Photosynthesis, Respiration and Growth of Forest Tree Seedlings in Relation to Seed Source and Environment

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Problems of selecting the proper tree species and variants within species for a specific planting site in Iowa are acute because of the diversities of micro-climate, soil and topography and the frequent use of introduced species (Kepler and Gatherum 1964). Current guides for selecting tree species to plant for timber, wind barriers, erosion control and wildlife cover are based on limited studies and observations (Iowa State College 1957). To improve planting recommendations, more accurate information is needed on the adaptability to specific sites of species and variants within species. This information should be provided by (1) field species and provenance studies designed to determine the kind and magnitude of variation between and within the species planted on specific sites and by (2) fundamental studies designed (a) to determine the effects of species and their variants and direct environmental factors on tree physiological processes underlying survival and growth and (b) to determine the relationships between survival and growth/ and these physiological processes, as affected by genetic and environmental factors.

Iowa has established field provenance studies independently and in cooperation with members of the NC-51 Regional Forest Genetics group. Planting sites are located on Fayette silt loams in northeast Iowa and Weller-Lindley soil complexes in southeast Iowa. Iowa also is conducting controlled environmental studies in which photosynthesis, respiration and growth of forest tree seedlings are determined in relation to seed source or clone and selected environmental factors (Table 1).

The primary objectives of the controlled environmental studies are to (1) permit further identification and evaluation of within-species variation of physiological processes of forest tree seedlings (2) provide a clearer understanding of the causes of variation in tree vigor and quality and (3) permit an investigation of the possibilities of early selection of seed sources for planting on specific sites in Iowa. Examples of field provenance and controlled environmental studies conducted at Iowa State University are presented below.

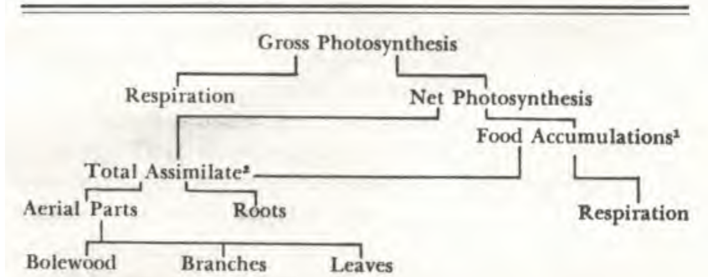
Japanese Larch Provenance Trial in Northeast Iowa
(Kepler and Gatherum 1964)

An investigation of survival and growth of seven provenances of Japanese larch (*Larix leptolepis* [Sieb. and Zucc.] Gord.) was established in Allamakee County, Iowa. Four 2-0 seedlings of each of seven seed origins from Japan were planted in April 1960 at an 8 x 8-foot spacing in each of ten replications. An evaluation of 3-year-old seedling data has shown high survival of all provenances and good growth of provenances Schm.-l6, Gumma prefecture; and Schm.-12, Nagano prefecture (Table 2). Average height growth was correlated positively with attitudinal origin of seed source (Figure 1). A similar relationship was observed in diameter growth, r = 0.88**. It is suggested that the positive correlations may be related to the introduction of these sources from 36° N latitude in Japan to 43° N latitude in Iowa.

Scotch Pine Provenance Trial in Southeast Iowa
(Gatherum and Jensen 1964)

An investigation of survival, growth and development of eight provenances of Scotch pine (*Pinus sylvestris* L.) was established in southeast Iowa. Approximately

Table 1. Flow diagram representing the distribution of assimilate to be determined for each species and its variants in relation to controlled environmental factors



[1] Primarily CHO used in growth and respiration during periods when little or no photosynthesis is occurring.
[2] Assimilation—integral part of growth in which food is converted into new protoplasm and cell walls by existing protoplasm.

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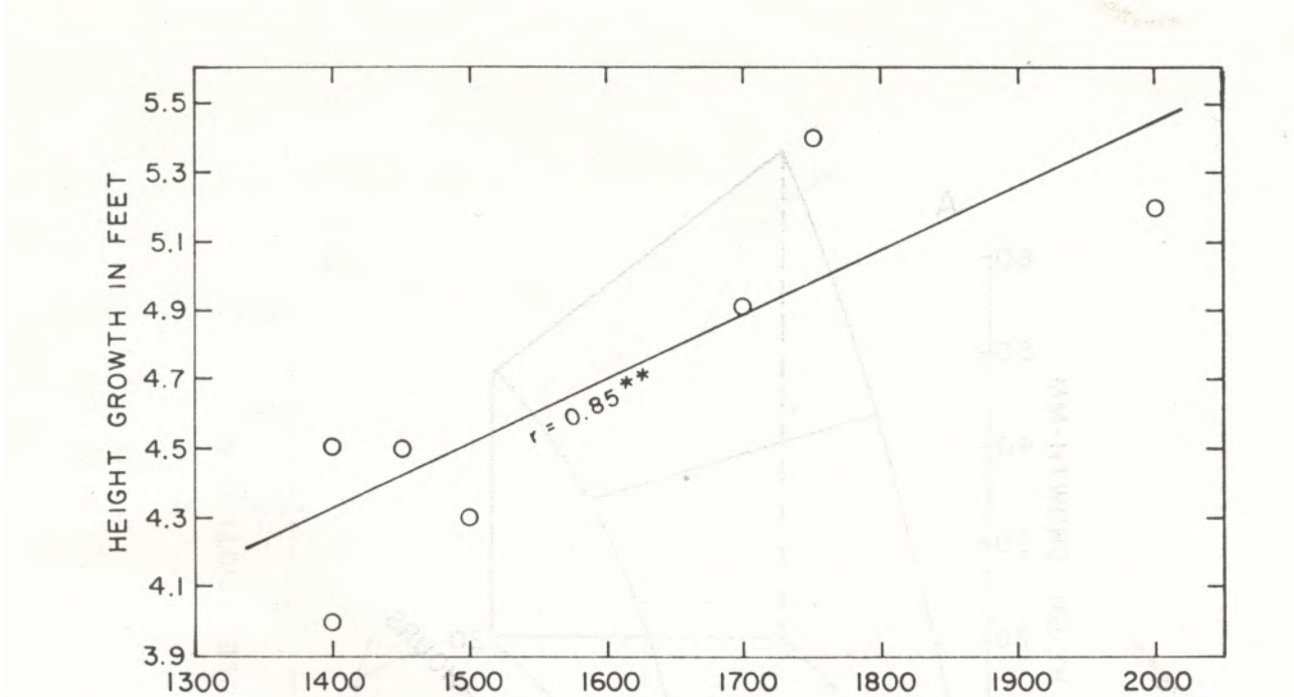


ALTITUDE IN METERS

Figure 1. Correlation of average 3-year height growth of Japanese larch seedlings with attitudinal origin of seed source

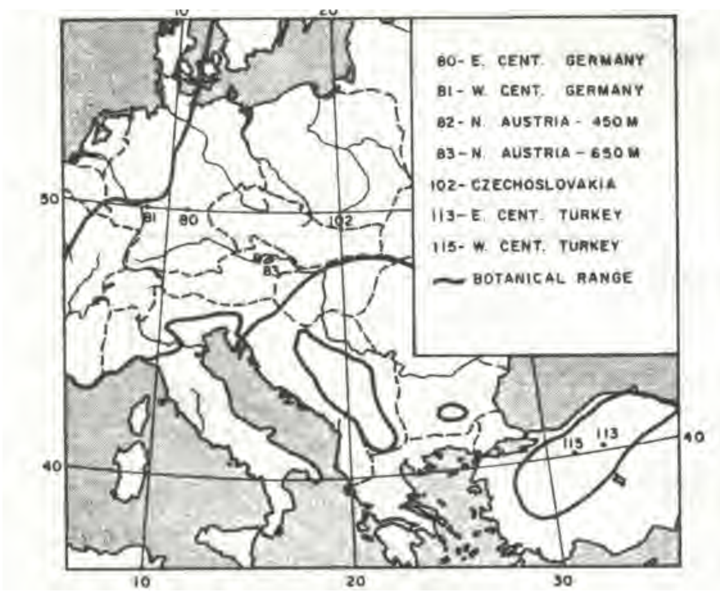


Figure 2. Origin of Scotch pine seed sources used in study

Table 2. Average 3-year provenance survival in percent, height growth in feet and diameter growth in inches

Provenance number[1] Schm.—	Prefecture	Altitude (meters)	Survival	Average height growth[2]	Average diameter growth[2]
16	Gumma	1700–1800	94	5.4	1.0
12	Nagano	2000	94	5.2	1.0
15	Tochigi	1700	95	4.9	0.9
			5%	1%	5%
9	Nagano	1450	94	4.5	0.9
24	Nagano	1400	91	4.5	0.8
4	Nagano	1500	90	4.3	0.7
22	Nagano	1400	86	4.0	0.7

1 Numbers given are Schmalenbeck, Germany numbers, by which the material will be known in other NC-51 publications as well as publications by German workers.

Means grouped by a line do not differ at the designated probability level (Duncan 1955).

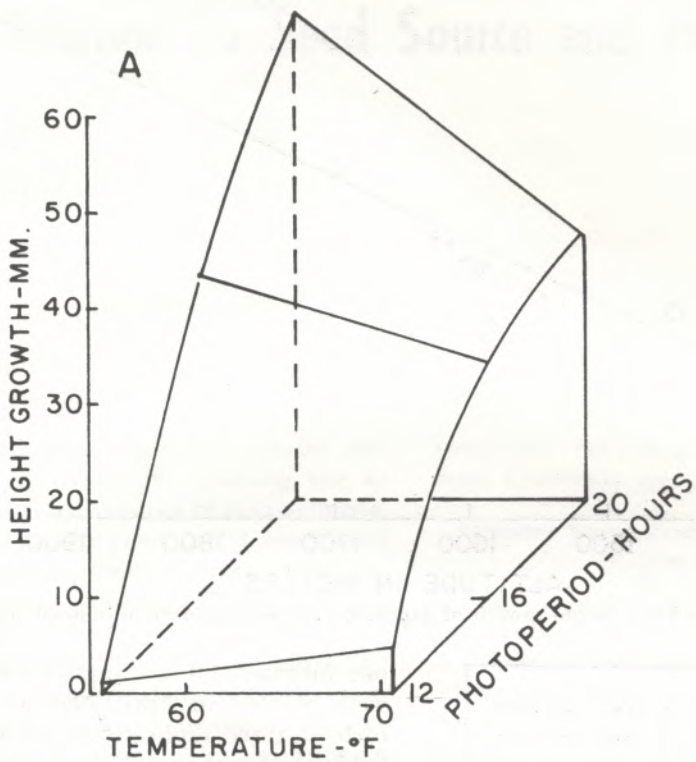
one hundred 2-0 seedlings of each of eight seed origins were planted in April 1958 at a 6 x 7-foot spacing in each of three replications. An evaluation of 5-year-old field data has shown (1) high survival of all provenances, (2) good height growth of the central European seed sources, 47° to 50° N latitude, and (3) highest quality Christmas trees, with green fall-winter foliage, flaring-taper shape and dense, compact foliage, from the Spanish source on Weller silt loam, Lindley loam and Colo-Gravity-Olmitz complex (Table 3). Because of the preponderance of crooked stems from the central European sources (McComb[1], Wood 1949 and Wright and Baldwin 1957), they should not be selected for timber trees. Moreover, freezing injury to the Spanish source at the Ames nursery prior to outplanting in southeast Iowa and the low first-year survival in northeast Iowa (Jensen and Gatherum 1964b) must be considered further before this source can be confidently recommended for Christmas tree production.

Table 3. Average 5-year provenance survival in percent and height growth in feet

Provenance and Iowa State number		Survival[1]		Height growth[1]	
W. central Germany (81)		89		6.0	
E. central Germany (80)		90		5.7	
Northern Austria (83)		85		5.2	
	5%		1%		5%
Northeast Austria (76)		82		5.1	
Czechoslovakia (102)		81		5.1	
N. central Germany (78)		83		4.9	
Central Spain (75)		87		3.8	
Southern Finland (77)		81		3.7	

1 Means grouped by a line do not differ at the designated probability level (Duncan 1955).

1 McComb, A. L., Ames, Iowa. 1963. Data from species adaptation studies. Private communication.



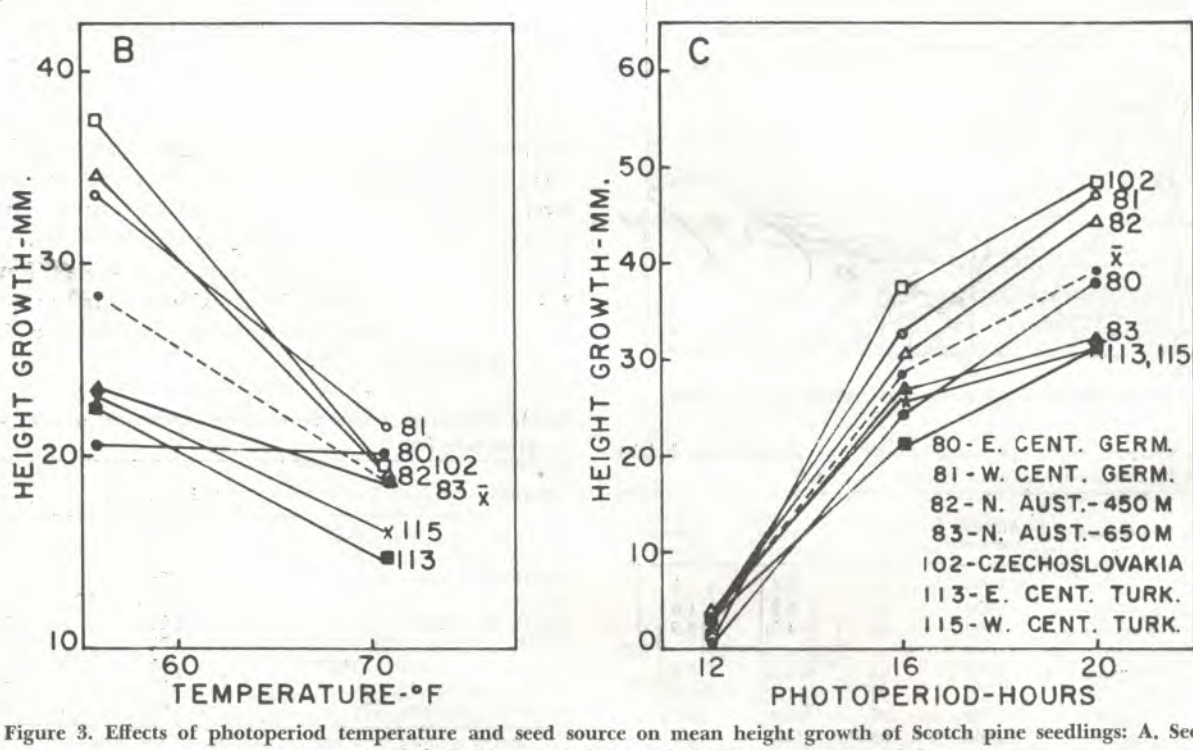


Figure 3. Effects of photoperiod temperature and seed source on mean height growth of Scotch pine seedlings: A. Seed sources pooled; B. Photoperiods pooled; C. Temperatures pooled

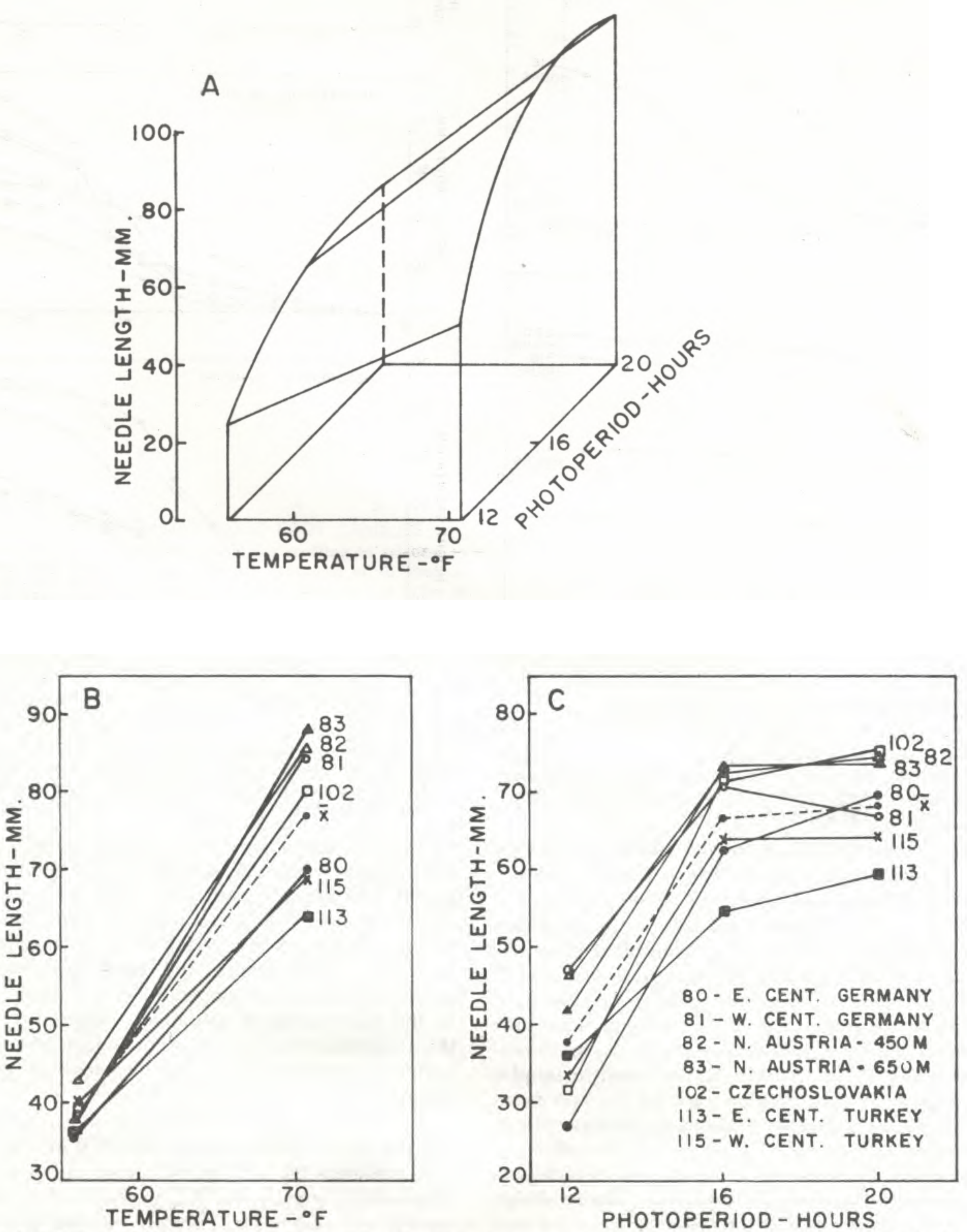


Figure 4. Effects of photoperiod, temperature and seed source on mean needle length of Scotch pine seedlings: A. Seed sources pooled; B. Photoperiods pooled; C. Temperatures pooled

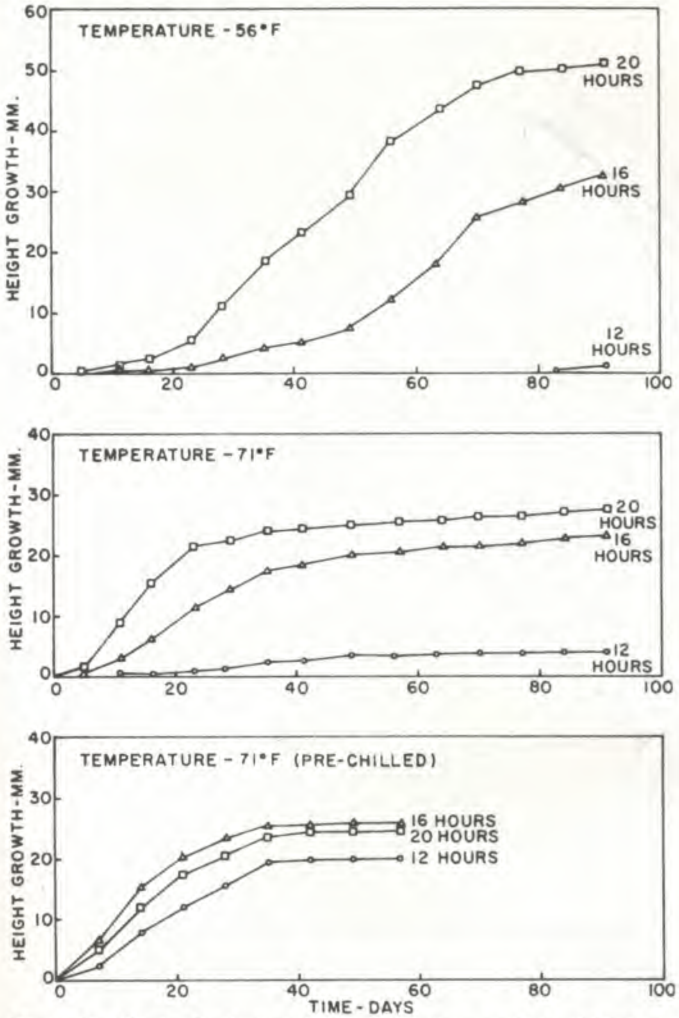


Figure 5. Effects of photoperiod, temperature and pre-chilling on height growth patterns of Scotch pine seedlings, seed sources pooled. Time was measured from the date that height growth was first noted in the study.

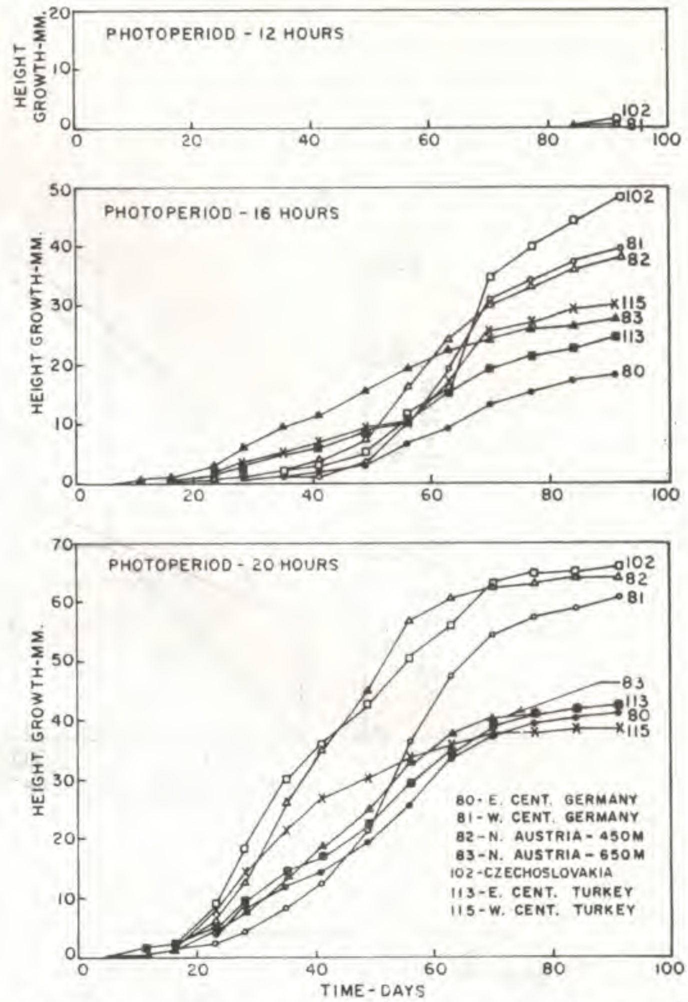


Figure 6. Effects of photoperiod and seed source on height growth patterns of Scotch pine seedlings at the cooler temperature. Time was measured from the date that height growth was first noted in the study.

Effects of Temperature, Photoperiod and Provenance on Growth and Development of Scotch Pine Seedlings (Jensen and Gatherum 1964a)

Growth and development of Scotch pine seedlings were determined in relation to (1) controlled photoperiods of 12, 16 and 20 hours, (2) temperatures of 56 7°F and 71 ± 5°F and (3) seven seed sources, ranging from central Turkey to central Germany (Figure 2). The study was established as a split-plot experiment in a randomized block design within unreplicated main-plot temperature treatments. Within each of the two mean daily temperatures, three replications of the three photoperiods were established. To determine the effect of pre-chilling on the height growth pattern of Scotch pine seedlings, a supplementary investigation of similar design was established, but without the colder temperature and the two seed sources from Turkey.

Height growth, needle length and total green weight increased and bud burst occurred earlier with increased photoperiod. Height growth was less, needle length greater and bud burst earlier at the higher temperature. In general, height growth and needle length increased with increased latitudinal origin of seed sources. Height growth and needle length were influenced markedly by the photoperiod, temperature and seed source interactions (Figures 3 and 4). The lower height growth, increased needle length and unchanged total green weight with increased temperature may indicate a change in the distribution of assimilate. Apparently, more of the total assimilate was used in height growth at the lower temperature and in needle length at the higher temperature.

Seedling height growth initiation occurred earlier, and the rate of growth was greater with increased photoperiod (Figure 5). Differences among photoperiods were considerably greater at the lower temperature. Conversely, no differences occurred among photoperiods when seedlings were pre-chilled. The pre-chilling treatment apparently offset the shorter photoperiod effect. Height growth patterns varied among seed sources (Figure 6). Growth rates of the Czechoslovakia, northern Austria-450m and west central Genrmany seed sources

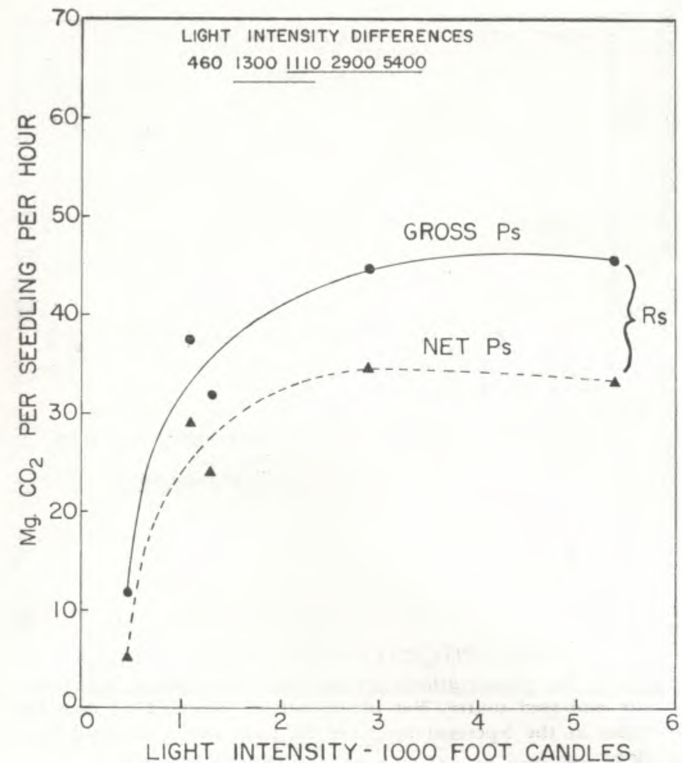


Figure 7. Gross and net photosynthesis per seedling in relation to light intensity. Each point represents the mean of 16 observations. Gross and net photosynthesis per seedling do not differ at the 1-percent level for light intensities grouped by a line.

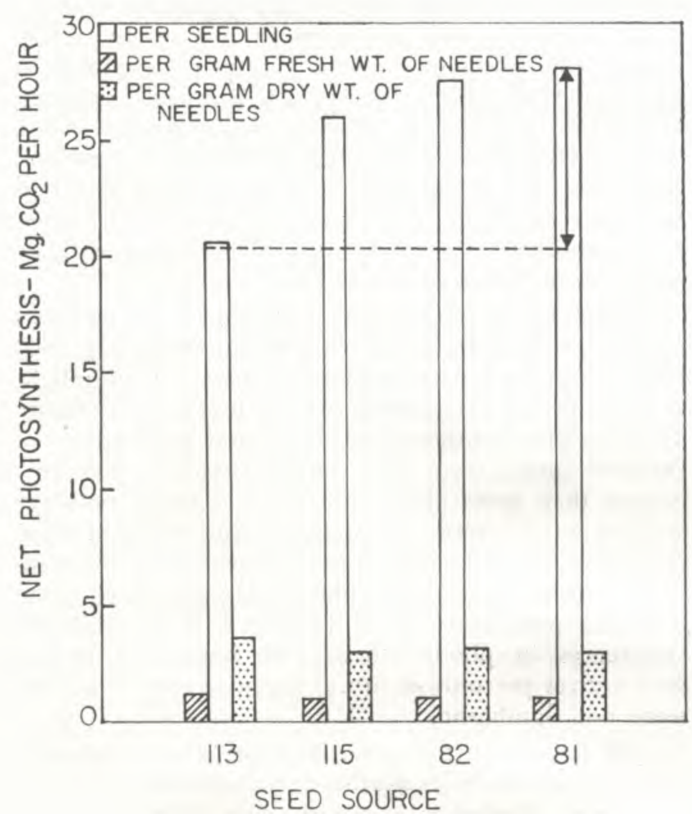


Figure 8. Net photosynthesis in relation to seed source. Net photosynthesis per seedling does not differ at the 5-percent level for seed sources grouped by an arrow.

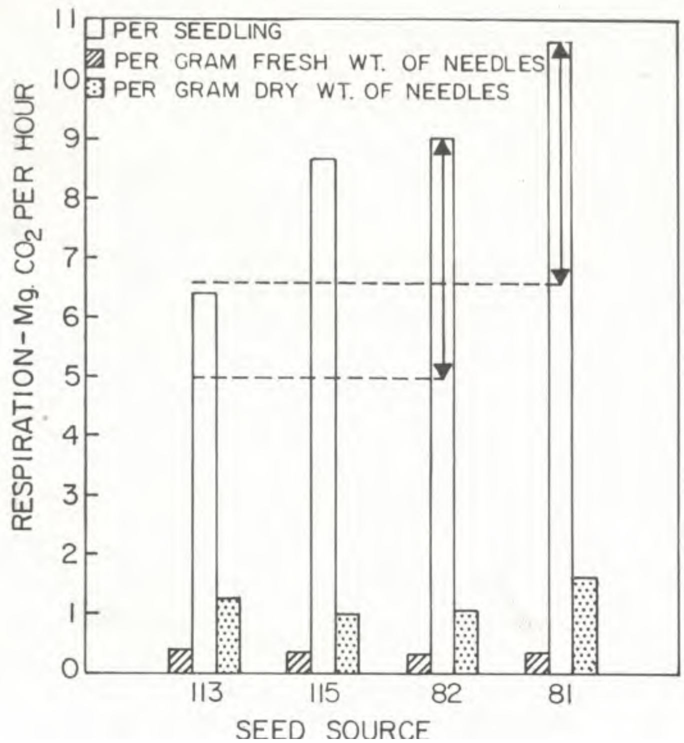


Figure 9. Respiration in relation to seed source. Respiration per seedling does not differ at the 1-percent level for seed sources grouped by an arrow.

were considerably greater than growth rates of the other sources. Moreover, growth of these three sources at the cooler temperature began earlier and continued longer at the 20-hour than at the 16-hour photoperiod.

The following was concluded: (1) growth and development of Scotch pine seedlings are affected appreciably by photoperiod, temperature, seed source and their interactions, (2) magnitude of the variation among seed sources, within the limited latitudinal range tested, appears to justify a more comprehensive evaluation of the within-species variation of Scotch pine to find suitable variants for plantings in Iowa, (3) photoperiod and temperature appear to be two environmental factors important in the process of natural selection within Scotch pine, even over the limited natural range of seed sources studied; adaptive value and fecundity, characteristics important in a consideration of natural selection, are controlled by growth and differentiation processes within the plant (Loomis 1953); in this study, magnitude of the variation in the distribution of assimilate and of the variation in the period and rates of growth for the seven seed sources of Scotch pine in relation to temperature and photoperiod, suggests a rather marked influence of these environmental factors on growth and differentiation; consequently, (4) an evaluation of the effects of temperature, photoperiod, seed source and their interactions on the growth and development of Scotch pine seedlings in the greenhouse has provided some criteria to test the feasibility of early selection of variants within Scotch pine for field planting in Iowa.

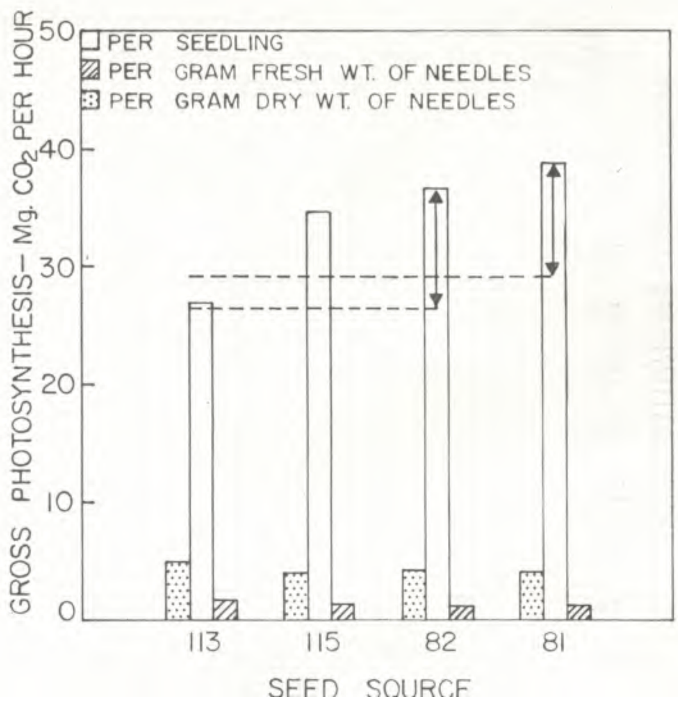


Figure 10. Gross photosynthesis in relation to seed source. Gross photosynthesis per seedling does not differ at the 5-percent level for seed sources grouped by an arrow.

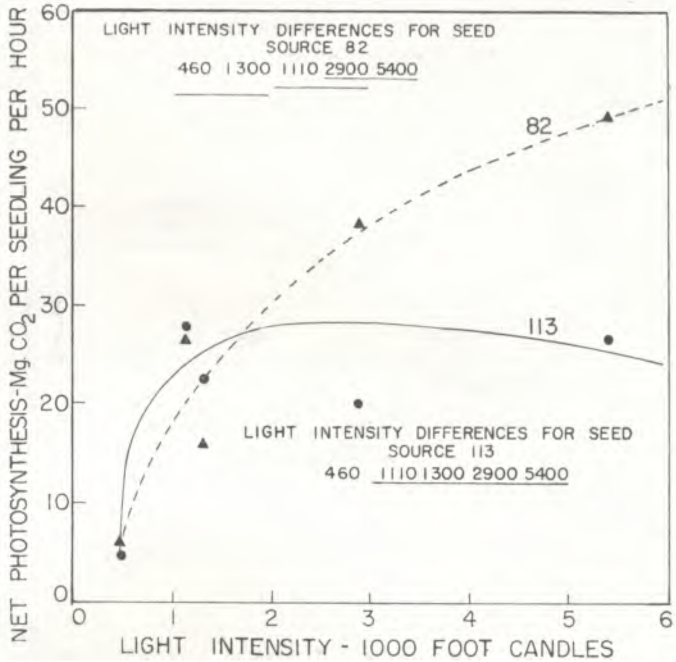
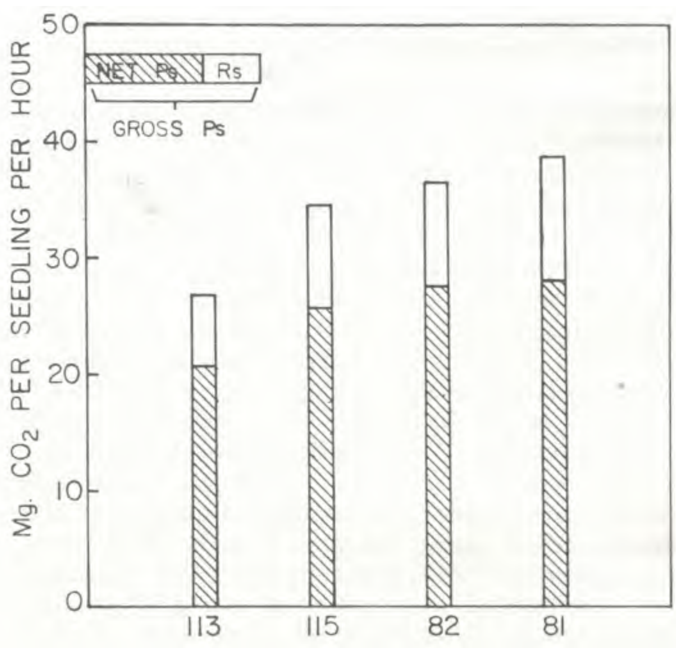


Figure 12. Net photosynthesis per seedling in relation to light intensity and seed source. Net photosynthesis per seedling does not differ at the 5-percent level for light intensities grouped by a line.

Photosynthesis, Respiration and Growth of Scotch Pine Seedlings in Relation to Seed Source and Light Intensity (Gatherum, Gordon and Broerman 1964)

Photosynthesis and respiration of Scotch pine seedlings were determined in relation to (1) light intensities of 460, 1,110, 1,300, 2,900 and 5,400 foot-candles and (2) four seed sources, ranging from central Turkey to central Germany (Figure 2). The study was established as a simple split-plot experiment with four replicates of five light intensity plots, each divided into four seed source sub-plots. Photosynthesis and respiration of intact potted seedlings were measured in a gas-tight, refrigerated, controlled-environment chamber described by Broerman *et al.* (1964). A Beckman LAB infrared analyzer, model 15A, was used to measure the uptake and evolution of CO_2 within the chamber. In addition, height and green- and dry-weight growth of Scotch pine seedlings were determined in relation to seed source. The study was established as a randomized block design with 20 replicates of four seed source plots.



SEED SOURCE

Figure 11. Gross and net photosynthesis per seedling in relation to seed source

Net and gross photosynthesis of Scotch pine seedlings increased with light intensity up to approximately 2,000 foot-candles, and dark respiration increased with light intensity preconditioning up to 5,400 foot-candles (Figure 7). Gross photosynthesis and respiration per seedling of the seed source from west central Germany (81) were greater than gross photosynthesis, and respiration per seedling of the seed source from east central Turkey (113), and the differences in net photosynthesis per seedling between these sources approached significance at the 5-percent probability level (Figures 8, 9, 10 and 11). Differences in photosynthesis and respiration among seed sources per unit of dry or green weight of needles were not significant.

Differences in net photosynthesis per seedling between the seed sources from northeast Austria-450m (82) and east central Turkey (113) varied among light intensities (Figure 12). Light saturation occurred at approximately 1,500 foot-candles for the seed source from east central

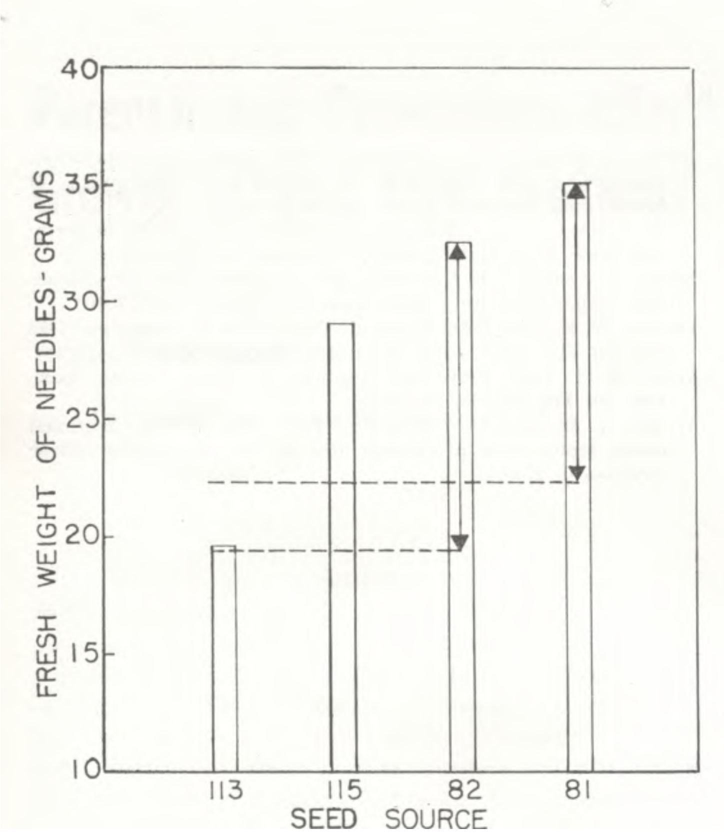


Figure 13. Fresh weight of needles in relation to seed source. Fresh weight of needles does not differ at the 5-percent lye! for seed sources grouped by an arrow.

Turkey, but light saturation had not occurred at the highest light intensity used in the study, 5,400 foot-candles, for the seed source from northeast Austria-450m.

Fresh weight of needles and stem length of the seed source from west central Germany (81) were greater than the fresh weight of needles and stem length of the seed

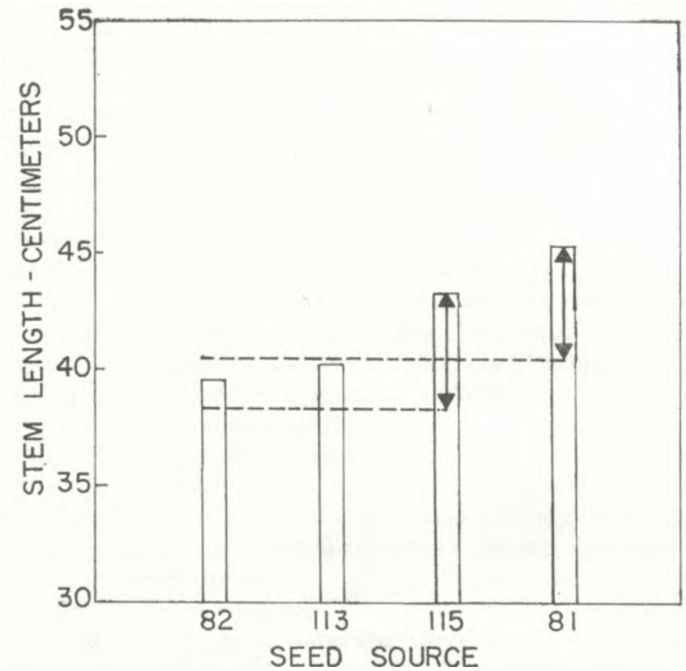


Figure 14. Stein length in relation to seed source. Stem length does not differ at the 5-percent level for seed sources grouped by an arrow.

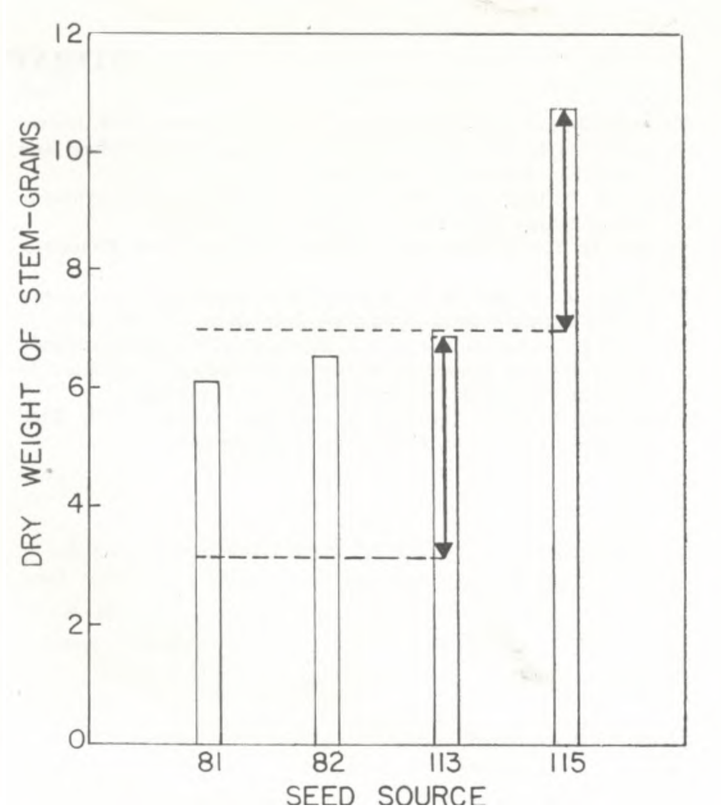


Figure 15. Dry weight of stein in relation to seed source. Dry weight of stem does not differ at the 5-percent level for seed sources grouped by an arrow.

source from east central Turkey (113) (Figures 13 and 14). Moreover, stem length of the seed source from west central Germany was greater than the stem length of the seed source from northeast Austria-450m (82). However, dry weight of the stem of the seed source from west central Turkey (115) was greater than the dry weight of the stems of all other sources (Figure 15).

The following was concluded from this controlled environmental study of Scotch pine seedlings: (1) light saturation varies among seed sources but appears considerably lower than reported by Decker 1954; (2) photosynthesis and respiration differ among seed sources if measurements are expressed on a per seedling basis, thus indicating no difference in gross and net photosynthetic efficiency; (3) the greater fresh needle weight, indicating greater photosynthetic area, of the seed source from west central Germany (81) over the seed source from east central Turkey (113) probably accounts for the differences in photosynthesis and respiration between these seed sources; (4) variation in the distribution of assimilate as shown by the differences in net photosynthesis, fresh weight of needles, stem length and dry weight of stem among seed sources and light intensities appears to indicate that (a) to provide a clearer understanding of the causes of variation in tree vigor and quality and (b) to permit an investigation of the possibilities of early selection of seed sources for planting, intensive controlled environmental investigations are needed of the physiological processes involved from gross photosynthesis to assimilation.

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