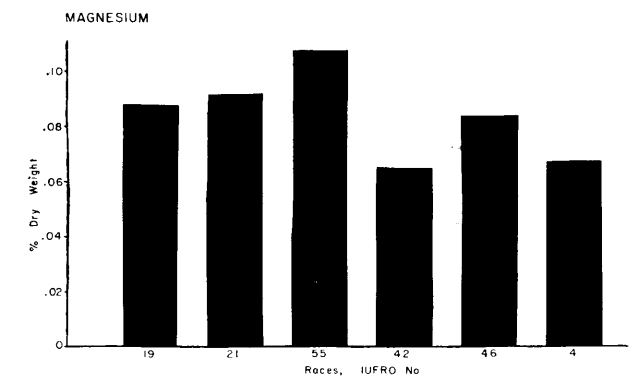

Fig. 6. — Concentration of magnesium in the needles of the six geographic races of Scotch pine, average values of August and February.

Table 6. — F values from variance analyses of color, pigments, and nutrient elements in the needles of six geographic races of Scotch pine in August and February.

Subject of Analysis	Source of Variation: Races	Seasons	R × S
Needle color	27.47***	916.79***	42.98***
Total chlorophyll	3.46*	173.29***	17.39***
Total carotenoids	.32	140.61***	1.93
Potassium	1.11	13.49**	1.19
Copper	.36	20.98***	.73
Phoshporus	.05	23.98***	1.30
Manganese	.06	4.55	.12
Magnesium	7.50**	.05	1.14
Nitrogen	9.35***	82.13***	6.62**
Iron	3.38*	22.83***	2.49
Calcium	4.87*	34.29***	.05
Boron	2.59	.05	.07
critical F values			
.05	3.11*	4.75*	3.11*
.01	5.06**	9.33**	5.06**
.001	8.89***	18.64***	8.89***

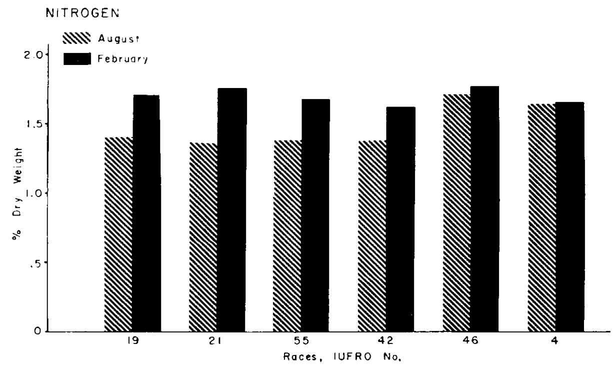

Fig. 7. — Concentration of nitrogen in the needles of the six geographic races of Scotch pine in August and February.

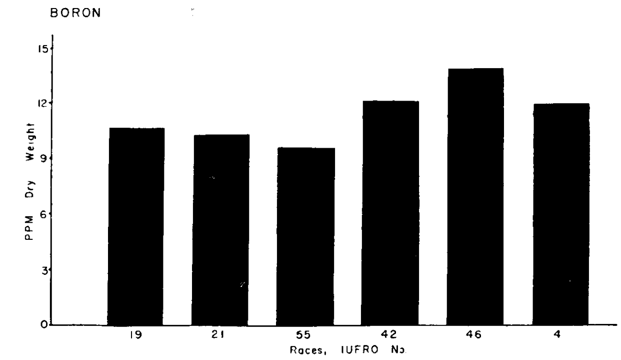

Fig. 10. — Concentration of boron in the needles of the six geographic races of Scotch pine, average of August and February values.

in the levels of these elements in the two northern races. Variations in the concentrations of manganese and boron were rather large, and consequently the illustrated differences (*Figures 5* and *10*) are somewhat below the 5 percent level of significance.

Graphical and statistical analyses revealed no relationships between nutrient elements, and either needle color, total chlorophyll, or the log of (total carotenoids ÷ total chlorophyll). None of the figures depicting element contents

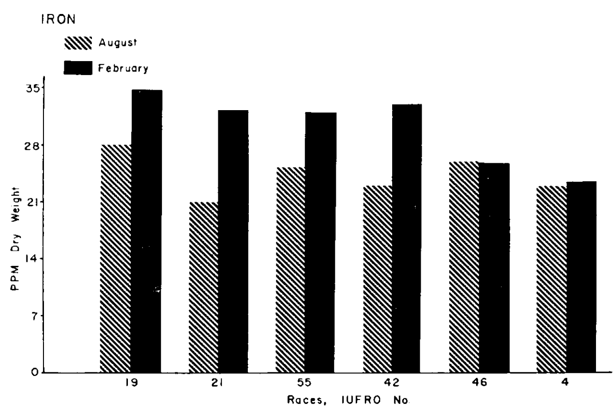

Fig. 8. — Concentration of iron in the needles of the six geographic races of Scotch pine in August and February.

resembles the pattern of discoloration. Potassium and copper were the only elements that decreased from August to February, and the decrease was of the same magnitude in all of the races, while the degree of discoloration differed considerably among the races. Comparison of elements and pigments in the needles of individual trees was also without apparent significance. There seemed to be

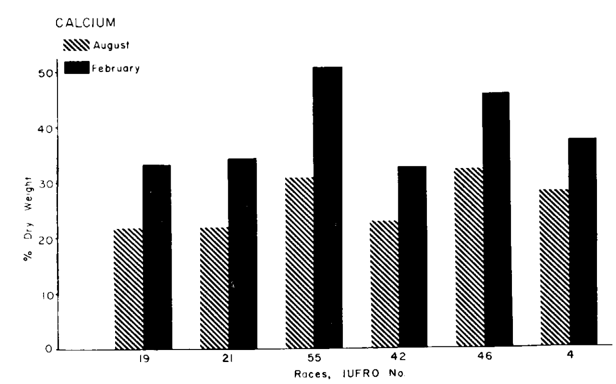

Fig. 9. — Concentration of calcium in the needles of the six geographic races of Scotch pine in August and February.

some association with color for several of the elements, but in no instance could a regression line with a significant slope be fitted to the data.

Fertilizer Trials

An attempt was made to improve the needle color of Scotch pine trees by the foliar application of liquid fertilizers in late October 1955, after discoloration was well underway. Three races were chosen to represent varying degress of discoloration: IUFRO numbers 19, 42, and 46. Ten fertilizers were dissolved in water and used at two levels each, one representing the concentration recommended by the manufacturer, and the other level was five times this concentration (*Table 7*). All of the fertilizers were readily soluble, and several of them were in a chelated form. A detergent which acted as a spreader was added to the solutions. Each fertilizer was applied by two methods: spraying trees until foliage was drenched, and submerging twigs for five minutes. Needle colors were evaluated using Munsell Color Charts (1952).

Table 7. — Fertilizers applied to Scotch pine foliage

Fertilizer	Elements Supplied	Recommended Concentration
		grams per gallon
"Rapidgro"	"Complete"	15.12
"Hyponex"	"Complete"	4.54
Epsom salts	Mg	30.28
"Nugreen"	N	22.68
"Nullapon" NaFe-13	Fe	2.27
Muriate of potash	K	30.28
"Sequestrene" Chel 330	Fe	2.27
"Sequestrene" Na_2 Zn	Zn	2.27
"Sequestrene" Na_2 Mn	Mn	2.27
"Versenol"	Fe	2.27

The foliar application of fertilizers had no visible effect on the color of Scotch pine needles in the following two weeks. Although these trials were by no means exhaustive, they do help to substantiate the results of the pigment and nutrient element analyses.

Discussion

Chloroplast pigment contents reported here can best be compared with those of LANGLET (1942), for he also investigated them in relation to geographic seed source. While the two sets of figures vary somewhat in magnitude, due to different races, site factors, and methods of analysis, both indicate that the trees of northern origin contain more chlorophyll in the summer and less in the winter than the more southern races. But the effects of latitude alone do

Table 8. — Elements in current year's needles of Scotch pine according to various sources. Minimum and maximum values are given on a dry weight base

Element	Present Investigation		LEYTON and ARMSON (1955) October	TAMM (1955) Winter	BYRNES (1956) December	VAN GOOR (1956) Autumn	
	August	February				healthy	chlorotic
N percent	1.22 — 1.86	1.32 — 1.87	1.00 — 1.76	1.42 — 2.03	1.34 — 1.96	1.44 — 1.81	1.30 — 1.79
P percent	.06 — .14	.09 — .14	.07 — .21	.12 — .27	.14 — .33	.38 — .49	.35 — .49
K percent	.58 — 1.09	.56 — .81	.64 — 1.46	.52 — 1.07	.32 — .58	.36 — .57	.22 — .44
Ca percent	.13 — .45	.20 — .78	.19 — .41	.16 — .68	.15 — .79	.22 — .48	.22 — .44
Mg percent	.04 — .15	.04 — .15			.08 — .30	.07 — .19	.10 — .17
Fe ppm.	15 — 38	15 — 46			15 — 117		
Mn ppm.	89 — 690	111 — 1000+			230 — 350		
Cu ppm.	6.0 — 10.5	3.8 — 8.8			2 — 7		
B ppm.	7 — 17	5 — 17			22 — 82		

not explain all of the variation in chlorophyll content encountered in this analysis. It appears that climatic changes which accompany changes in altitude and longitude may also affect the inherent needle color of geographic races, as suggested by ENGLER (1913). However, the data from these six races are insufficient to support any definite conclusions on this point.

The success of the regression of needle color on chloroplast pigments in accounting for the major portion (88 percent) of the variability in needle color merits further comment. It had been assumed previously that changes in chloroplast pigments were largely responsible for needle discoloration. This assumption, however, had been reached by reasoning, and without any real evidence of a direct link. The regression equation, in conjunction with results of pigment analyses, provides a basis for stating that a decrease in chlorophyll is primarily responsible for the discoloration of Scotch pine. It gives additional assurance for reasoning further that if any nutrient element is involved in discoloration, it must bear a relationship to the chloroplast pigments. More specifically, it must account for racial differences in the seasonal loss of chlorophyll, since the seasonal increase of carotenoids is the same for the six races investigated.

To see whether or not there was a possible connection between discoloration and the nine nutrient elements, three approaches were tried. First, the concentrations of nutrient elements in the needles were compared with other data available for Scotch pine to see if any element was near or below its critical level *(Table 8)*. Only phosphorus and magnesium might have been placed in this category, and both of these were higher in February, when discoloration was very great, than in August, when all the trees were green. Secondly, average values for pigments and elements illustrated in *Figures 2* to *10* were compared to see if any of them exhibited similar seasonal and racial changes. No similar trends of this nature were found. Finally, values for pigments and elements in individual trees were subjected to regression analyses in a search for possible correlations. Iron, magnesium, potassium, nitrogen, and phosphorus in particular were suspected, because they are essential for chlorophyll synthesis and photosynthesis (RABINOWITCH, 1945; 1956). Although in some cases higher or lower levels of elements were reflected in the concentration of chlorophyll, these trends were not of such a nature that they could account for any appreciable portion of the discoloration. In conclusion, no evidence was found to indicate that a deficiency of any of the nine elements is involved in the seasonal discoloration of Scotch pine, and the ranges of elements contained in the needles *(Table 8,* Present Investigation) can be regarded as falling within the normal variability in Scotch pine.

Failures to improve needle color by means of fertilizers, including those reported here, help to substantiate the above conclusion. These results do not conflict with those reports where the application of fertilizers to supplement deficient elements have noticeably improved the needle color of Scotch pine. In these instance the lack of chlorophyll is correctly termed "chlorosis". But the decrease of chlorophyll in Scotch pine needles during the dormant season is natural, not abnormal, and "seasonal discoloration" would be better terminology for this phenomenon. It has been demonstrated previously that the seasonal yellowing is the result of a genetically conditioned physiological response to microclimatic factors, a process which enables the trees to endure severe winters in the dormant state (GERHOLD, 1959).

Racial and seasonal effects on the elements in the needles of Scotch pine are great enough to warrant careful consideration when foliar diagnosis is used to evaluate the nutrient status of trees or soils. It is not unlikely that other species which also have a wide geographic distribution are affected in an similar manner.

Summary

Chloroplast pigments and nutrient elements in the needles of six geographic races of Scotch pine were analyzed and related to seasonal discoloration. Chlorophylls a and b and total carotenoids were determined by spectrophotometry. Nitrogen was determined chemically; phosphorus, potassium, calcium, magnesium, iron, manganese, copper, and boron were determined simultaneously by spectrographic analysis.

Discoloration is caused primarily by the loss of chlorophyll, and partly by an increase of carotenoids. A regression of needle color on chloroplast pigments accounted for 88 percent of the variability. In August the total chlorophyll in two Scandinavian races was higher than in races from Central Europe, but in February the opposite was true. Carotenoids were higher in February than in August in all the races, with no racial differences.

Many significant effects of races and seasons on levels of the nine elements in the needles were noted. These are large enough to warrant careful consideration in sampling for foliar diagnosis of Scotch pine. But no connection between pigments and elements could be established to account for any appreciable amount of the discoloration. Foliar applications of ten liquid fertilizers had no apparent effect on needle color. It is concluded that the seasonal discoloration of Scotch pine is not caused by a

deficiency of any of the nine elements analyzed in this investigation.

Résumé

Titre de l'article: *Variation saisonnière des pigments des chloroplastes et des éléments nutritifs dans les aiguilles de différentes races géographiques de pin sylvestre.*

Les pigments des chloroplastes et les éléments nutritifs contenus dans les aiguilles de 6 races géographiques de pin sylvestre ont été analysés en relation avec la décoloration saisonnière.

Les chlorophylles a et b et les caroténoïdes totaux ont été déterminés par spectrophotométrie. L'azote a été déterminé par analyses chimiques; le phosphore, le potassium, le calcium, le magnésium, le fer, le manganèse, le cuivre et le bore ont été déterminés en même temps par analyses spectrographiques.

La décoloration est dûe, surtout à la perte de chlorophylle et partiellement à l'augmentation des carotenoïdes. La relation entre la couleur des aiguilles et les pigments des chloroplastes rend compte de 88% de la variabilité. En août, la chlorophylle totale dans deux races Scandinaves est plus élevée que dans les races originaires d'Europe Centrale, mais en février, c'est le contraire. La teneur en caroténoïdes est plus élevée en février qu'en août pour toutes les races, sans aucune différence entre elles.

On a noté de nombreuses relations significatives entre, d'une part, les races et les saisons, et d'autre part, les teneurs des 9 éléments énumérés ci-dessus. Ces variations sont assez grandes pour qu'il soit nécessaire de les prendre en considération lorsqu'on prélève des échantillons de pin sylvestre en vue du diagnostic foliaire; mais aucune relation entre pigments et éléments nutritifs qui puisse influer de façon appréciable sur la décoloration n'a été mise en évidence. Des applications par les feuilles de 10 engrais liquides n'ont pas d'effet apparent sur la couleur des aiguilles.

En conclusion la décoloration saisonnière du pin sylvestre n'est pas dûe à une diminution d'un quelconque des 9 éléments analysés.

Zusammenfassung

Titel der Arbeit: *Jahreszeitliche Schwankungen der Blattfarbstoffe und der Nährstoffe in den Nadeln verschiedener geographischer Rassen der Pinus silvestris.*

In den Nadeln von sechs geographischen *Silvestris*-Rassen wurden Blattfarbstoffe und Nährsalze bestimmt und auf die jahreszeitlichen Nadelverfärbungen bezogen. Ebenso wie Chlorophyll a, Chlorophyll b und die gesamten Karotinoide wurden die Elemente P, Na, Ca, Mg, Fe, Mn, Cu und B auf spektrographischem Wege nachgewiesen. Stickstoff wurde chemisch analysiert.

Die Verfärbungen wurden hauptsächlich durch Abnahme des Chlorophylls und zum Teil durch Zunahme der Karotinoide verursacht. Eine Regression von Nadelfarbe und Blattfarbstoffen erklärt diese Zusammenhänge zu 88 Prozent. Im August war der Gesamtgehalt von Chlorophyll in zwei skandinavischen Herkünften höher als in den mitteleuropäischen Provenienzen. Im Februar traf das Gegenteil zu. Der Gehalt an Karotinoiden war ohne Unterschiede zwischen den Herkünften im Februar höher als im August.

Die genannten neun Elemente waren je nach Kiefernrasse und Jahreszeit verschieden stark in den Nadeln vertreten. Diese Effekte sind groß genug, um bei der Probenahme für Nadelanalysen an *Pinus silvestris* mit großer Sorgfalt vorzugehen. Zwischen den Blattfarbstoffen und den genannten Elementen fand sich kein Zusammenhang der eine merkliche Nadelverfärbung erklären könnte. Die Behandlung der Nadeln mit 10 Düngerlösungen blieb ohne Einfluß auf die Nadelfarbe. Daraus wird geschlossen, daß die jahreszeitliche Nadelverfärbung der Kiefer nicht auf Mangel an einem der neun analysierten Elemente zurückzuführen ist.

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Berichte

6. Tagung der Arbeitsgemeinschaft für Forstgenetik und Forstpflanzenzüchtung 1958

Die 6. Tagung und die Mitgliederversammlung der Arbeitsgemeinschaft fand vom 4. bis 6. August 1958 in Weinheim an der Bergstraße statt. Es nahmen etwa 40 Mitglieder und Gäste teil.

Zum neuen Vorsitzenden wählte die Mitgliederversammlung Professor Dr. E. ROHMEDER, München, nachdem der bisherige Vorsitzende, Oberlandforstmeister O. BAUMANN, sein Amt zur Verfügung gestellt hatte. Er wird in Zukunft der Arbeitsgemeinschaft als Ehrenvorsitzender angehören. Zweiter Vorsitzender wurde Dr. H. H. HEITMÜLLER, Geschäftsführer Forstassessor R. DIMPFLMEIER, Kassenwart bleibt Dr. P. SCHÜTT.

Im Mittelpunkt der Diskussionen stand ein von Dr. HEITMÜLLER vorgelegter Entwurf für Richtlinien zur Anerkennung von Samenplantagen und ein Referat von G. SCHELL über die Organisation der Nachkommenschaftsprüfung von Plantagenklonen. Zwei der gehaltenen Vorträge erschienen inzwischen als Originalarbeiten in dieser Zeitschrift: E. ROHMEDER, *Über das Mikroklima in Bestäubungsschutzbeuteln*, Silvae Genet. 8, 1—13; und H. J. FRÖHLICH, *Grundlagen der autovegetativen Vermehrung*, Silvae Genet. 8, 49—58. Weitere Vorträge sind, soweit sie inzwischen bei der Schriftleitung eingegangen sind, als Autorreferate diesem Bericht angefügt.

Das Tagungsprogramm wurde durch Exkursionen in den Weinheimer Exotenwald und zur Zweigstelle Wächtersbach des Bundesinstitutes für Forstgenetik und Forstpflanzenzüchtung ergänzt.

Die nächste Tagung soll 1960 in München stattfinden.

STERN

J. GREHN, Wetzlar: *Neue mikroskopische Methoden in Genetik und Züchtung* (Übersichtsbericht).

In der Cytogenetik gewinnen moderne mikroskopische Verfahren, deren Entwicklung vorwiegend in der Nachkriegszeit liegt und die quantitative physikalische und chemische Methoden in den Mikrobereich übertragen, zunehmend an Bedeutung. Über die routinemäßige Anwendung des Phasenkontrast-Verfahrens hinaus ist genetisch vor allem die *Interferenz-Mikroskopie* von Wert, da sie hohe quantitativ erfaßbare Empfindlichkeit für die Änderung des Brechungsquotienten besitzt und bei Berücksichtigung der geringen Schwankung des Brechungsinkrements (BARER) Bestimmungen der Trockenmasse kleinster Volumina (bis zur Größenordnung etwa 10^{-14}g) zuläßt. Die mit der Änderung von Wassergehalt und Trockenmasse zusammenhängenden Erscheinungen im Ablauf der Mitose und Meiose wurden kurz besprochen. — Die *Absorptionsphotometrie*, für den Bereich der UV-Strahlung insbesondere von CASPERSSON entwickelt und im Anschluß daran unter Berücksichtigung kritischer Überlegungen auf quantitative Farbreaktionen auch im Bereich des sichtbaren Spektrums übertragen, gibt insbesondere über die cytologisch wichtige Verteilung von Nucleinsäuren und Proteinen weiterführende Informationen. Sie wird sich darüber hinaus vor allem für Untersuchungen über