GEOGRAPHIC AND SEASONAL VARIATION IN THE MOISTURE CONTENT OF SCOTCH PINE FOLIAGE

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Early results from the rangewide provenance tests of Scotch pine *(Pinus sylvestris* L.) established in the North Central States in 1961 and 1962 under the NC-51 Project [1] have been of great interest and benefit to the Christmas tree industry. These have been reported in a regional summary by Wright, *et al.* (1966) and in numerous subsequent reports by members of the North Central Regional Forest Tree Improvement Committee. Trees of Spanish and other south European seed origins retain green foliage through the winter, have dense compact crowns, and are intermediate in rate of growth have been found most suitable for planting for Christmas trees in all but the northern portion of regions where they are not winter hardy (Jokela, Culver, and Stewart, 1966; Wright, 1968; and Read, 1973). Data presented herein suggest that trees of southern seed sources are to be favored also for the high moisture content of their foliage.

This study was suggested by observations of the moisture contents of foliage of live trees made for studies relating to the freshness of cut Christmas trees. Live trees were sampled in a planting of non-yellowing commercial strains on heavy silt loam near Urbana in central Illinois and a NC-51 provenance test on light sandy loam in Sinnissippi Forest in northern Illinois in December, 1968, and monthly during the fall of 1969. The considerably lower means of the northern Illinois samples might quite plausibly have been attributed to a colder climate and drier site if the seed origins of the trees in the samples were not known. Examination of the data showed that the means were depressed by the inclusion of trees of north European seed origin in the samples, and that the foliage moisture contents of trees of south European origin were comparable to those of the non-yellowing trees (hence of south European seed origin) in the central Illinois planting. This suggested that moisture content was under strong genetic control and that differences among seed sources were sufficiently large to be of practical importance.

Materials and Methods

Seasonal variation in foliage moisture contents of several varieties representative of the natural range of Scotch pine was studied in the NC-51 provenance test at Sinnissippi Forest from August, 1970, through December, 1971. A broader study of variation among geographic seed sources was based on foliage samples obtained on March 11, 1971, in the NC-51 provenance test on the Sand Ridge State Forest in west-central Illinois. Both plantings are on light sandy loam and were established in 1961 with 2-0 stock furnished by Michigan State University. Initially, varietal designations proposed by Ruby (1964) were employed; however, the data were regrouped to conform with a slightly modified version recommended by Professor J. W. Wright.

Field Collections.—Moisture contents of the foliage of five varieties of Scotch pine were sampled monthly during the fall of 1970 at Sinnissippi Forest to obtain information on the effect of cutting date on the freshness of Christmas trees. Foliage samples were taken on or as near to the fifteenth of each month as weather conditions permitted, from the same 10 trees of each variety. Sufficient amounts of the current year's (1970) foliage to fill a 4-ounce bottle (15-20 gm.) were taken from the unshaded crown (excluding the 1970 branch whorl and leader which often was beyond reach) of each tree. In addition, similar samples of the previous year's (1969) foliage were taken from the 10 trees representing var. *iberica* (for varietal designations by geographic origin, see Table 1). The sample bottles were closed immediately with air-tight lids and stored at 2 C[1] until weighed and dried. The sampling was enlarged to include four additional varieties in January, 1971, and continued through 1971. Sampling of 1971 foliage was begun in June.

The foliage of all healthy, surviving trees on four replicates of the 106-origin provenance test in the Sand Ridge State Forest was sampled on March 11, 1971. Only 1970 foliage on the unshaded upper half of the crown, excluding the 1970 branch whorl and leader, was sampled. Enough foliage was collected from all trees of a given provenance surviving in replicates 7 and 9 to fill a one-quart bottle (100-180 gm.). Whenever possible, one-half of this quantity was obtained from each 4-tree plot. A similar sample of each provenance was obtained in replicates 8 and 10. The bottles were closed with air-tight lids and stored in a cool room until they were weighed and dried.

[1]North Central Regional Project "Forest Tree Improvement Through Selection and Breeding" (presently NC-99) supported in part by regional research funds from the U.S. Department of Agriculture.

Table 1. Mean Moisture Content and Length of One-year-old Foliage of Scotch Pine Varieties in Sand Ridge State Forest (UIFGP-61-3) Mason County, Illinois on March 11, 1971

Variety[1]	*Geographic area*	*Provenances* (No.)	*Moisture Content* Mean	Std. dev. (percent)	*Needle Length* Mean	Std. dev. (mm.)
Lapponica	Finland, Sweden, Siberia	5	128.3	1.6	48.2	4.0
Sepentrionalis	Finland, Sweden, Norway	15	135.0	5.2	54.8	3.9
Rigensis	Latvia, Sweden	5	138.2	5.3	62.9	5.4
Uralensis	Ural Mountains	4	131.4	3.9	64.0	3.7
Scotia	Scotland	4	142.2	4.1	56.2	3.2
Jakutensis	Siberia	3	133.6	5.6	63.2	5.9
Krasnoyarsk	Siberia	1	139.0	-	63.0	-
Polonica	Poland	2	136.0	2.2	74.0	2.0
Hercynica	Czechoslovakia, Germany	20	144.3	4.3	69.8	4.4
'East Anglia'	England	2	150.9	3.7	66.0	10.0
Carpatica	Czechoslovakia	3	143.8	6.5	72.0	4.8
Haguenensis	Belgium, France, Germany	10	148.0	3.4	78.9	4.8
Pannonica	Hungary	2	148.7	3.6	77.8	11.5
'North Italy'	Italy	4	143.2	4.0	60.4	9.5
Aquitana	Central France	5	152.6	6.7	54.5	4.2
Illyrica	Yugoslavia	1	146.6	-	63.0	-
'French Pyrenees'	South France	1	162.4	-	53.5	-
Iberica	Spain	5	164.3	6.2	57.6	2.6
Armena	Turkey, Georgia S.S.R.	8	145.0	6.5	62.8	4.8
Rhodopaea	Greece	5	145.3	9.4	61.0	3.6
'Boonville'	Commercial Variety	1	154.9	-	65.0	-

[1]Varietal groupings according to J. W. Wright, 1973.

Determination of Moisture Content.—Sample bottles were allowed to warm to room temperature before the lids were removed. The bottles and their contents were weighed to the nearest .01 gm. immediately after the lids were removed and again upon cooling to room temperature after being taken out of the drying oven. All samples were dried at 102 C. for 24 hours in the case of the small samples from Sinnissippi Forest and 48 hours in the case of the larger samples from Sand Ridge State Forest. Moisture content was measured as the weight lost upon drying and was expressed as a percentage of the oven-dry weight of the foliage.

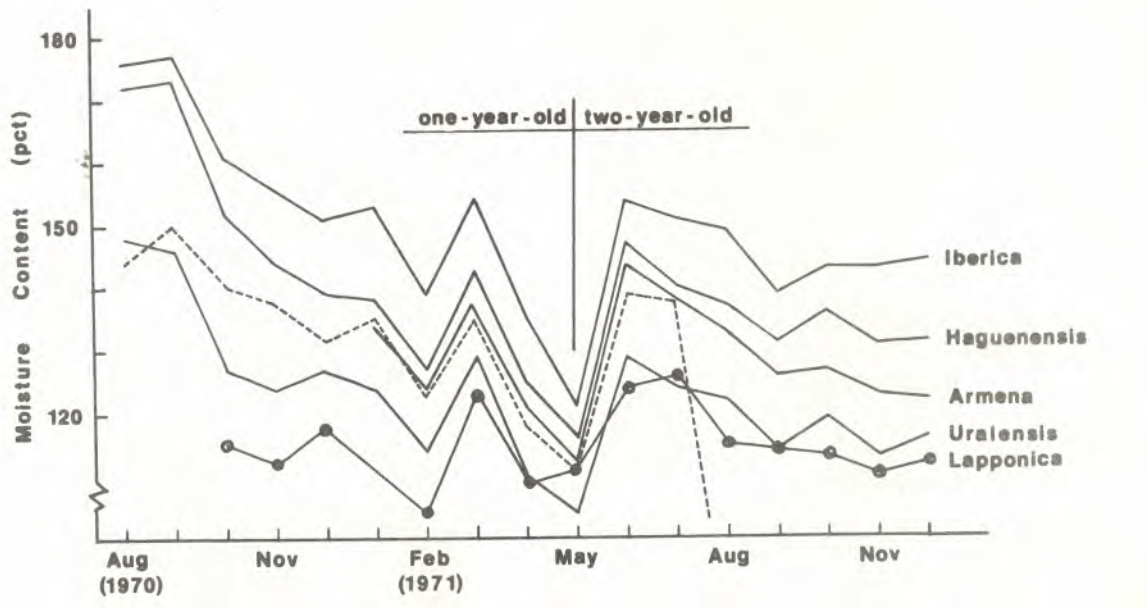

Fig. 1. Seasonal variation in moisture contents of 1970 foliage of varieties of Scotch pine at Sinnissippi Forest. (Plotted values are means of midmonthly samples of 10 trees.) The broken line connects monthly means of 1969 foliage during its second and third year of life.

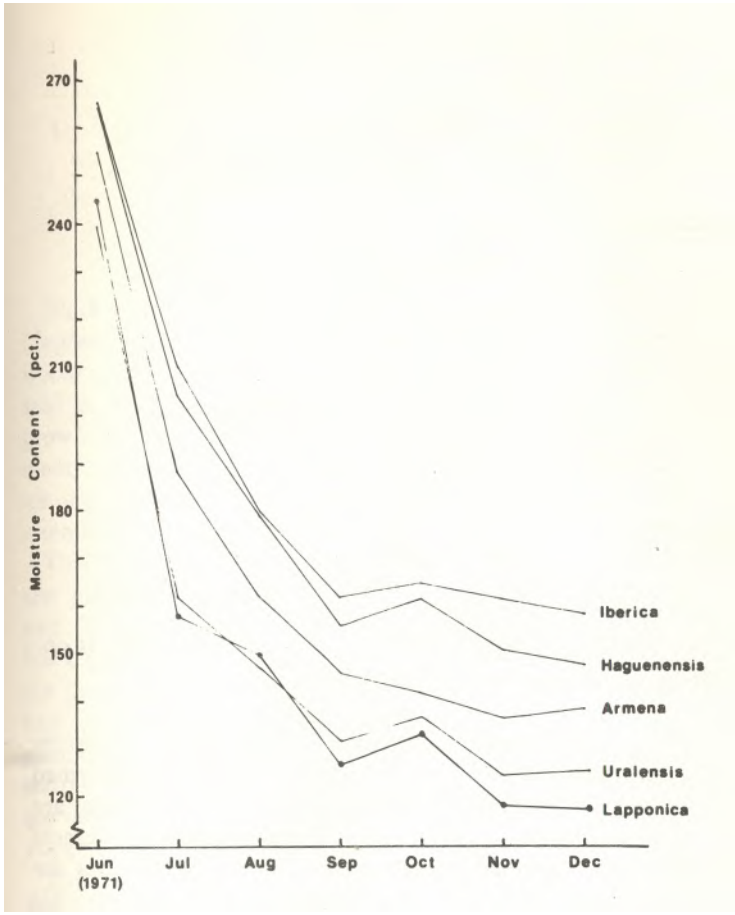

Fig. 2. Variation in moisture contents of one-year-old foliage of varieties of Scotch pine at Sinnissippi Forest. (Plotted values are means of midmonthly samples of 10 trees.)

Results and Discussion

Large and consistent differences were found among the mean moisture contents of the foliage of the nine varieties of Scotch pine which were sampled monthly at Sinnissippi Forest. These differences became apparent soon after the foliage was formed and persisted beyond the second growing season. Whether or not they persisted into the third and final year of foliage life was not determined. Monthly means of five varieties representing most of the range of Scotch pine are plotted in Fig. 1 and 2. The major fluctuations in moisture content are believed to reflect varying balances between water uptake by the roots and transpiration loss through the foliage. The strikingly similar patterns of fluctuations exhibited by the five varieties suggest that the varieties responded similarly to varying environmental conditions. The low moisture contents observed in May correspond to similar lows recorded in April in 1971 and 1972 in the planting of commercial strains of Scotch pine at Urbana where the growing season begins two to three weeks earlier.

The moisture contents of one-year-old foliage averaged 15 to 20 percentage points greater than that of two-year-old foliage during the fall months when Christmas trees are harvested. Three-year-old foliage which began to shed after the growing season was practically nonexistent during this period.

The mean moisture contents of the 20 varieties and one commercial strain of Scotch pine, which were sampled in the Sand Ridge State Forest on March 11, 1971, are given in Table 1. Mean needle lengths are also given for comparative purposes. These were computed from the measured lengths of the longest needle of 20 needle fasicles selected at random from each one-quart foliage sample (40 needles per provenance).

Differences among varieties are highly significant (.01 level of probability) for both traits. Differences among provenances within varieties are scarcely significant (.05 level of probability) in the case of moisture content and highly significant in the case of needle length. Replicate differences are nonsignificant in the case of moisture content and highly significant in the case of needle length.

Separate analyses of die data for the 17 varieties represented by two or more provenances were made. Provenance differences were significant only in var. *haguenensis* with respect to moisture content and in var. *haguenensis* and *hercynica* with respect to needle length. Replicate differences were significant only for needle length in the case of var. *haguenensis, hercynica* and *uralensis.* The standard deviations of varietal means computed from these analyses are generally substantially less than 6.5 (max. observed) percent of the mean in the case of moisture content, and varied from 2.7 to 15.7 percent of the mean in the case of needle length.

The dry-matter content of the needles of Scotch pine nursery stock of varying provenance was studied during the dormant season in the vicinity of Stockholm by Langlet (1936, 1959). He concluded that dry-matter content and numerous factors related to it, e.g., resistance to frost and disease, sugar content, and rate of growth varied continuously with latitude and altitude of seed origin in the same degree as determinative environmental factors vary continuously. A positive correlation between Langlet's dry-matter determinations and resistance to injury by *Scleroderris lagerbergii* Gremmen after 27 years was found by Dietrichson (1968). Trees of Spanish seed origin which have suffered the most winter injury in test plantings in North Centra United States are shown here to have the highest foliage moisture content.

The results of this study extend Langlet's finding throughout the year in North Central United- States. Th gradual and consistent decrease of varietal means fror Spain (164 percent) to Lapland (128 percent) shown i Fig. 3 is indicative of a strong latitudinal cline. Chang(in moisture content from Asia Minor to Central Euroi are less definitive. From an examination of provenance means in relation to altitude and longitude of se(origin, it appeared that longitude would explain as mu variation as those related to altitude. Conceivably t variation in moisture content could be depicted qu adequately by slightly curved isograms drawn frc northwest to southeast.

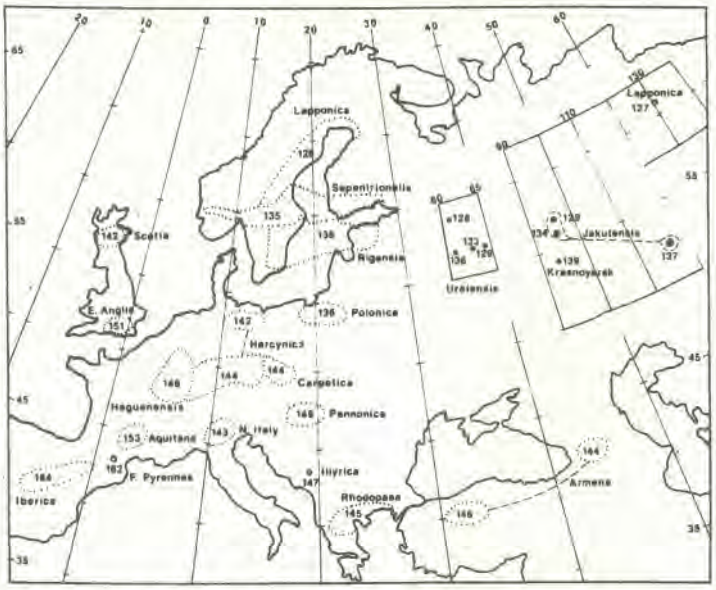

Fig. 3. Mean moisture contents of 1970 foliage of varieties of Scotch pine sampled in the Sand Ridge State Forest on March 11, 1971. Dotted lines enclose seed collection areas. Means of Siberian provenances are set in insets.

The results of this study might also be cited as evidence in support of the "varietal" concept of variation (Wright and Baldwin, 1957). However, this could be countered by the argument that the outcome could not be otherwise even though variation were clinal because of discontinuities in the data. These discontinuities would be inherent in all data obtained in NC-51 provenance tests of Scotch pine because of the discrete nature of the original seed collections. This is evident from the seed collection areas diagrammed in Fig. 3.

Maintaining the freshness of cut Christmas trees is of great concern to an industry competing with plastic trees in the face of increasing regulations aimed at promoting public fire safety. A measure of the problem is provided by a 1968 survey which showed that one-fourth of the trees offered for sale in central Illinois that year had foliage moisture content below 90 percent (Jokela and Yocom, 1971). Canadian studies, confirmed by the author, showed that if Scotch pine trees are allowed to dry to moisture contents below 85 percent they will continue to dry even though their butts are immersed in water. Accordingly, an unacceptable number of trees offered for sale would have become highly inflammable in about one week, even though properly displayed in water. Early cutting, "when the sap is still up," does not assure freshness. Moisture content decreases in living trees during the fall months observed at Sinnissippi Forest and Urbana are greatly surpassed by measured losses from cut trees under ordinary storage. The higher moisture contents of trees of Spanish origin may provide up to several additional weeks of storage time.

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