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Autecological & Populational Investigation of Carpinus Caroliniana Walt.

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AUTECOLOGICAL AND POPULATIONAL INVESTIGATION OF *CARPINUS CAROLINIANA* WALT.

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AUTECOLOGICAL AND POPULATIONAL INVESTIGATION OF

CARPINUS CAROLINIANA WALT.

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AUTECOLOGICAL AND POPULATIONAL INVESTIGATION

OF *CARPINUS CAROLINIANA* WALT.

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Analysis of habitats containing *Carpinus caroliniana* in two distinct physiographic regions of Kentucky revealed that this species has a wide range of tolerance to light intensities and soil pH. Species most commonly associated with *Carpinus* within the two physiographic regions were *Platanus occidentalis*, *Acer saccharum*, *Liquidambar styraciflua*, *Fraxinus* spp. and *Fagus grandifolia*.

Morphological and anatomical investigations of populations representing the geographic distribution of *Carpinus caroliniana* in the United States indicated that the more northern population had heavier fruit, larger bracts, and secondary wood with higher specific gravity.

Growth chamber experiments involving dormant buds collected from natural habitats indicated differences in bud burst correlated with habitat of origin that shows possible ecotypic differentiation. Populations of *Carpinus* from habitats with fluxuating spring temperatures may have a longer cold requirement prior to bud burst than populations representing the latitudinal extremes.

INTRODUCTION

Since Turesson's (1922) pioneering study of ecotypes, significant research has shown many species to be composed of discrete populations with physiological and morphological differences enabling each population to better cope with its particular enviornmental regime. Literature reviews have revealed that when considering the total number of plant species relatively few have been subjected to intensified or even superficial investigations of populational differentiation (Hiesey and Milner, 1965).

Evidence of ecotypic variation in dominant tree species has availed a broad new area of research to the plant ecologist. Recent graduate research at Western Kentucky University on the dominant canopy species Acer negundo (Williams, 1970) and Liquidambar styraciflua (Randel, 1975) has demonstrated their wide populational differentiation.

Carpinus caroliniana (commonly called Ironwood, Blue Beech, American Hornbeam, or Water Beech; Fernald, 1950) is a dominant understory species in Eastern North America; its range extends from Nova Scotia to Minnesota south to Texas and Florida. Wide distribution and relative abundance makes Ironwood an ideal species for broad ecotypic and community investigations.

Despite the abundance of Carpinus caroliniana very little information has been published on this species. A literature survey of such references as Excerpta Botanica, Biological Abstracts and Dissertation Abstracts confirmed that there is virtually no information on the autecology of this genus. This is not unexpected since it is currently of little economic importance. As wood and fiber demands increase, this seemingly noneconomic tree may prove to be an important source of wood fiber. Other species as Pinus elliottii (Slash Pine) of the southern pine forest were thought to be valueless until the last two decades when they were recognized as an available source of wood pulp.

In the past Ironwood has been utilized for wagon axles, spokes, implement handles, mallet heads, and charcoal of hornbeam was often mixed with gunpowder (deWit, 1966).

Recent studies in plant ecology are placing emphasis on the functional role of dominant species in deciduous forest biomes. Thomas (1969) hypothesized that Cornus florida (Dogwood) functions as a calcium pump in forest ecosystems, as it is found to have significantly higher levels of calcium than other represented species. Forty-six percent of the calcium in Cornus was incorporated into the leaf material, foliar leaching being the major form of calcium release. Carpinus reportedly accumulates higher than normal amounts of aluminum (Kruckeburg, 1969) availing it as an ideal subject for investigating the possibility of its functional niche as an aluminum pump.

Whereas much information is available on the economically significant forest biomes, comparatively little research has been conducted in the area of vegetational community analysis in Kentucky, particularly in the understory dominants and their associated species.

This report is an investigation of the aspects of community structure of Carpinus caroliniana with its associated species in the Mississippian Plateau and Western Kentucky Coal Fields. The study will also provide an introductory examination of populational differentiation in regard to wood quality, seed size and weight, fruiting structure morphology and bud bursting.

Carpinus caroliniana is a small deciduous tree found in the eastern portion of North America from Nova Scotia to Minnesota south to Texas and Florida. It also occurs in the mountains of Mexico and South America. It may attain a height of 10 to 12 meters, and is characterized by a short fluted trunk, with thin blue-grey bark and light or darker patches. The leaves are alternate, simple, ovate to oblong 6 to 12 cm long, 2.5 to 7 cm wide becoming sharply pointed at the tip. Staminate catkins are 2 to 4 cm long with up to 20 stamens, usually seen in April or May. Pistillate catkins are 1 to 2 cm long, located near the end of the branch. The fruit forms a loose strobilus; a corrugated nut is subtended by a three lobed bract 1 to 3.5 cm long. Ironwood is a very flood tolerant tree found in both rich and poor soils along streams and swamps (Petrides, 1958; deWit, 1966; Mohr, 1901; Fernald, 1950; Stupka, 1964).

MATERIALS AND METHODS

Ten collection sites were established in Western Kentucky, of which five sites were situated on the Mississippian Plateau and five in the Western Kentucky Coal Fields, representing two distinct physiographic regions as outlined by Braun (1950). The actual collection sites were subjectively chosen to be as similar as possible in physical habitat (Table 1). Table 1 lists the closest stream or body of water at each collection site. Ten individuals of Carpinus at each site were located and marked for future reference. Associated woody species were recorded by identifying the five nearest woody stems with a diameter breast height (dbh) greater than 5 cm. An analysis of the canopy above Ironwood was undertaken by photographing directly up, toward the above canopy, near the distal end of the Carpinus branches. This procedure was repeated four times at each tree with each position corresponding to major compass points of North, East, South, and West. The negatives were analyzed using a constant light source, film mask and light meter. This procedure utilized a light proof tube with inside diameter of 75 mm, containing a 15 watt non-frosted bulb approximately 15 cm from the film mask held directly in front of the light meter. Light transmission was measured to the nearest footcandle.

Table 1. The location and description of ten collection sites of Carpinus caroliniana Walt. in Kentucky.

Code	Site[1]	County	Lat.	Long.	Elev.[2]
Western Kentucky Coal Fields					
CF1	Guy	Butler	37°07'	86°37'	128
CF2	Glenmore	Edmonson	37°08'	86°23'	134
CF3	Woodbury	Butler	37°11'	86°37'	123
CF4	Flener	Butler	37°17'	86°42'	122
CF5	Calhoun	Calhoun	37°31'	87°15'	122
Mississippi Plateau Region					
MP1	Franklin	Simpson	36°43'	86°29'	183
MP2	Bonayer	Barren	37°01'	86°02'	228
MP3	Hadley	Warren	37°05'	86°37'	161
MP4	Brownsville	Edmonson	37°16'	86°15'	140
MP5	Leitchfield	Grayson	37°33'	86°21'	149

Collection sites were established for comparisons of widespread populations along a north-south line between 83 and 86 deg. W. longitude and a latitudinal distribution between 31 and 43 deg. N. (Table 2). Mature fruits of Ironwood were picked in July and August of 1975, from the Michigan to Alabama collection sites, and dried at room temperature in paper containers. Fifty nuts were removed from the three lobed bracts of each population and further dried in a 70 C desicating oven until constant weight was obtained. Once dried the nuts were weighed on a Roller - Smith Precision Balance to 0.1 of a milligram, and a comparison of weights of the ten populations were undertaken.

A comparison of bract lengths, widths, and length to width ratio was made of the ten latitudinally diverse populations. Length measurements were determined by measuring tip to base of the middle lobe of the bract; width was defined as a tip to tip measurement of the lateral lobes. Sixty bracts from each population were measured to the nearest 0.1 cm.

Latitudinal variation in wood specific gravity was investigated by cutting secondary wood samples from eleven trees at each of the ten collection sites noted in Table 2. Rectangular wood blocks approximately 8 mm X 8 mm X 25 mm were cut from samples excluding the wood formed during the three previous years. Wood used for specific gravity was from the growing seasons of 1970 - 1972. Utilizing Smith's (1954) specific gravity maximum moisture content method, as followed by Randel (1975), oven dry and saturated wood weights were

Table 2. The location and description of ten collection sites of Carpinus caroliniana Walt. from Michigan to Alabama.

Code					Elev.[2]
M1 Vestaburg	Isabella	Michigan	43°29'	84°43'	286
M2 Dryden	Lapeer	Michigan	42°58'	83°12'	249
I1 Kokomo	Howard	Indiana	40°25'	86°00'	260
I2 Austin	Scott	Indiana	38°42'	85°50'	185
K1 Leitchfield	Grayson	Kentucky	37°33'	86°21'	149
K2 Franklin	Simpson	Kentucky	36°43'	86°30'	183
T1 Nashville	Davidson	Tennessee	36°07'	86°41'	164
A1 Athens	Limestone	Alabama	34°48'	86°49'	219
A2 Montgomery	Montgomery	Alabama	32°18'	86°24'	67
A3 Opp	Covington	Alabama	31°10'	86°20'	79

[1] Closest town or community

[2] Meters above sea level

necessary for calculations. Wood samples were saturated under vacuum in distilled water for 48 hours and oven dried at 70 C until complete dry weight was reached.

Buds were collected in late December 1975 from the 10 sites listed in Table 2. They were placed in a cold chamber and maintained at 4 C until removed to test for ecotypic variation in bud bursting. Twenty twigs were taken from each population, cut to approximately 20 cm, put in a test tube with tap water and covered with a plastic bag. The twigs were then placed in an environmental growth chamber (Environator Corporation model 3448) with a day-night temperature of 32 - 24 C and a 16 hour photoperiod with light intensities of 6500 to 8600 Lux. Buds receiving this treatment were checked daily for evidence of bursting.

Samples of the top 8 cm of soil were taken from centrally located points at the 10 Michigan to Alabama and 10 Kentucky collection sites. Soil pH analysis was undertaken in the laboratory according to the LaMotte pH kit method.

A germination test of seed from four different populations (M_1, I_2, T_1, A_3) was attempted. Forty fruits of Carpinus were treated with fungicide, placed on filter paper in a petri dish and stratified at 4 C for approximately 30 days. The fruit were then placed in a growth chamber with a day-night temperature of 32 - 24 C, and a 16 hour photoperiod at 6500 - 8350 Lux light intensity.

RESULTS

The results of this study show greater promise of finding differences between widespread populations of Carpinus caroliniana rather than differences in communities of this species located within Kentucky. Comparative analysis of Ironwood's associated species and relative canopy densities in two different physiographic regions in Kentucky demonstrated no significant differences between the two regions. Collections of Carpinus from ten latitudinally diverse populations revealed possible ecotypic differentiation when fruit weight, specific gravity and cold requirements for bud bursting were analyzed.

Analysis of associated species (Tables 3 and 4) show Platanus occidentalis, Acer saccharum, Liquidambar styraciflua, Fraxinus spp. and Fagus grandifolia to be the five most abundant species associated with Carpinus in Mississippian Plateau and Western Kentucky Coal Field regions. No significant differences were observed between the two regions in respect to the five most abundant species or the frequency of occurrence of those species.

Soil pH at each of the ten Kentucky sites shows no correlation with represented species or the percent frequency of each of the species. However, Tables 3 and 4 demonstrate

Table 3. The soil pH, number (N), relative density (RD), and percent frequency (%F) of the species most commonly found in association with *Carpinus caroliniana* at five sites in the Western Kentucky Coal Fields.

Code	CF1	CF2	CF3	CF4	CF5			
Soil pH	7.2	7.0	7.0	7.0	4.4			
Species						N	RD	%F
Carpinus caroliniana	27	9	10	8	9	63	25.2	100
Platanus occidentalis	-	6	3	4	9	22	8.8	80
Acer saccharum	3	1	4	8	8	24	9.6	100
Liquidambar styraciflua	-	2	7	6	3	18	7.2	80
Fraxinus spp.	4	5	3	6	2	20	8.0	100
Fagus grandifolia	4	-	-	7	3	14	5.6	60
Ostrya virginiana	-	5	4	2	4	15	6.0	80
Acer saccharinum	5	1	3	4	-	13	5.2	80
Quercus spp.	-	5	-	-	-	5	2.0	20

Table 4. The soil pH, number (N), relative density (RD), and percent frequency (%F) of the species most commonly found in association with Carpinus caroliniana at five sites on the Mississippian Plateau.

Code	MP1	MP2	MP3	MP4	MP5			
Soil pH	6.4	5.2	7.0	5.8	4.4			
Species						N	RD	%F
Carpinus caroliniana	13	13	15	8	15	64	25.6	100
Platanus occidentalis	7	-	2	6	7	22	8.8	80
Acer saccharum	3	-	4	7	1	15	6.0	80
Liquidambar styraciflua	5	6	4	-	6	21	8.4	80
Fraxinus spp.	-	3	4	3	1	11	4.4	80
Fagus grandifolia	-	8	-	3	4	15	6.0	60
Ostrya virginiana	2	-	1	2	2	7	2.8	80
Acer saccharinum	-	-	6	-	2	8	3.2	40
Quercus spp.	-	1	1	6	5	13	5.2	60

soil pH on the Mississippian Plateau is generally more acidic than represented sites in the Western Kentucky Coal Fields.

Results of the relative canopy density study (Table 5) show wide variation in the percent of open canopy above Carpinus. A range between 11.6% to 35.4% open canopy in the Western Kentucky Coal Fields and 14.2% to 33.2% open canopy in the Mississippian Plateau Region was evident. Clearly, no significant difference is observed between the two regions, and no correlation is found when contrasting site canopy density with species relative density.

Results of the fruit weight investigation of diverse populations from Michigan to Alabama indicate that although a perfect ecocline is not observed, particularly in Southern Indiana, Kentucky and Tennessee, a significant difference (0.05 level of confidence) is found between northern and southern latitudes when separated by growing seasons (Table 6). The habitats with 120 to 180 days annual growing season exhibit a mean weight of 1292.5 mg/100 fruit, while fruit from a growing season of 210 to 260 days has a mean weight of 1053.9 mg/100 fruit.

Analysis of bract length and width (Table 7) revealed a clinal increase in mean width from southern (1.6 cm) to northern latitudes (2.1 cm). The lowest values observed in bract length were found in the central latitudes. A ratio of length to width indicates that the northern latitude populations have a greater surface area than the southern latitudes populations. Variation of these relative values, although not

Table 5. Mean relative canopy densities above *Carpinus* and the number of closely associated *Carpinus* in 2 physiographic regions in Kentucky.

Code	Site	Relative Canopy Density	Carpinus No.
CF1	Guy	11.6	27
CF2	Glenmore	35.4	9
CF3	Woodbury	18.8	10
CF4	Flener	12.0	8
CF5	Calhoun	13.4	9
MP1	Franklin	33.2	13
MP2	Bonayer	14.2	13
MP3	Hadley	17.3	15
MP4	Brownsville	18.7	8
MP5	Leitchfield	14.8	15

Table 6. Average fruit weights of different populations of *Carpinus caroliniana*.

Site Code	Avg. Annual Growing Season	Avg. Wt./ 100 Fruit mg	Range of Variation mg	No. of Parental Trees
M1	120	1225.8	1092-1342	4
M2	150	1354.4	1272-1428	4
I1	160	1193.4	920-1328	5
I2	180	1396.4	1246-1480	3
K1	190	971.6	876-1068	4
K2	190	989.6	748-1122	5
T1	210	1265.0	998-1574	6
A1	210	784.4	692- 878	4
A2	240	1192.2	1082-1242	4
A3	260	974.2	936-1042	3

Table 7. Average bract lengths and widths, with their collective means from 3 different trees (20 measurements from each tree) representing 10 populations of *Carpinus caroliniana*.

Site Code	Tree 1		Tree 2		Tree3		Mean	
	l	w	l	w	l	w	l	w
M1	25	22	25	19	25	19	25	20
M2	21	19	22	17	23	18	22	18
I1	23	20	21	19	26	24	23	21
I2	28	24	21	16	29	23	26	21
K1	23	17	20	16	21	16	21	16
K2	21	16	22	17	22	16	22	16
T1	23	17	22	16	23	16	23	16
A1	26	17	24	19	25	16	25	17
A2	26	17	27	17	27	17	26	17
A3	22	16	27	17	24	14	24	16

perfectly clinal, demonstrate a significant degree of separation at the 0.05 level of confidence between the north and south (Table 8).

Wood specific gravity studies reveal a significantly higher specific gravity in the northern latitudes than found in the southern regions, as demonstrated by the mean separation technique (Table 9).

Winter buds of Carpinus collected from field populations and placed in a growth chamber at regular intervals displayed a possible ecotypic response to the amount of cold experienced prior to spring-like conditions. After a minimum of 50 to 87 days of 4 C temperatures, a latitudinal response in bud bursting could be seen from Michigan to Alabama (Table 10). The southernmost populations exhibited 50% bud initiation after only 19 days in the growth chamber. As latitude increased northward so did the time required for maximum bud bursting (up to 51 days).

When subjected to a minimum of 72 to 109 days at 4 C, the time required for 50% bud bursting decreased for all latitudes. The Alabama populations continued to display the earliest bud bursting while the central and northern latitudinal populations required longer periods of time to attain 50% bud bursting. The Kokomo, Indiana population reached maximum bud bursting sooner than the other northern populations, however, all of the buds included in the Kokomo value were from one tree. In the other bud bursting experiments, the Kokomo population did not reach 50% or even 25% bud bursting; therefore the data of that population is of questionable validity.

Table 8. Average bract length to width ratios and collective means of 3 different trees (20 measurements from each tree) representing 10 different populations of *Carpinus caroliniana*.

Site Code	Tree 1	Tree 2	Tree 3	Population Mean[1]
I1	1.15	1.15	1.13	1.15
M1	1.13	1.23	1.25	1.21
M2	1.20	1.13	1.30	1.21
I2	1.28	1.29	1.25	1.30
K2	1.33	1.28	1.36	1.32
K1	1.37	1.26	1.40	1.34
T1	1.37	1.32	1.4.	1.37
A1	1.53	1.20	1.50	1.40
A3	1.48	1.59	1.63	1.57
A2	1.53	1.65	1.63	1.60

[1]Length to width ratios connected by a line are not significantly different at the 0.05 level.

Table 9. Statistical separation of populations of *Carpinus caroliniana* with respect to wood specific gravity.

Latitude	Site Code	Specific Gravity[1]
40°25'	I1	.654
43°29'	M1	.619
38°42'	I2	.612
37°20'	K1	.612
42°53'	M2	.598
36°07'	T1	.589
36°43'	K2	.578
31°10'	A3	.571
32°18'	A2	.563
34°48'	A1	.532

[1]Specific gravity means connected by lines are not significantly different at 0.05 level.

Table 10. Populational differences in bud bursting under controlled environmental conditions.

Site	M1	M2	I1	I2	K1	K2	T1	A1	A2	A3
Program I										
Days Below 4° C[1]	75	80	82	72	61	43	51	56	40	47
25% Bud Burst	33	--	--	34	19	26	23	20	18	18
50% Bud Burst	--	--	--	51	20	27	27	22	18	19
Program II										
Days Below 4° C[1]	97	102	104	93	83	65	72	78	62	69
25% Bud Burst	18	19	14[2]	26	16	17	17	14	12	13
50% Bud Burst	21	23	15[2]	28	18	20	19	14	13	13
Program III										
Days Below 4° C[1]	118	123	125	114	104	86	93	99	83	90
25% Bud Burst	9	11	--	19	10	10	9	9	9	8
50% Bud Burst	10	14	--	--	13	12	13	10	10	9

[1]Days include field conditions prior to January 9, 1976, as well as days held in cold chamber at 4° C subsequent to collection.

[2]All bud bursting occurring in one tree only.

Results of the third set of buds placed in the growth chamber receiving 93 to 130 days of below 4 C temperatures showed the northern and southern populations to experience bud bursting at approximately the same time (Table 10). The material from the central latitudes required a considerably longer period of warm temperatures before initiating spring activity.

Soil pH values collected from 10 sites in the Central United States were consistantly within the range of 4.4 to 6.8 as reported in Table 11.

The preliminary germination test was unsuccessful as none of the seeds from the four populations tested germinated under the controlled environmental conditions. At this point it is not known if the lack of germination was due to low viability of the seeds or to the test conditions. Further investigation is needed to examine such factors as seed stratification and light requirement in order to determine what regulates germination of this species.

Table 11. Soil pH at ten collection sites of *Carpinus caroliniana* in the Central United States.

Site Code	pH
M1	6.8
M2	6.6
I1	6.2
I2	6.0
K1	4.4
K2	6.4
T1	4.8
A1	6.4
A2	5.6
A3	5.2

DISCUSSION

The autecological and physiological investigation of Carpinus caroliniana was two fold: first, a community and site analysis in Western Kentucky revealing percent frequency, and relative density of Carpinus and its five most abundant associated species in the Mississippian Plateau and the Western Kentucky Coal Fields; secondly, morphological and physiological investigations of this species along a latitudinal gradient to determine potential populational differentiation in fruit weight, fruiting structure morphology, wood specific gravity and bud bursting.

As previously mentioned, the two physiographic regions studied in Kentucky demonstrated no major differences in relative density or percent frequency of Carpinus, or of the five most common species associated with Carpinus. This may indicate that Carpinus has a broad ecological amplitude, allowing wide distribution over varied physiographic conditions. Comparison of relative canopy densities above Carpinus reaffirm this hypothesis. Although wide variation in canopy cover was observed between several populations, no correlation between the amount of light penetrating the canopy and the number of associated Carpinus at each site was evident. This indicates a wide range of light tolerance, increasing the species amplitude.

Results of the soil pH investigation show wide variation between the two Western Kentucky regions, with no apparent correlation between the pH variation and the number of Ironwood or the abundant species at each site. Wherry (1968) reports that Carpinus is preferential to soils ranging from pH 6.0 to 8.0. However, collection sites with a recorded pH of 4.4 showed equal or greater numbers of associated Carpinus than the more neutral soils observed at other collection sites.

Fruit weight comparison of latitudinally diverse populations of Carpinus reveals possible ecotypic variation. The heaviest fruit originated from northern latitudes which experience the shortest growing season. Generally, the lightest fruit came from the southern latitudes which consequently have the longest growing season. Similar results from Acer negundo L. were reported by Williams and Winstead (1972) when northern and southern populations were pooled latitudinally and tested for variance. McWilliams et al. (1968) demonstrated congruent findings working with Amaranthus retroflexus L. from various latitudes of origin when grown under uniform environmental conditions. They found a highly significant (0.01) level of correlation between seed weight and latitude of origin. Other species documented to have similar results are Phoradendron tomentosum (May, 1969), Fraxinus americana, Prunus serotina, and Acer rubrum (Winstead et al., in press). Increased fruit weight in higher latitudes may be related to greater productivity. Black (1958) pointed out that larger seeds apparently have some competitive advantage in northern habitats. More stored

food in a larger seed may provide a selective advantage in habitats where the growing season is short and seedling establishment is beneficial before canopy closure. However, it must be remembered that the Carpinus fruit was taken from field collections. The latitudinal seed weight variation observed may be ecophenic responses to the local environments, masking the true genetic potential.

The apparent variation observed in the fruit weight raises the question as to whether a similar clinal response in bract size is present in the Carpinus fruit. Results of this study indicate that bract surface area gets larger with a corresponding increase in latitude. Differentiation of this nature may be related to fruit weight variation. Bracts of northern populations with greater surface area demonstrated generally heavier seeds, while the southern populations with a lesser surface area produced smaller seeds. The three lobed subtending bract of a Carpinus nut acts as a dissemination unit. Morley and Katznelson (1965) concluded that larger seed size may be accompanied by a disadvantage in dispersion. Williams (1970) documented a latitudinal clinal correlation between seed weight and wing size of Acer negundo. As seed weight increased the wing length also increased. The longer and wider bracts of Carpinus, collected from higher latitudes, could conceivably be a selective adaptation for maximum dispersability of the heavier nuts.

The results of the wood specific gravity investigation depict a tendency toward greater specific gravity in northern latitudes and a significantly lower specific gravity in the

southern regions. Although not perfectly clinal, a definite pattern can be observed. Deviations from the ecoclinal character may be attributed to ecophenic differences masking the genetic potential of these populations.

Reporting on wood specific gravity differences in Pinus ponderosa, Echols and Conkle (1971) found that wood specific gravity decreased as elevation of the seed parent tree increased. Trees in their study were grown from seed under uniform environmental conditions. This may explain the variation observed in the Athens, Alabama population which is 152 meters higher in elevation than the other Alabama populations. From the present study, it is only possible to say that significant differences in specific gravity of field samples do exist. True ecotypic potentials can only be determined by growth of seedlings under uniform environmental conditions.

Winstead (1972) documented that differences in specific gravity due to latitudinal variation in Liquidambar styraciflua were caused by differences in lumen diameter, not cell wall thickness. Northern populations exhibited the lowest lumen to cell wall ratio, resulting in a corresponding high specific gravity. Ironwood's overall slow growth and high density may be indicative of a small lumen to cell wall ratio. The latitudinal variation observed might be due to a decrease in lumen size in northern populations, yielding an increase in specific gravity.

Winter buds collected from latitudinally diverse field populations demonstrated a high degree of interpopulational variation in response to cold temperature preconditioning.

After receiving only 50 to 87 days of temperatures below 4 C, the first program showed apparent latitudinal response to bud bursting with a longer time period required for bud bursting as latitude increases. McMillian and Peacock (1964) documented a similar response in Prosopis (Mesquite), grown under uniform conditions. They concluded that late bud bursting in northern populations (Oklahoma and Texas) was a selective advantage, preventing frost damage after early warm periods.

The second program of 72 to 109 minimum days at 4 C depicted a similar pattern but with a shorter time period between maximum bud bursting in the north and south. Following 93 to 130 cold days at 4 C, the third program revealed the central latitude populations (Indiana, Kentucky and Tennessee) retaining the longest dormancy. The northern and southern populations experienced bud bursting at approximately the same time. McNaughton (1967) reported a similar response in altitudinally diverse forest community samples placed under controlled environmental conditions. He reported that woody plants originating from the intermediate elevations required a greater time duration for maximum bud bursting than did either of the extreme elevations. McNaughton proposed that unstable temperature and frequent late frosts of the intermediate altitudes selected against the early bud bursting genotypes. In regard to Carpinus, the central latitudes are noted for their winter thaws and warm periods followed by frost. Without a protective mechanism to prevent

spring bud initiation, frost damage would be severe. On the other hand when spring begins in the northern and southern extremes there is generally little variation and consequently no need for an extended dormancy.

It may be concluded from this study that Ironwood bud bursting is primarily dependent on two factors: first, the amount of cold preconditioning experienced prior to spring-like conditions; secondly, the latitudinal origin of the parent plant, the duration of cold necessary to break winter dormancy is latitudinally variable. Extended cold requirements of the central latitude populations in the Eastern United States can be viewed as a protective mechanism impeding spring development during brief warm periods in the winter.

SUMMARY

Community analysis of *Carpinus caroliniana* from a wide range of habitats in Western Kentucky revealed a characteristic association with *Platanus occidentalis*, *Acer saccharum*, *Liquidambar styraciflua*, *Fraxinus* spp. and *Fagus grandiflora*. There was little variation of *Carpinus* and its most common associates in Western Kentucky. Broad ecological amplitude in *Carpinus* is indicated by a wide range of tolerance to variation in light intensity and pH, in conjunction with its unchanging character in different physiographic regions. This broad amplitude allows *Carpinus* to easily adapt to different habitats not only in Kentucky but in all of the Eastern United States.

In the study of latitudinally diverse populations of *Carpinus* fruit weight in the northern habitats was significantly heavier than observed in the lower latitudes. This possibly denotes increased productivity in northern areas. A clinal response in bract size was found from Michigan to Alabama, with the greatest surface areas occuring in the higher latitudes. Response of this nature may have evolved from a selective pressure for larger dispersal wings to correspond with heavier seeds.

Higher wood specific gravity in the more northern populations sampled in this study indicates possible inherent differences in growth rates between populations that merit further study. The latitudinal variation observed might be due to a decrease in lumen size in northern populations, yielding an increase in specific gravity. Possible ecotypic variation in bud bursting was found within the latitudinal range studied. Bud bursting in the central latitudes required the longest period of cold treatment before spring initiation would occur. This possibly indicates a protective mechanism in preventing freeze damage after unseasonably warm periods.

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