BLACK WALNUT IN CENTRAL KENTUCKY: GROWTH AND DEVELOPMENT OF HALF-SIB FAMILIES UNDER ARTIFICIAL SHADE.

Stanley B. Carpenter 1/

Abstract.--Net photosynthesis and growth and development of black walnut half-sib families from open and forested habitats were studied in the laboratory and the field under artificial shade. Maximum net photosynthesis occurred at a relatively low light intensity of 4,000 foot-candles in comparison to intolerant conifers which reach maximum rates of photosynthesis at full sunlight. Photosynthesis was similar in seedlings from open and forested habitats. Germination, height growth, dry matter production, leaf surface areas and nitrogen, potassium, and phosphorous contents of seedlings grown under light and medium shade levels were greater than that achieved in the open and under heavy shade. Photosynthetic adaption to contrasting light climates has not occurred in central Kentucky.

Additional Keywords. Net photosynthesis, height growth, dry matter production, mineral contents, *Juglans nigra*.

Although black walnut (*Juglans nigra* L.) has long been classed an intolerant species (Baker 1950), there have been few physiological studies of its tolerance. Current recommendations call for the planting of this species at wide spacing in pure plantations where thorough competition control has been achieved (Burke 1973). The growth and form of trees in black walnut plantations in Kentucky has not always been equal to that which occurs in natural stands. Several times the author has observed excellent natural stands of walnut where this species has grown under competition pressure from other species, particularly boxelder (*Acer negundo* L.). After several years of a black walnut superior tree selection program in Kentucky, we have found few superior trees in the Bluegrass physiographic region where open, park-like forests prevail. The walnut in this area shows poor form and growth and little natural regeneration is observed.

These observations have led us to question the planting of walnut on exposed sites. In 1972 and 1973, we established a study to examine the effect of light intensity on net photosynthesis in black walnut and development under four levels of artificial shade. Another objective

1/ Assistant Professor, Department of Forestry, University of Kentucky, Lexington, Kentucky 40506

of the study was to compare the growth and development and net photosynthesis of half-sib families collected from open and forested habitats in central Kentucky and to determine if photosynthetic and adaption to contrasting light climates had occurred as in Atriplex (Bjorkman 1972).

METHODS

In October 1972, we collected seed from four open-pollinated black walnut trees in central Kentucky. Two of the parent trees were located in open park-like forest stands typical of the bluegrass region surrounding Lexington. The second two parent trees were located in a heavily forested section of the Daniel Boone National Forest, about fifty miles from Lexington. The seeds were stratified at 38° F until the spring of 1973. In May, seed from each half-sib family was divided into two groups. One group was planted in 3-gallon pots in the green house and grown for two months to use in a laboratory study of net photosynthesis. The remaining walnut seed was sown in 3-gallon pots in an outdoor study of artificial shade.

Photosynthesis study.

After two months of growth under a 14-hour photoperiod in the greenhouse, twelve seedlings were selected for uniformity of size and appearance from each half-sib family. Photosynthesis was studied under conditions where light intensity was varied while temperature and relative humidity were maintained at constant levels. Measurements of photosynthesis were made in a closed system using a controlled environment chamber constructed of acrylic plastic. Five 500-watt weather resistant floodlamps were immersed in an acrylic plastic water bath above the chamber. Temperature control was achieved by circulating water cooled by a large water bath through the outer walls of the growth chamber and was maintained at 25°C ± 1. Light intensity was controlled with a Powerstat Type variable transformer. Relative humidity was maintained at approximately 50%.

A Beckman infrared gas analyzer and recorder were used to detect and record CO_2 concentration changes. Small fans circulated air in the chamber and a masterflex tubing pump maintained a flow rate of 1100ml/min in the closed system.

Individual seedlings including their pot container were placed into the growth chamber and subjected to photosynthesis runs at light intensity ranging from 500 to 12,000 foot-candles. The seedling was conditioned at each new light intensity for a 15-minute period before photosynthesis was recorded. The rate of CO_2 depletion from 330 to 270 ppm was used as the measure of net photosynthesis. Rates were computed from slopes of lines drawn tangent to the recorder tracings.

Artificial shade study.

In May 1973, twelve shade frames were constructed at the University of Kentucky Robinson Forest near Jackson, Kentucky. Each frame was

6 x 8 x 6 feet, 288 cubic feet in size and contained 24 - 3 gallon plastic pots buried and spaced at 2 x 2 feet. The frames were covered with Armex green saran shade fabric to establish three levels of artificial shade and an open treatment. The treatments established included open, light shade (30% RI), medium shade (50% RI), and heavy shade (75% RI). The pots were fertilized frequently and a Chapin Watermatic irrigation system was used to maintain soil moisture at high levels. The twelve frames were organized into a randomized block experiment in which each of three blocks contained an open treatment and three shade levels.

In Late May 1973, five seeds from each of the four half-sib families were planted in each pot. Germination was recorded and each pot was thinned back to one seedling as germination progressed. Growth and development was observed during the 1973 growing season and in September, 150 days after planting, the seedlings were harvested, leaf areas were determined by planimeter, and dry weights were determined for the root, stem, and leaf fractions. A single half-sib family from each habitat was chosen and nitrogen, potassium, phosphorous, calcium, and magnesium levels were determined by plant part. The Kjeldahl procedure was used for the determination of nitrogen levels. Levels of the other elements were measured with a Varian Techtron atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Photosynthesis study.

Few studies of net photosynthesis have been conducted with black walnut. Carpenter and Hanover (1974) studied the photosynthetic efficiency of first-year black walnut seedlings from a southern Michigan source. We found that peak photosynthetic activity occurred in Michigan two months after germination and then declined rapidly to low levels. Light saturation was not studied but to appeared to be rather low in comparison to conifers.

The rates of net photosynthesis determined in this study were comparable to those previously reported. Figure 1 shows the light saturation curve developed in this study. Maximum photosynthetic activity in the Kentucky sources was reached at a light intensity of approximately 4,000 foot-candles. Net photosynthesis increased rapidly from a low of 3.4 mg CO2/dm2/hr at the lowest light intensity studied, 500 foot-candles; peaked at 6.3 mg CO_2/dm2/hr at 4,000 foot-candles and remained at a high level until it began to decline at light intensities above 7,000 foot-candles. There were no significant differences in photosynthetic activity between half-sib families from the two contrasting habitats.

The light saturation curve developed in this study differs somewhat from those previously determined for other hardwood species. The hardwoods studied by Kramer and Decker (1940) achieved maximum photosynthesis at light intensities of one-third or less full sunlight while in loblolly pine net photosynthesis increased up to full sunlight. Other studies have also shown that hardwoods reach maximum rates of photosynthesis at relativity low light intensities. Most of the hardwoods previously studied are from the mid-tolerant range of Baker (1950).

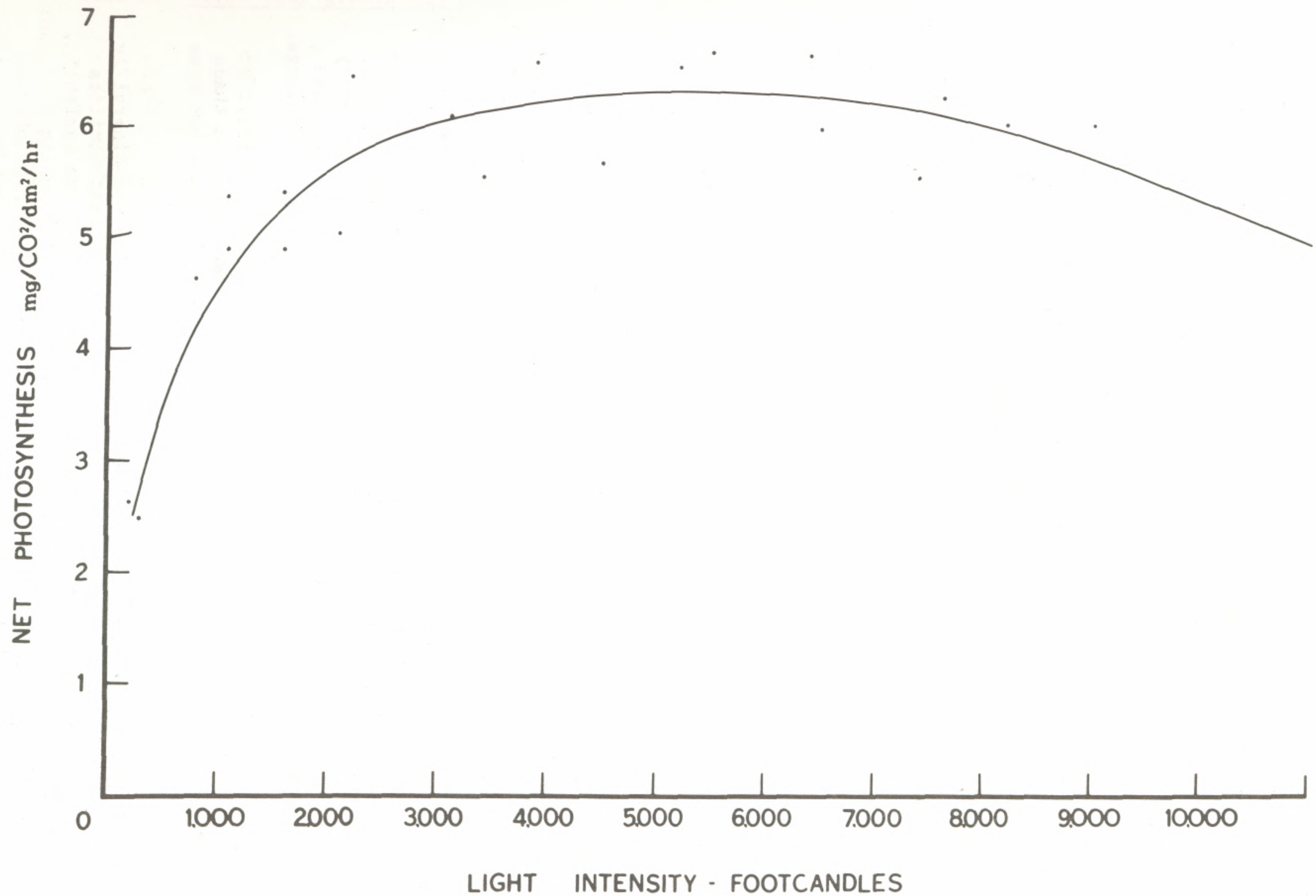

Figure 1.--Light saturation curve for Kentucky source of first-year black walnut seedlings.

The results of this study suggest that intolerance in hardwoods and conifers cannot be equated.

Artificial shade study.

Germination began in the open treatment about two weeks prior to that in the shade treatments. Germination was highest under medium and light shade and lowest in the open and heavy shade treatments (Table 1). Both the open and forested families responded to shade in similar fashion.

Cumulative height growth of black walnut under artificial shade is shown in Figure 2. Height growth was greatest under heavy shade. Medium shade also resulted in increased height growth. Height growth of both the open and forested families was significantly reduced under light shade (Table 1). There was considerable variation among the four families in height growth (Figure 3). There was especially wide variation among the two open habitat families. Although there was variation in cumulative height growth, all families began and ended growth at about the same time.

The effect of light intensity on leaf structure and size is well known. In this study, both the medium and heavy shade levels greatly increased leaf surface area, but leaf dry weight was relatively stable at all light intensities (Table 1).

Shade apparently had little effect on the development of stem tissues. Only the forested source produced more stem dry weight under shade (Table 1).

Usually, increased light intensity stimulates root development at the expense of shoot development. This did not occur in black walnut. Increased dry weight of the root fraction occurred under light and medium shade. Root-shoot ratios were also highest under these treatments (Table 1).

The effect of shade level on whole seedling dry weight (Table 1) is interesting in that it appears to reinforce the laboratory study of net photosynthesis reported earlier. Both sources of black walnut appeared to benefit in total dry weight production under light and medium shade. However, the shade climate is complicated and the results reported here may not be entirely due to light intensity. Heiligmann (1971) reported that wind protection increased the growth of young black walnut seedlings.

Low light intensity usually results in the production of a tall, spindly seedling. This occurred with black walnut under the heavy shade treatment (Table 1). Height growth was greatest under 75% shade but stem dry weight and stem diameter were considerably reduced.

Table 2 reports the effect of our shade treatments on the mineral contents of the leaf, stem, and root fractions of black walnut families from open and forested habitats. There were too few samples to apply

Table 1.--First-year growth and development of open and forested black walnut half-sib families under four levels of artificial shade

Growth and Development	Performance of Open Grown Sources Under Shade				Performance of Forest Grown Sources Under Shade				Performance of All Sources Under Shade			
	Open	Light	Medium	Heavy	Open	Light	Medium	Heavy	Open	Light	Medium	Heavy
Leaf area (cm^2)	928a	1/ 898a	1316b	1186c	647a	647a	1141b	1115b	788a	7772a	1228b	1150c
Number of compound leaves	5a	7a	8a	7a	7a	6a	6a	6a	6a	6a	7a	6a
Leaf dry weight (grams)	5.2a	5.2a	5.3a	4.8b	3.7a	3.6a	4.3b	3.3a	4.4a	4.4a	4.8b	4.0c
Stem dry weight (grams)	2.9a	3.5a	3.2a	3.0a	2.0a	2.2a	2.8b	2.2a	2.4a	2.8a	3.0a	2.6a
Root dry weight (grams)	9.7a	13.8b	13.7b	10.3a	10.2a	8.9b	11.4c	8.6b	9.9	11.4	12.6	9.4
Whole seedling dry weight (grams)	17.8a	22.5b	22.2b	18.1a	15.9a	14.7a	18.5b	14.1a	16.7a	18.6b	20.4b	16.0a
Root/Shoot ratio	1.2a	1.6b	1.6b	1.3a	1.8a	1.5a	1.6a	1.6a	1.4a	1.6a	1.6a	1.4a
Stem diameter (cm)	0.74a	0.62b	0.82a	0.67b	0.63a	0.62a	0.72b	0.66a	0.50a	0.62b	0.77c	0.66b
Height (cm)	28.1a	24.8b	30.8a	31.4a	26.4a	24.4b	26.0a	28.8c	27.2a	24.6b	28.4a	30.1c
Germination (percent)	42a	72b	58c	44a	36a	48b	72c	56d	39.a	60b	60b	50c

1/ Mean values in any row followed by the same letter do not differ significantly at the 5-percent level of probability.

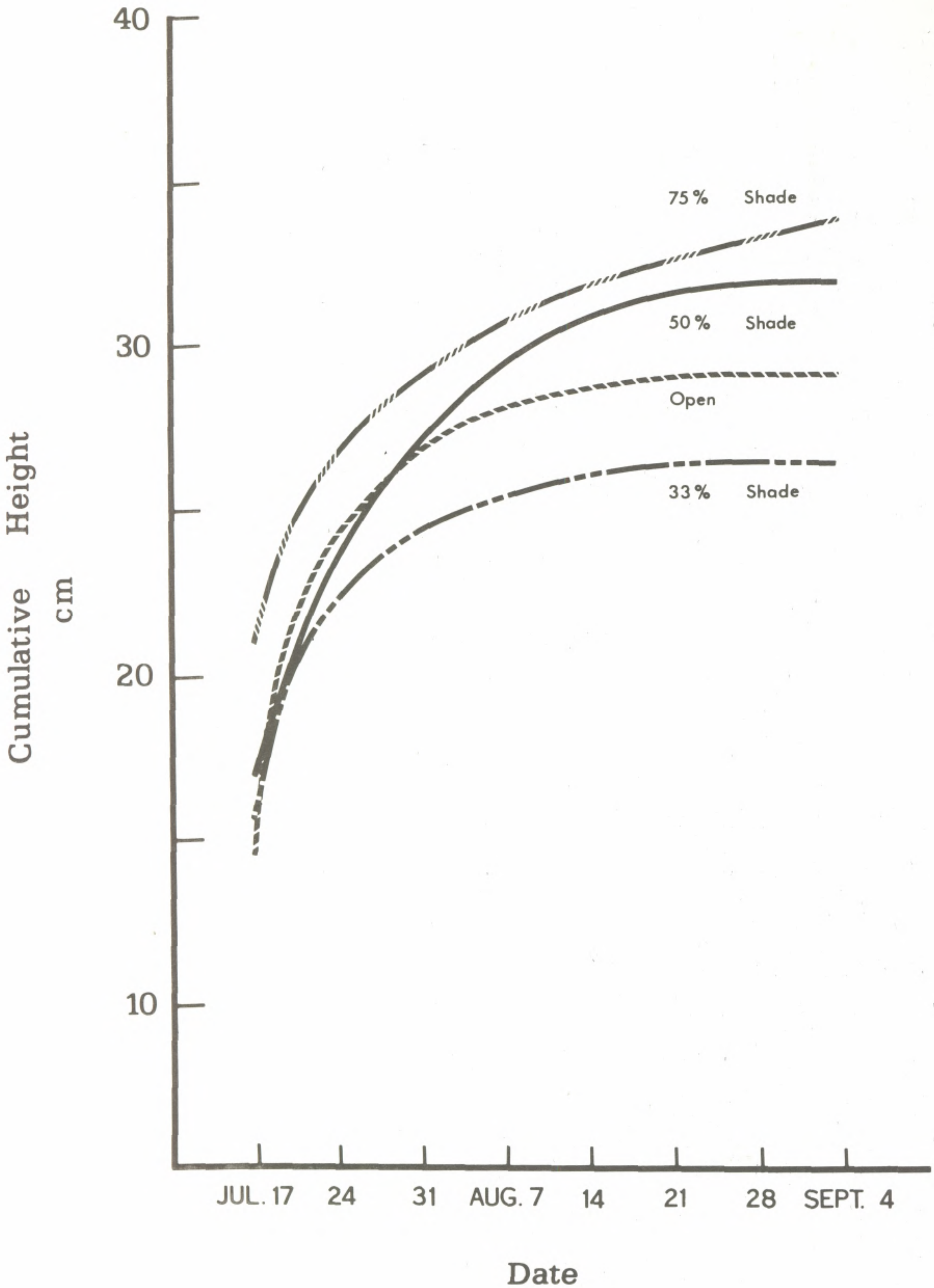

Figure 2.--Cumulative height growth of first-year black walnut seedlings under four levels of artificial shade.

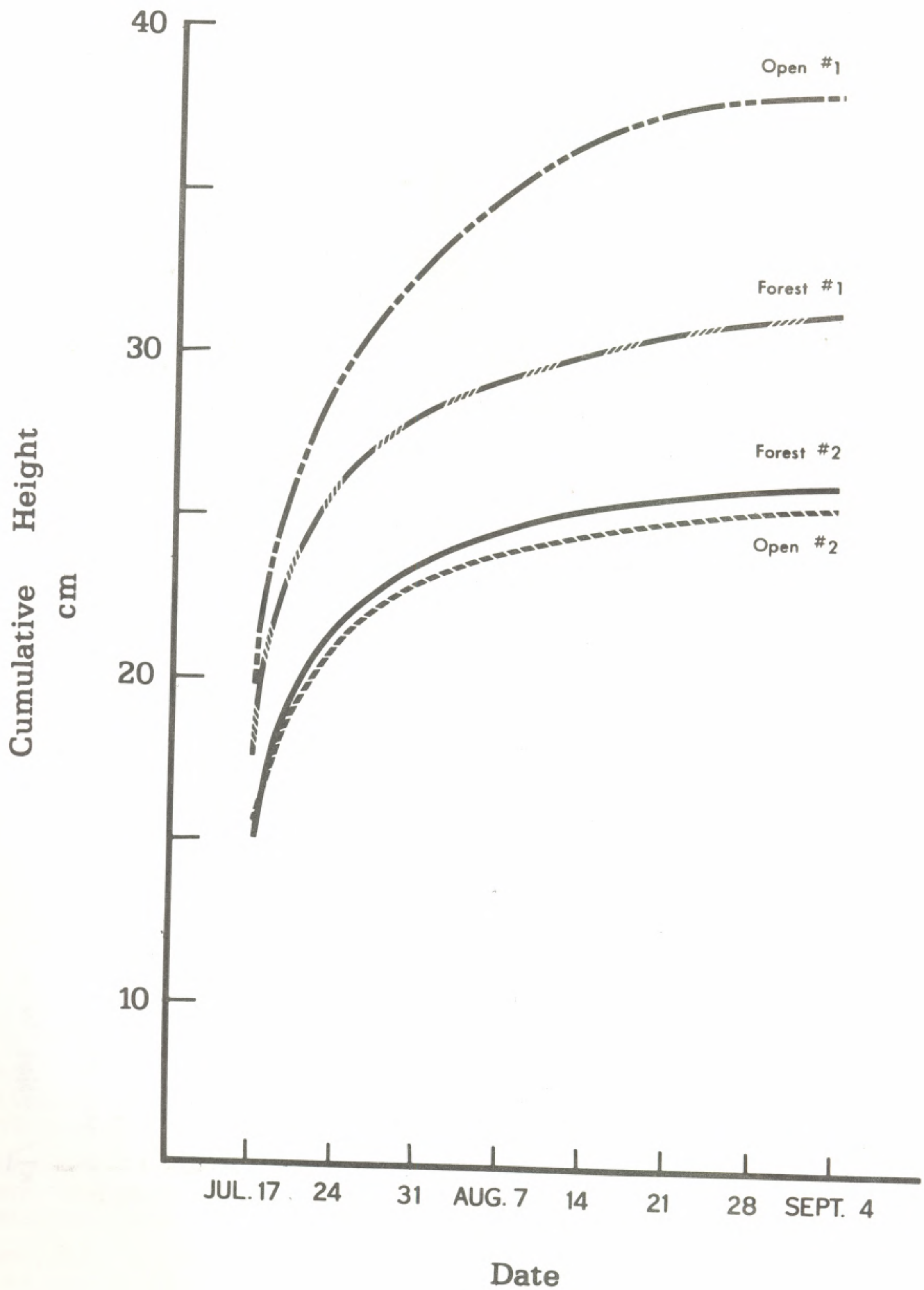

Figure 3.--Cumulative height growth of four black walnut half-sib families.

Table 2.--Mineral contents of black walnut families grown under four levels of artificial shade

Degree of Shade/Plant Part		Open Grown Source (Per cent) Ca	Mg	K	P	N	Forest Grown Source (Per cent) Ca	Mg	K	P	N
Open	Leaf	1.15	.24	1.53	.12	1.19	1.18	.26	1.26	.10	1.42
	Stem	.78	.12	.56	.04	.39	.73	.11	.52	.04	.42
	Root	.48	.11	.67	.08	.36	.76	.10	.69	.09	.55
	Whole Plant	2.41	.47	2.76	.24	1.94	2.67	.47	2.47	.23	2.39
Light	Leaf	*1/	1/	1/	1/	1.20	.82	.25	.82	.16	1.43
	Stem	1/	1/	1/	1/	.44	.58	.13	.51	.06	.51
	Root	.36	.15	.72	.07	.44	.43	.16	.77	.10	.73
	Whole Plant	.36	.15	.72	.07	2.08	1.83	.54	2.10	.32	2.67
Medium	Leaf	1.49	.28	1.64	.18	1.53	1.23	.28	1.42	.14	1.42
	Stem	.86	.13	.58	.08	.39	.94	.14	.65	.07	.39
	Root	.53	.15	.73	.25	.45	.54	.12	.57	.11	.49
		2.83	.56	2.95	.51	2.37	2.71	.54	2.64	.32	2.30
Heavy	Leaf	1.11	.21	2.26	.16	1.49	1.25	.31	2.64	.19	1.71
	Stem	.76	.17	.84	.08	.51	.62	.14	.73	.07	.44
	Root	.46	.15	.93	.13	.65	.32	.13	.84	.13	.56
	Whole Plant	2.33	.53	4.03	.37	2.62	2.19	.58	4.21	.39	2.71

*1/ Not Determined

statistics to this area of the study, but some interesting trends are indicated. Nitrogen contents of all fractions increased as shade level increased. Phosphorous and potassium followed this trend also. However, magnesium and calcium appeared to remain constant regardless of shade level. There were no apparent differences between open and forested sources.

CONCLUSIONS

The results of this study indicate that some shade may be beneficial to the establishment and early growth of black walnut. No evidence was found to suggest that photosynthetic adaptation to contrasting light climates has occurred in central Kentucky. Seedlings from both sun and shade habitats responded to artificial shade in similar fashion.

The effect of light intensity and shade on black walnut should be further studied in the laboratory and field. What environmental factors in the shade microclimate caused the increased growth of black walnut seedlings? There is great need to study the growth and development of older seedlings and saplings under shade. Studies should include the effect of shade on apical dominance and form.

It is obvious from this study and others in the area of hardwood physiology that intolerance in hardwoods and conifers should not be equated and silvicultureal practices developed for the culture of conifers should not be applied to hardwoods without considerably study.

LITERATURE CITED

Barker, F.S. 1950. Principles of silviculture. 414 p. N.Y.: McGraw-Hill Book Company.

Burke, R.D. 1973. Establishment and early culture of populations. In Black walnut as a crop, Black walnut symposium, Carbondale, Ill., August 14-15, 1973; p. 36-40. U.S.D.A. For. Serv. Gen. Tech. Rep. NC-4.

Bjorkman, 0. 1972. Photosynthetic adaption to contrasting light climates. 1971-1972. Annual Rep. Director Dept. of Plant Biol.: 82-85. Carnegie Institute, Stanford, Calif.

Carpenter S.B. and J.W. Hanover 1974. Comparative growth and photosynthesis of black walnut and honeylocust seedlings. Forest Service (In Press).

Heiligmann, R.B. 1971. Effect of wind and wind protection on the early growth response of black walnut (*Juglans nigra*). Ph.D. Dissertation Michigan State University, East Lansing, Michigan.

Kramer, P.J. and J.P. Decker 1944. Relation between light intensity and rate of photosynthesis of loblolly pine and certain hardwoods. Plant physiol. 19: 250-358