

THE ECONOMIC POTENTIAL OF *CHENOPODIUM BERLANDIERI* IN PREHISTORIC EASTERN NORTH AMERICA

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ABSTRACT.—A thin-testa domesticate chenopod (*Chenopodium berlandieri* ssp. *jonesianum*) was present in the eastern woodlands of North America by approximately 3500 BP., and this cultigen subsequently became one of the more important components of pre-maize plant husbandry systems in the East. The economic potential of this prehistoric domesticate can be projected through harvest studies of present day wild/weedy stands of *Chenopodium berlandieri*. During the fall of 1984 and 1985 a total of 86 plants located in nine states were harvested, with timed harvest hand stripping experiments carried out on 16 stands. Harvest yield values varied from 276 kg/ha to 2854 kg/ha. Harvest rate values ranging from .41 kg/hr to 1.6 kg/hr were recorded. Relatively conservative harvest yield and harvest rate values of 750-1500 kg/ha and 0.7 - 1.1 kg/hr are proposed for *C. berlandieri* in the prehistoric eastern woodlands, and when a seed coat thickness correction factor is applied, the resultant relatively conservative harvest yield range estimate of 500 - 100 kg/ha is found to favorably compare to quinoa and maize, as well as other eastern pre-maize cultigens.

INTRODUCTION RESEARCH DESIGN

The tropical cultigen triad of corn, beans, and squash often is considered the core of prehistoric plant husbandry in Eastern North America, and these three crops were certainly of substantial economic importance during the late prehistoric period. But maize apparently was not introduced into the East any earlier than about A.D. 200-300 (Ford 1987, Chapman and Crites 1987, Yarnell and Black 1985:102; Smith 1985a:51), and food production systems dominated by maize did not develop in the eastern woodlands of North America until after A.D. 1000 (Smith 1985a:51, 1986).

When it first arrived in the eastern woodlands maize was adopted as just another starchy seed crop within already established "pre-maize" plant husbandry systems which centered on a group of six plant species: sumpweed (*Iva annua*), sunflower (*Helianthus annuus*), goosefoot (*Chenopodium berlandieri*), ¹ erect knotweed (*Polygonum erectum*), maygrass (*Phalaris caroliniana*), and little barley (*Hordeum pusillum*) (Yarnell and Black 1985). The two pre-maize oily-seed crops, sunflower and sumpweed, were long-standing domesticates in the East, as was at least one of the starchy-seed crops—a thin testa cultivar chenopod (Smith 1987a, Smith and Cowan 1987). When maize was initially introduced into the East at ca. A.D. 200-300, these three long standing domesticates had recently been joined by a no-testa or naked cultivar chenopod (Fritz 1986), as well as by, perhaps, a domesticated variety of knotweed (Fritz 1987). Little barley and maygrass, both spring harvested starchy-seed crops, were also important in pre-maize food production economies, even though no archaeological specimens of either species have *as yet* been demonstrated to exhibit morphological changes associated with domestication.

Variation in the relative abundance of seeds of these pre-maize cultigens in archaeobotanical assemblages from different regions of the East suggest both geographical and temporal diversity in their economic importance (Smith 1985a:52). These assemblages

also reflect a fairly uniform increase in the importance of such regionally diverse pre-maize plant husbandry systems across the mid-latitude interriverine area of the East at about 2,500-2,000 B.P. (Smith 1985a:52,70), and these indigenous seed crops appear to have continued in importance up through the post A.D. 1000 transition to maize agriculture. But they seem to have all but disappeared from view by the time of European contact. With the possible exception of Harriot's 1586 account from the Carolinas of sunflower and *melden* (Sturtevant 1965), and LePage's eighteenth century description of *choupichoul* being grown by the Natchez (Smith 1987b), the ethnohistorical record is silent in regard to possible remnant pre-maize cultigens of the eastern woodlands.

In the past decade the developmental trajectory of these pre-maize plant husbandry systems, from initial emergence to eventual decline, has attracted increasing research interest because of their likely central role in the evolution of more complex Woodland period (2500-1200 B.P.) prehistoric societies in the prehistoric East. One important aspect of gaining a better understanding of these early cultigens involves attempting to determine their economic potential through both nutritional analyses of seeds, and present day harvesting experiments to establish their potential yield. The nutritional composition of seeds has been established for *Polygonum erectum* (Asch and Asch 1985:361); *Chenopodium berlandieri/bushianum* (Asch and Asch 1985:361); *Phalaris caroliniana* (Crites and Terry 1984); *Iva annua* (Asch and Asch 1978); and *Helianthus annuus* (Earle and Jones 1962, Watt and Merrill 1963; Jones and Earle 1966:15). In addition, Seeman and Wilson (1984) and Murry and Sheehan (1984) provide nutritional composition information for other species of *Polygonum* and *Chenopodium*. Efforts to obtain potential harvest yield information for these six pre-maize crops, on the other hand, have proven difficult because of the apparent present-day absence of large wild or weedy stands suitable for harvest studies. Because of this difficulty modern harvest yield research has yet to be carried out on either maygrass or little barley. Potential harvest yield estimates for sunflower are derived from modern commercial field crop statistics (e.g. Martin and Leonard 1967:932-933). In addition, potential yield information for *Polygonum erectum* is limited to a single 25 ft² (2.29 m²) stand harvested by Murray and Sheehan during their study of five species of *Polygonum* in Illinois and Indiana (1984:288, 290-291). Similarly, harvest yield projections for *Chenopodium berlandieri/bushianum* are based on two isolated plants, each occupying about 1 m² (Asch and Asch 1978:313). Unable to locate any populations of *Chenopodium berlandieri* large enough to sample repeatedly, Seeman and Wilson (1984) provide detailed harvest yield information for *Chenopodium missouriense* stands harvested in Indiana. *Iva annua* is the best documented of these six early cultigens in terms of both harvest rate values (based on 20 timed collections from seven stands) and harvest yield values (based on eight total yield collections from 1 m² plots) (Asch and Asch 1978).

In light of their central role in fueling prehistoric Woodland period cultural change, it is surprising that information concerning the potential prehistoric economic potential of these pre-maize seed plants is so limited, and that so few present-day wild stands have been harvested. In order to begin to fill this gap in our understanding of these prehistoric crop plants, and to learn more about their habitat requirements, present day geographical ranges, and harvest yield potential, I began, in the fall of 1984, an annual fall harvesting circuit through the eastern United States. For the first two years field studies focused on *Iva annua* and *Chenopodium berlandieri*, and this article reports the results of the 1984 and 1985 harvests in regard to *Chenopodium berlandieri*.

METHODS

One of the main goals of the 1984-1985 fall harvesting project was to locate and harvest stands of *Iva annua* and *C. berlandieri* over a broad area of the Midwest and

Southeast. Accordingly, instead of spending an extended period of time in any one area, I selectively concentrated my survey efforts in those high probability target habitats I thought likely to support stands of either of these two species. Because sumpweed was known to be a component of early successional floodplain communities, I selected a route of travel through the East that crossed and recrossed a number of river valleys, and surveyed at each river crossing, up and down the floodplain for several miles in search of stands of *Iva annua* and *C. berlandieri*.

These two species frequently colonize recently disturbed soil in both floodplain and upland locations, and are often found growing on construction sites, in vegetable gardens and agricultural fields, as well as in a wide range of other settings, including vacant lots, abandoned gas stations, playgrounds, parking lots, cotton gin waste dumps, dredging spoil piles, under bridges, etc. Such disturbed ground habitat settings were easy to recognize from a moving car, and I frequently stopped to investigate them, particularly when chenopod plants were observed in passing. Although most chenopod stands occurring in such disturbed soil situations were dominated by the ubiquitous *C. missouriense*, pockets of *C. berlandieri* were occasionally located within larger stands of *C. missouriense*. By combining the deliberate surveys of river valley segments with more opportunistic surveys of upland disturbed soil situations as they were observed, I was able to investigate a large number of chenopod stands while still traveling over 200 miles per day.

Each *C. berlandieri* stand located was assigned a field catalog number and this, along with its geographical location and habitat setting and plant characteristics, were recorded in a field notebook. Stand and individual plant characteristics which were described included: (1) Stand size in square meters; (2) Individual plant height in centimeters; (3) Plant habit and habitat—the shape and habitat setting of plants (e.g. slender and unbranched, growing in dense cover, light shade); (4) The color and condition of individual plants.

Harvesting was accomplished by hand stripping individual infructescences (fruit clusters) into a bag attached to the belt loops of the collector. Large plastic garbage bags served admirably in this capacity when simply twisted through belt loops and tied off, leaving both hands free for me to grasp an infructescence in a closed fist and strip it from the plant into the waist bag (see Seeman and Wilson 1984:305 for other harvesting options for *Chenopodium*). Harvest times for individual plants were recorded in most cases. Each evening, after removing the infructescence material harvested that day from the plastic waist bags, I placed it on newspaper overnight to partially dry, then repackaged it in paper bags for further drying. When I found a stand containing *C. berlandieri* plants which still retained leaves, a voucher specimen was pressed for the National Herbarium (NMNH). Occasionally I also collected entire plants after stripping their infructescences, returning them to the lab to be dried and weighed.

Subsequent to thorough drying and weighing in the laboratory, harvested fruit was winnowed from perianth, leaf and stem fragments². Cleaned fruits comprised from 65% to 79% of unwinnowed material (Table 1).

TABLE 1.—Harvest Yield Information for 86 *Chenopodium berlandieri* Plants.

| Catalog Number | Plant Height (cm) | Plant Weight (gms) | Unwinnowed Fruit Wt. (gms) | Winnowed Fruit Wt. (gms) | Unwinnowed /Winnowed Ratio | Harvest Time (min.) |
|----------------|-------------------|--------------------|----------------------------|--------------------------|----------------------------|---------------------|
| 20 | 122 | 8.6 | | 4.62 | | |
| 21 | 127 | 18.2 | | 27.19 | | |
| 22 | 84 | 7.7 | | 5.31 | | |

TABLE 1.—*Harvest Yield Information for 86 Chenopodium berlandieri Plants. (continued)*

| Catalog Number | Plant Height (cm) | Plant Weight (gms) | Unwinnowed Fruit Wt. (gms) | Winnowed Fruit Wt. (gms) | Unwinnowed /Winnowed Ratio | Harvest Time (min.) |
|----------------|-------------------|--------------------|----------------------------|--------------------------|----------------------------|---------------------|
| 23 | 112 | 13.1 | | 12.88 | | |
| 24 | 79 | 4.3 | | 3.66 | | |
| 25 | 46 | 4.7 | | 3.73 | | |
| 26 | 56 | 5.1 | | 4.01 | | |
| 27 | 61 | | | 14.76 | | |
| 28 | 183 | | | 72.4 | | |
| 39 | 152 | | | 109.0 | | 7:00 |
| 40 | 124 | | | 11.14 | | 0:45 |
| 41 | 58 | | | 2.98 | | 0:15 |
| 42 | 142 | | | 19.17 | | 1:00 |
| 82A | 183 | 160.0 | | 49.0 | | 2:00 |
| 87 | 200 | 126 | | 91.8 | | 8:00 |
| 89A | 58 | 16.8 | | 12.6 | | 1:00 |
| 89B | 86 | 36.4 | | 38.4 | | 2:00 |
| 90A | 105 | 220.0 | 75.7 | 55.2 | 73 | 2:00 |
| 90B | 83 | 95.3 | 41.9 | 30.3 | 72 | 1:30 |
| 90C-1 | | 5.4 | 3.3 | 2.3 | 73 | 0:15 |
| 90C-2 | | 17.3 | 11.0 | 8.4 | 77 | 0:15 |
| 90C-3 | | 24.1 | 22.6 | 17.3 | 77 | |
| 90C-4 | 48 | 1.4 | .9 | .7 | 78 | |
| 90C-5 | | 10.5 | 4.0 | 2.8 | 70 | |
| 91 | 150 | 497.5 | | 428.1 | | 16:00 |
| 92A | | 3.2 | | 2.6 | | |
| 92B | | 18.5 | 11.7 | 8.5 | | |
| 92C | | 18.5 | | 16.7 | | |
| 92D | | 12.5 | | 8.6 | | |
| 92E | 21.1 | | 18.6 | | | |
| 92F | | 10.7 | 5.6 | 3.9 | | |
| 92G | | 26.1 | | 31.5 | | |
| 92H | | 23.1 | | 20.5 | | |
| 92I | | 60.0 | 30.4 | 19.7 | 65 | |
| 92J | | 82.2 | 103.8 | 71.6 | 69 | |
| 94A | 125-150 | | 93.3 | 71.7 | 77 | 8:00 |
| 94B | 125-150 | | 148.2 | 101.6 | 68 | 8:00 |
| 94C | 125-150 | | 144.7 | 100.8 | 70 | 11:00 |
| 94D | 175-200 | | | 127.3 | | 10:00 |
| 94E | 125-150 | | | 89.1 | | 6:00 |
| 94F | 100-125 | | | 74.4 | | 9:00 |
| 94G | 100-125 | | | 10.8 | | 1:00 |
| 94H | 175-200 | | 71.5 | 56.7 | 79 | 4:40 |
| 94I | 150-175 | | | 9.7 | | 1:40 |
| 94J | 75-100 | | | 5.1 | | 1:00 |

TABLE 1.—*Harvest Yield Information for 86 Chenopodium berlandieri Plants. (continued)*

| Catalog Number | Plant Height (cm) | Plant Weight (gms) | Unwinnowed Fruit Wt. (gms) | Winnowed Fruit Wt. (gms) | Unwinnowed /Winnowed Ratio | Harvest Time (min.) |
|----------------|-------------------|--------------------|----------------------------|--------------------------|----------------------------|---------------------|
| 94K | 75-100 | | | 20.6 | | 1:00 |
| 94L | 75-100 | | | 14.9 | | 2:12 |
| 94M | 100-125 | | | 58.5 | | 2:30 |
| 94N | 75-100 | | | 10.4 | | 0:49 |
| 94O | 75-100 | | 21.4 | 16.6 | 78 | 1:19 |
| 94P | 100-125 | | | 41.4 | | 3:15 |
| 94Q | 125-150 | | | 61.5 | | 3:55 |
| 94R | 125-150 | | | 76.0 | | 6:30 |
| 94S | 100-125 | | | 73.0 | | 4:00 |
| 94T | 100-125 | | | 33.3 | | 1:30 |
| 94U | 50- 75 | | | 7.0 | | 0:54 |
| 94V | 100-125 | | | 34.0 | | 5:15 |
| 94W | 125-150 | | | 68.0 | | 7:00 |
| 94X | 100-125 | | | 79.2 | | 5:00 |
| 94Y | 75-100 | | | 32.2 | | 1:30 |
| 94Z | 175-200 | | | 84.6 | | 4:17 |
| 94AA | 75-100 | | | 36.2 | | 4:00 |
| 94BB | 100-125 | | | 80.5 | | 4:30 |
| 94CC | 175-200 | | 230.6 | 175.5 | 76 | 11:00 |
| 94DD | 100-125 | | | 32.2 | | 2:00 |
| 94EE | 75-100 | | | 15.0 | | 2:27 |
| 94FF | 75-100 | | | 9.1 | | 0:15 |
| 94GG | 75-100 | | | 1.5 | | 0:30 |
| 94HH | 75-100 | | | 9.5 | | 1:13 |
| 94II | 100-125 | | | 78.7 | | 6:00 |
| 94JJ | 125-150 | | | 66.8 | | 5:10 |
| 95A | 75-100 | | | 35.0 | | 4:05 |
| 95B | 75-100 | | | 26.8 | | 2:13 |
| 95C | 75-100 | | | 31.0 | | 3:40 |
| 95D | 125-150 | | | 129.8 | | 10:10 |
| 95E | 75-100 | | | 23.4 | | 1:27 |
| 95F | 75-100 | | | 13.4 | | 0:30 |
| 95G | 75-100 | | | 22.3 | | 2:45 |
| 95H | 175-200 | | | 30.5 | | 3:34 |
| 95I | 75-100 | | | 5.0 | | 0:45 |
| 95J | 125-150 | | 83.2 | 54.4 | 65 | 4:30 |
| 96 | 100 | | | 49.2 | | 3:00 |
| 101A | 200 | 32.2 | | 9.1 | | |
| 101B | 100 | | | 0.3 | | |
| 105 | 86 | 5.0 | 2.6 | 2.0 | 77 | |
| 108 | 60 | | 4.5 | 3.4 | 76 | |

RESULTS

During harvesting trips through the eastern United States in the autumn of 1984 and 1985, *C. berlandieri* stands were harvested in Maryland, Pennsylvania, Ohio, Michigan, Missouri, Tennessee, Arkansas, Alabama, and South Carolina. I recorded individual plant yield information for a total of 86 *C. berlandieri* plants (Table 1), and carried out timed harvest experiments on 16 *C. berlandieri* stands (Table 2).

TABLE 2.—*Harvest Yield Information for Sixteen Stands of Chenopodium berlandieri.*

| Catalog Number | Stand Area [square meters] | Number of Plants | Fruit Weight [grams] | Harvest Yield [kg/ha] | Harvest Time [min] | Harvest Rate [kg/hour] |
|-------------------------------------|----------------------------------|------------------------|----------------------------|-----------------------------|--------------------------|------------------------------|
| 30 | 250 | 4000(?) | 459.8 | — | 22 | 1.250 |
| 39-42 | 1 | 4 | 142.3 | 1423 | 9 | .949 |
| 57 | 1 | 10 | 108.9 | 1089 | 9 | .726 |
| 58 | 1 | 9 | 83.3 | 833 | 6 | .832 |
| 59 | 1 | 7 | 121.3 | 1213 | 8:30 | .856 |
| 82A | 1 | 3 | 49.0 | 490 | 2 | 1.470 |
| 87 | 1 | 1 | 91.8 | 918 | 8 | .689 |
| 88 | 2 | 58 | 112.6 | 563 | 5 | 1.350 |
| 890 | 1 | 2 | 51.0 | 510 | 3 | 1.020 |
| 90 | 1 | 4 | 95.9 | 959 | 4 | 1.438 |
| 91 | 1.5 | 1 | 428.1 | 2854 | 16 | 1.605 |
| 92 | 3 | 10 | 202.2 | 679 | 12 | 1.010 |
| 94 Top Ten Plants | | | | | | |
| 94CC | 1 | 1 | 175.0 | 1750 | 11 | .955 |
| 94D | 1 | 1 | 127.3 | 1273 | 10 | .764 |
| 94B | 1 | 1 | 101.6 | 1016 | 8 | .762 |
| 94C | 1 | 1 | 100.8 | 1008 | 11 | .540 |
| 94E | 1 | 1 | 89.1 | 891 | 5 | 1.060 |
| 94Z | 1 | 1 | 84.6 | 846 | 4:17 | 1.190 |
| 94BB | 1 | 1 | 80.5 | 805 | 4:30 | 1.073 |
| 94X | 1 | 1 | 79.2 | 792 | 5 | .950 |
| 94II | 1 | 1 | 78.7 | 787 | 6 | .786 |
| 94R | 1 | 1 | 76.0 | 760 | 6:30 | .702 |
| 94 Top Ten Plants (clustered)[a] | 10 | 10 | 1064.0 | 1064 | 71 | .899 |
| 94 All 36 plants (clustered) | 32 | 36 | 1860 | 580 | 148 | .754 |
| 95D | 1 | 1 | 129.8 | 1298 | 10 | .778 |
| 95 All Ten Plants (clustered) | 10 | 10 | 371.6 | 371 | 34 | .655 |
| 96 | 1 | 1 | 49.2 | 492 | 3 | .984 |
| 97 | 3.5 | 27 | 96.7 | 276 | 14 | .414 |

[a] The individual plants comprising stands 94 and 95 were fairly widely scattered across a heavily overgrown soybean field (Figure 5). In order to estimate what the harvest yield values for each of the stands would be if the plants were not so scattered, "clustered" statistics were obtained by centering each plant in an arbitrary 1 meter square and then assuming that the one meter squares adjoined each other.

Because of the elusive nature of present-day stands of *C. berlandieri*, the absence of previous research, and the need for additional harvest experiments on modern descendant populations of this important prehistoric cultigen, I provide the following brief, if admittedly tedious, descriptions of the stands harvested in 1984 and 1985.

Wayne County, Michigan (Catalog numbers 20-30, 87-88).—Catalog numbers 20-28 were assigned to individual *C. berlandieri* plants harvested in October 1984 from a disturbed soil setting in a vacant lot in Grosse Pointe, Michigan. Large, often dense (>50 plants per m^2), stands of both *C. berlandieri* and *C. missouriense*, frequently mixed, occurred in both full sun and light shade. A mixed stand of *C. berlandieri* and *C. missouriense* covering an area of approximately $250 m^2$ and located in partial shade was assigned field number 30 and selectively harvested in October, 1984. With an approximate average density of 50 plants per m^2 (4 plots, counted, each $1 m^2$), the stand contained about 12,000 plants, ranging in height from 30-130 cm, with few lateral branches. As is almost always the case in upland mixed stands, *C. missouriense* was the more abundant of the two species, comprising over three-fourths of the stand. Rather than being scattered randomly, *C. berlandieri* plants formed a number of discrete pockets within the larger stand. The largely leafless, distinctively mustard colored *C. berlandieri* plants had dark, large fruited, and glomerate infructescences. I could easily distinguish them, both by touch and sight, from the still leafed purple stemmed *C. missouriense* plants had dark, large fruited, harvesting of the stand relatively easy. Moving through the stand and selecting the largest and most visible infructescences, I was able to hand strip 300 *C. berlandieri* infructescences into a waist bag in 22 minutes, yielding 575 g of infructescence material and 460 g of clean fruit after winnowing.

Returning to this vacant lot in October of the following year I harvested an isolated, still green, 2 m high *C. berlandieri* plant growing in full sun, and having 28 lateral branches (Catalog number 87). In addition, I harvested a $2m^2$ cluster of 58 *C. berlandieri* plants (Catalog number 88, Table 2) found growing within a 15×20 m stand of *C. missouriense*.

Fulton County, Pennsylvania (Catalog numbers 38-42).—Catalog numbers 38 (herbarium voucher) and 39-42 were assigned to 5 individual plants harvested from a $1m^2$ cluster of *C. berlandieri* found within a surrounding $4m^2$ stand of *C. missouriense* growing in a construction site dirt pile.

Mississippi County, Arkansas (Catalog numbers 57-59).—A 5×7 m stand of *C. missouriense* was observed growing in full sun on a roadside dirt pile in November of 1984. Catalog numbers 57, 58 and 59 were assigned to three separate clusters of *C. berlandieri* located within the larger dense stand of *C. missouriense*. Each less than $1 m^2$ in area, these clusters contained 10, 9 and 7 plants respectively. The *C. berlandieri* plants ranged in height from 130-150 cm, had few lateral branches within a meter of the ground, and could be visually distinguished from the surrounding, still green, *C. missouriense* plants by their grayish brown leafless condition and generally smaller size.

Cherokee County, South Carolina (Catalog numbers 82A-82Q).—Three clusters of *C. berlandieri* were observed growing adjacent to a bridge over the Broad river in November, 1984. Two of the clusters (82 A-C, 82 D-G) were approximately $1 m^2$ in area, while the third (82 H-Q) was 1×3 m in size. All of the plants were dead and had lost the majority of their fruit.

Prince Georges County, Maryland (Catalog numbers 89A, 89B).—In the spring of 1985 *C. berlandieri* seeds were scattered in turned soil adjacent to garden plots at the Museum

Support Center, Smithsonian Institution, in Silver Hill Maryland. Only two plants (89A, 89B) grew to maturity, however, likely due to a very dry growing season and a failure to expose the seeds to freezing temperatures during the preceding winter. Upon harvesting them in October, both plants were dry, brown, with partial seed loss, and were choked by a dense growth of grass and weeds.

Washington County, Maryland (Catalog number 90A, 90B, 90C1-90C5).—In November, 1985, I observed *C. missouriense* growing in fill dirt along a roadside guardrail. Within this stand I harvested a 1x2 m cluster of *C. berlandieri* containing two large (90A, 90B) and five smaller (90C1-90C5) plants. These seven plants were all dead, brown, and dry, with partial seed loss, and could be easily distinguished from the surrounding, still green *C. missouriense* plants. The two larger plants, along with two of the smaller plants (90C-1, 90C-2) occupied an area of less than 1 m².

Pike County, Ohio (Catalog numbers 91, 92A-92J).—Catalog number 91 was assigned in November 1985 to a single *C. berlandieri* plant growing in an overgrown creek bottom vegetable garden (corn, pumpkins, sunflowers, summer squash) (Fig. 1). Occupying a 1x1.5 m area, the large (height 1.5 m), bright yellow leafless plant had numerous lateral branches with black terminal infructescences (Fig. 2). Little seed loss was apparent. After hand stripping, the plant was felled and subsequently weighed in the laboratory. Occupying a 1x3 m area, a stand of ten *C. berlandieri* plants (92A-92J) was found growing in dense undergrowth in the same garden (Fig. 3). The plants all had leafless yellow stalks and black infructescences, and could be quickly distinguished from the surrounding dense undergrowth.

Mississippi County, Missouri (Catalog numbers 94A-94JJ, 95A-95J, 96, 97).—Forty six *C. berlandieri* plants (94A-94JJ, 95A-J) were found growing in an overgrown soy bean field



FIG. 1.—Overgrown creek bottom vegetable garden location of *Chenopodium* stands 91 and 92. Pike County, Ohio.

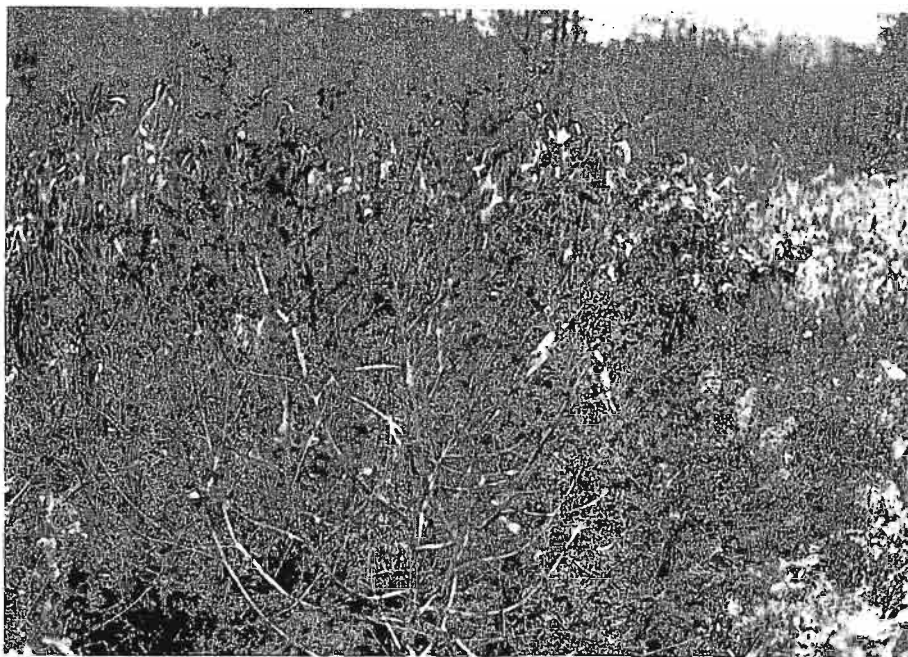


FIG. 2.—A large *Chenopodium berlandieri* plant, field catalog number 91, which yielded 428 gm of seeds [surrounding weeds removed prior to photograph].

in November, 1985. Separated from the main channel and sand bars of the Mississippi River on the east by a 20-30 m wide black willow vegetation zone, and from the levee on the west by a 100 m wide lowlying area of wet clay soil (Fig. 4), the soybean field was about 70 m wide and paralleled the river for approximately 160 m. The mature but unharvested field of soybeans, which appeared not to have been sprayed with herbicides and to have been generally neglected, was thickly overgrown with weeds, including johnson grass, wild bean (*Strophostyles helvola*) and both *C. missouriense* and *C. berlandieri*. In contrast to previously observed upland situations where these two chenopod species were found growing in the same locales, *C. missouriense* was not a dominant constituent of the weed plant community [see Seeman and Wilson 1984:305]. *C. berlandieri*, on the other hand, was quite abundant in the field.

C. Wesley Cowan and I mapped, described, and harvested a rather scattered linear stand of 46 plants over a period of 4 hours (Fig. 5). After being mapped and assigned a letter code, the height of each plant was recorded, along with information regarding stalk and infructescence color and condition, the relative abundance of lateral branches, and the presence/absence of wild bean vines. Catalog number 96 was assigned to a single *C. berlandieri* plant located 20 m from the main channel of the Mississippi River. Growing in full sun on the sand beach of the river, and partially entangled by *Strophostyles helvola*, this specimen was brown and dry, with numerous lateral branches (Fig. 6). After locating catalog specimen 96 along the sandy beach edge of the Mississippi River, C. Wesley Cowan and I walked further south along the river for a distance of about 400 m within the relatively narrow (20-50m) black willow vegetation zone which paralleled the river's edge. In the light shade setting under a willow canopy, *C. berlandieri* plants were quite common, often occurring in linear stands paralleling the river. In contrast to the habit of *C. berlandieri* plants observed growing in full sun, these partial shade understory plants



FIG. 3.—The dense understory setting of *Chenopodium berlandieri* stand 92.

had thin straight stalks and lateral branches having few leaves and small diffuse infructescences (Fig. 7). In addition, these understory plants were still green and in full leaf. We harvested a stand of 27 plants occupying a 3.5 m² area (Fig. 7).

Hardin County, Tennessee (Catalog numbers 101A, 101B).—Two *C. berlandieri* plants were found growing in a bank slump area along the Tennessee River and harvested in November of 1985. Located in partial shade, both plants were similar in habit to the understory plants described above (97), having tall thin stalks and lateral branches with diffuse infructescences. Both plants were leafless and brown, with 101A exhibiting little apparent fruit loss, while 101B had lost most of its fruits.

Cullman County, Alabama (Catalog number 105).—In November, 1985 I located a stand of 4 *C. berlandieri* plants in a flat floodplain area only 5 m from the edge of the Black Warrior River. All four plants were still green and were in excellent condition for herbarium specimens. Three of the four were pressed for the collections of the National Herbarium (NMNH), while the fourth was hand stripped for the present study.

Tuscaloosa County, Alabama (Catalog number 108).—In November 1985 I located a single plant in thick understory at the top of a steep sand bank down to the Black Warrior River. Growing in full sun, the plant was still green but leafless when harvested.



FIG. 4.—Looking east from the Mississippi River levee toward the soybean field location of *Chenopodium berlandieri* stands 94 and 95. The main channel and opposite shore of the Mississippi River are visible in the background, along with exposed sand bars. The low clay soil area separating the levee from the soybean field is visible in the foreground.

DISCUSSION

The Habitat of C. Berlandieri In The Eastern Woodlands.—The field research phase of this study confirmed what a number of previous researchers had noted—*C. berlandieri* is an elusive subject for harvest yield experiments since it is not generally abundant nor does it frequently occur in large stands in the Eastern United States (Seeman and Wilson 1984:303,304; Asch and Asch 1977:25; Munson 1984). As a result of the field research reported here, the preferred habitat situation of this species can now be described with a greater degree of accuracy, which should facilitate the location of stands for future harvest yield studies.

The primary habitat of *C. berlandieri* in the Eastern United States is river valley floodplains, particularly large meandering rivers such as the Mississippi River and its major tributaries. Within this river valley alluvium habitat zone *C. berlandieri* can be found growing in a number of different disturbed soil situations. Primary among these is as an abundant understory constituent of black willow river margin sand bank vegetation communities. These “naturally disturbed” river margin black willow zones are subject to annual scouring by floodwaters and deposition of alluvial, primary heavy fraction sandy, soil. Within this shady understory setting *C. berlandieri* plants are tall, slender, have small diffuse infructescences, and a quite low seed yield per square meter value (Table 2, Fig. 8, catalog number 97). Wahl (1954:44) briefly mentions this river margin understory habitat setting for *Chenopodium berlandieri*: “*C. bushianum* occurs most often as a weed of cultivated places but is found also in alluvium along streams and in waste places. The shade form is more delicate.” Steyermark (1963:614) also mentions this habitat: *C. bushianum* “occurs in sandy fields and alluvial ground along rivers, waste

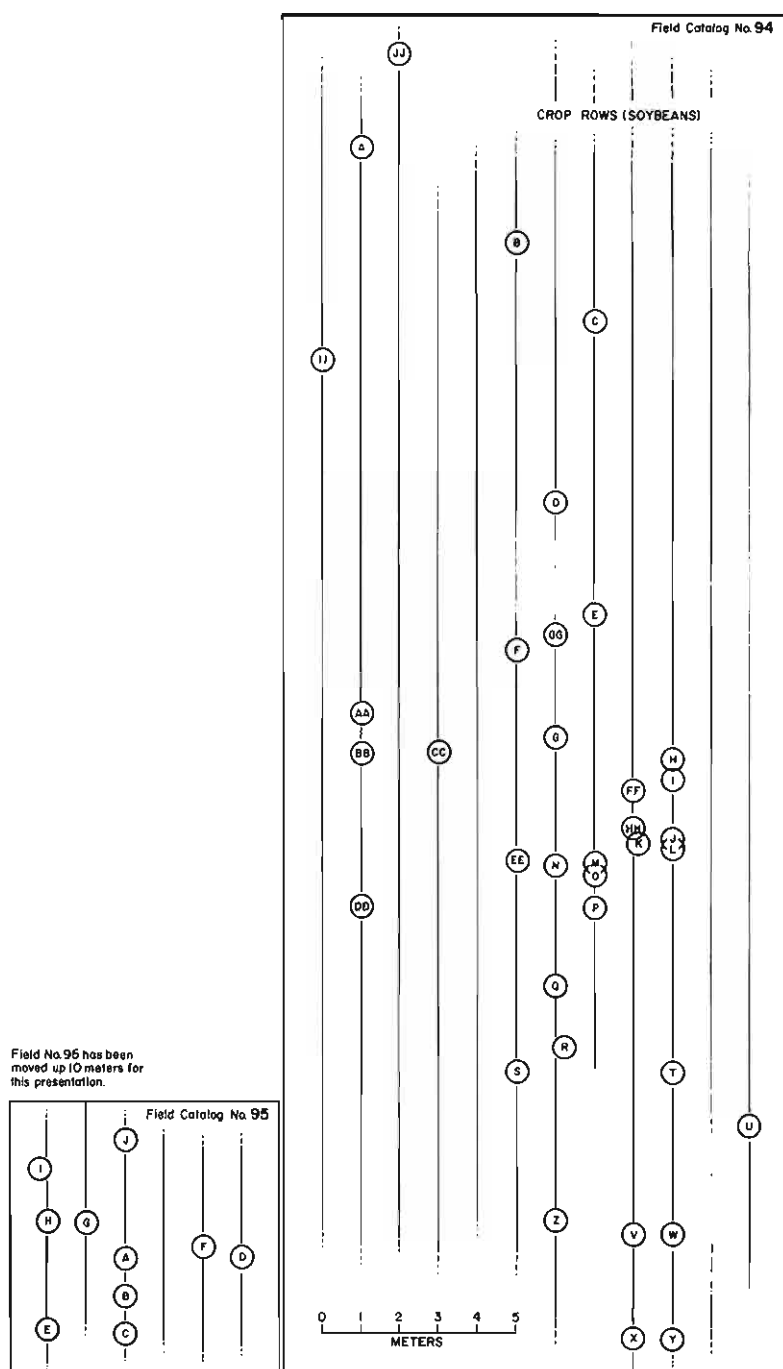


FIG. 5.—The location of the 46 *Chenopodium berlandieri* plants comprising stands 94 and 95. Illustration by Britt Griswold.

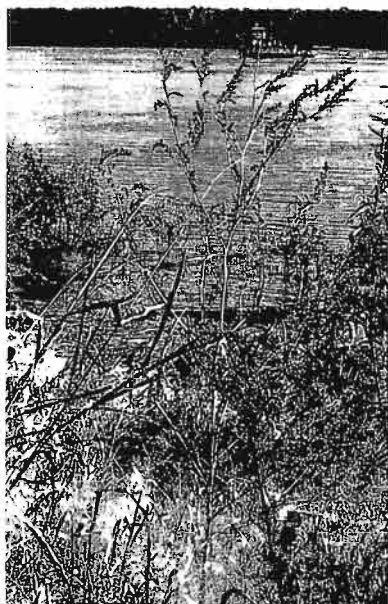


FIG. 6.—A *Chenopodium berlandieri* plant growing on the sandy bank of the Mississippi River.

places, wooded slopes, and dry open or shaded ground." In addition, a Field Museum of Natural History herbarium specimen identified as *C. bushianum* and examined by Asch and Asch [1977:36] carried the following habitat description: "riverbank among trees—Fargo, North Dakota."

While this understory setting can be considered the primary "natural" floodplain habitat of *C. berlandieri*, the plant also occurs in two other nearby "naturally disturbed" floodplain situations. Jackson's statement [1985:183] that "stands of chenopods also can be found along bank margins left bare by receding summer water level" corresponds with field observations made in November 1985 regarding *C. berlandieri*. As the water level of the Mississippi River receded during the summer and fall, the exposed river margin sand beach supports multibranched *C. berlandieri* plants with large terminal infructescences (Table 1, Fig. 6, catalog number 96). Unstable and actively eroding river and terrace banks and bluffs also support occasional, often solitary, *C. berlandieri* plants, particularly along the upper bank edge (Table 1, catalog numbers 101, 105, 108; Asch and Asch 1977:20; Munson 1984:381, 383-384). It is important to note that while *C. berlandieri* can be recognized as occurring in at least three different "naturally disturbed" habitat settings within river valley floodplains, Styermark's [1963:614] reference (quoted above) to the plant's association with sandy soil is quite perceptive in that *C. berlandieri* rarely occurs in other floodplain soils of heavier texture. Although Asch and Asch (1977) describe a late season stand of *Chenopodium berlandieri* growing on an exposed mudflat in the lower Illinois River Valley, such stands are rare. During



FIG. 7.—The light shade black willow understory setting of *Chenopodium berlandieri* stand 97.

extensive surveys by Klein, Daley and Wedum (1975) and by Munson (1984) of Illinois and Mississippi River Valley mudflats exposed during seasonal drying of shallow lakes, ponds, and sloughs no chenopod species were noticed in mudflat vegetation communities.

In addition to occurring in these three overlapping naturally disturbed sandy soil floodplain situations, *C. berlandieri* can also be found in a variety of anthropogenically disturbed soil settings. It is often the dominant chenopod weed in river valley fields and gardens (catalog numbers 91, 92, 94, 95). Wilson and Walters [n.d.] describe the habitat of *C. bushianum* as "disturbed ground, especially alluvial soil of agricultural areas", while Styermark (1963:614) has it occurring " . . . in sandy fields and alluvial ground along rivers", and Wahl (1954:44) considers it as "A weed of cultivated places . . .", also found "in alluvium along streams and in waste places." While floodplain sandy soil fields and

gardens can be considered the primary "anthropogenic" disturbed habitat setting for *C. berlandieri* in the Eastern United States, it is also found in other disturbed soil and waste place settings in both river floodplains (under bridges— catalog number 82) and upland areas (fields, gardens, construction sites and along highways). *C. berlandieri* occurs only infrequently in upland settings where it is rarely alone, but is almost invariably found growing in small scattered pockets, as a minor constituent within larger stands dominated by *C. missouriense* (catalog numbers 20-28, 38-42, 57-59, 87-88, 90) (Asch and Asch 1977:25-26; Seeman and Wilson 1984:303-305).

In summary, *C. berlandieri* in the Eastern United States is an early successional plant species inhabiting a variety of different natural and anthropogenically disturbed sandy soil situations within river valley floodplains. Within such river valley floodplains environments it would not be at all unusual to find *C. berlandieri* inhabiting a number of adjacent habitats all situated within 50 m of each other (exposed low water river margin sand beaches, black willow understory, eroding terrace sand banks, and floodplain agricultural fields). It is also an infrequent minor constituent in upland disturbed soil area chenopod stands. It is thus within the meander belt of the Mississippi River and its tributaries, adjacent to active main channels, that stands of *C. berlandieri* suitable for harvest studies are most likely to be encountered. Within this area, poorly weeded and overgrown natural levee fields and gardens provide the best opportunity for locating extensive stands of multiple branched plants. That floodplain gardens and fields hold the best promise for future harvest yield studies of this plant is underscored by the results of the 1984-1985 fall harvest project. While only four of the 16 stands harvested were situated in floodplain fields, those four stands (91, 92, 94, 95) yielded two-thirds of the total seed collected. Fortunately, such present-day floodplain fields and gardens also represent essentially the same setting within which prehistoric cultivation of *C. berlandieri* would have primarily occurred.

The Economic Potential Of C. Berlandieri.—Yield values obtained for the 16 *C. berlandieri* stands harvested in 1984 and 1985 show considerable variation (Table 2, Fig. 8), from a low of 276 kg/ha recorded for field catalog number 97—the 3.5 square meter black willow, partial shade stand, to a high of 2854 kg/ha for stand 91, a single plant occupying 1.5 m² and yielding 428 g of seed. This variability is to be expected because of considerable variation in both the amount of sun received by different stands and the degree of crowding and competition from surrounding plants. Variation in plant height to seed yield ratios and plant weight to seed yield ratios (Table 1) also reflect differing degrees of competition and sunlight. Substantial seed loss prior to harvesting was only occasionally a factor in harvest yield variation (82A, 101B). The long period seed retention of *C. berlandieri* is well documented (Wahl 1954, Seeman and Wilson 1984:303, 309). The application of fertilizers and herbicides played undocumented roles in influencing yield values.

In the only previous published consideration of the economic potential of *C. berlandieri*, Asch and Asch (1978:313), present yield values of 1330 and 1740 kg/ha for two tall multiple branched plants, each growing in an open full sun plot "in which the plants had maximum potential for vegetative growth." Because of the limited competition represented in the case of these two plants, Asch and Asch suggested that it was "probably unreasonable to extrapolate its production to a large stand where the chenopods would be competing with each other" (1978:313). While the harvest yield values presented by Asch and Asch fall toward the upper end of the range of yield values recorded in the present study (Fig. 8), I think that they do not represent unreasonably high approximations for prehistoric *Chenopodium* production in the Eastern Woodlands. Their average yield value [1535 kg/ha] is about half that of the most productive [plant] stand in the present study (field catalog number 91, yielding 2854 kg/ha), and falls about midway along the documented range of variation (276 - 2854 kg/ha). In addition, with the exception

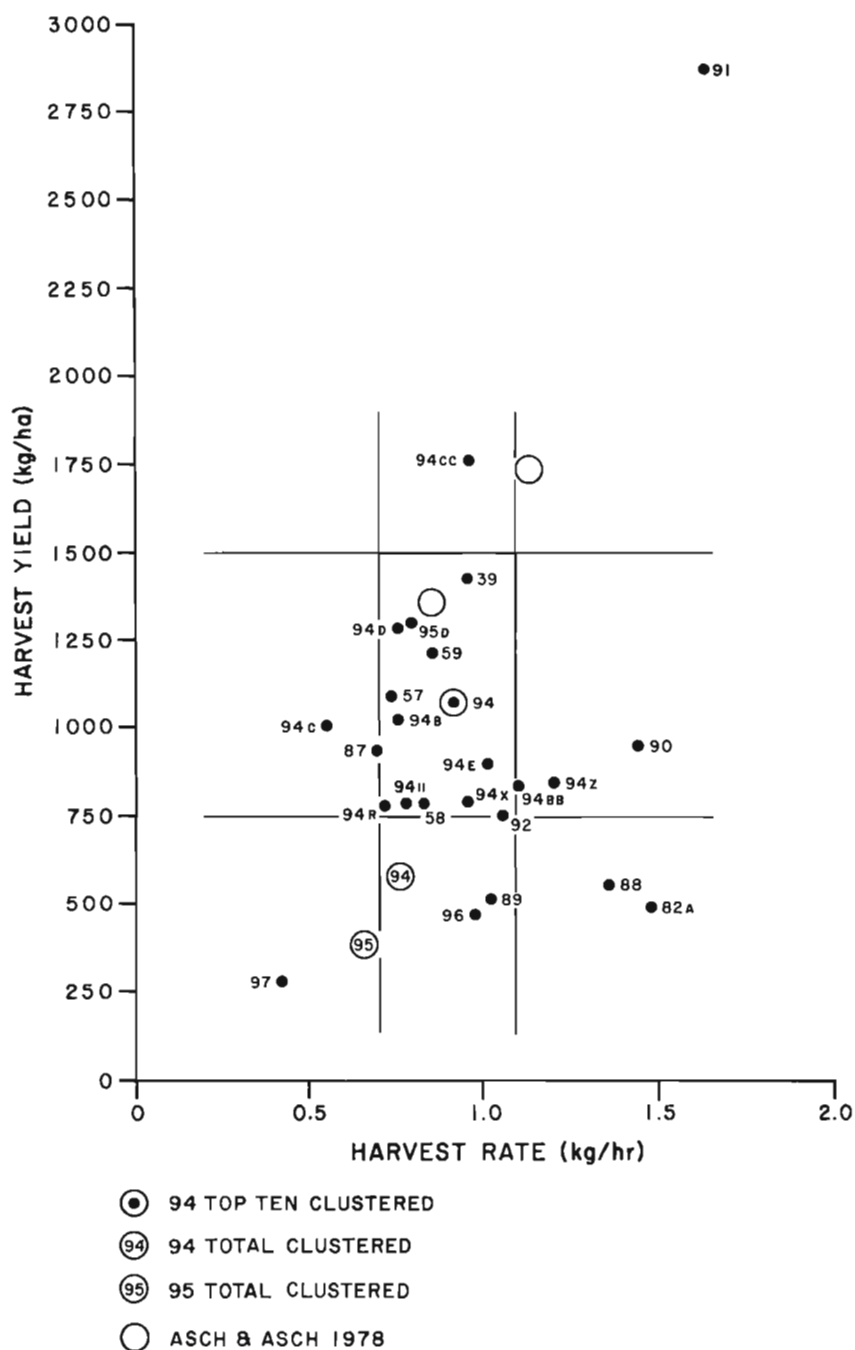


FIG. 8.—Harvest yield [kilograms/hectare] and harvest rate [kilograms/hour] values for 16 *Chenopodium berlandieri* stands harvested in 1984 and 1985, compared with the single plant yields reported by Asch and Asch (1978). See Table 2 for explanation of "clustered" values. Range estimates for harvest yield values [750-1500 kg/ha] and harvest rate [.7 - 1.1 kg/ha] are indicated.

of stands 82a and 87, all of the plants harvested in the present study were competing with other plants, either as small pockets surrounded by larger stands of *C. missouriense*, or in dense undergrowth situations (Figs. 1, 3, 9). As a result, with the exception of stand 91, the yield values obtained from the 16 stands harvested in 1984 and 1985, as presented in Fig. 8, could be considered as defining the lower end of the range of likely prehistoric

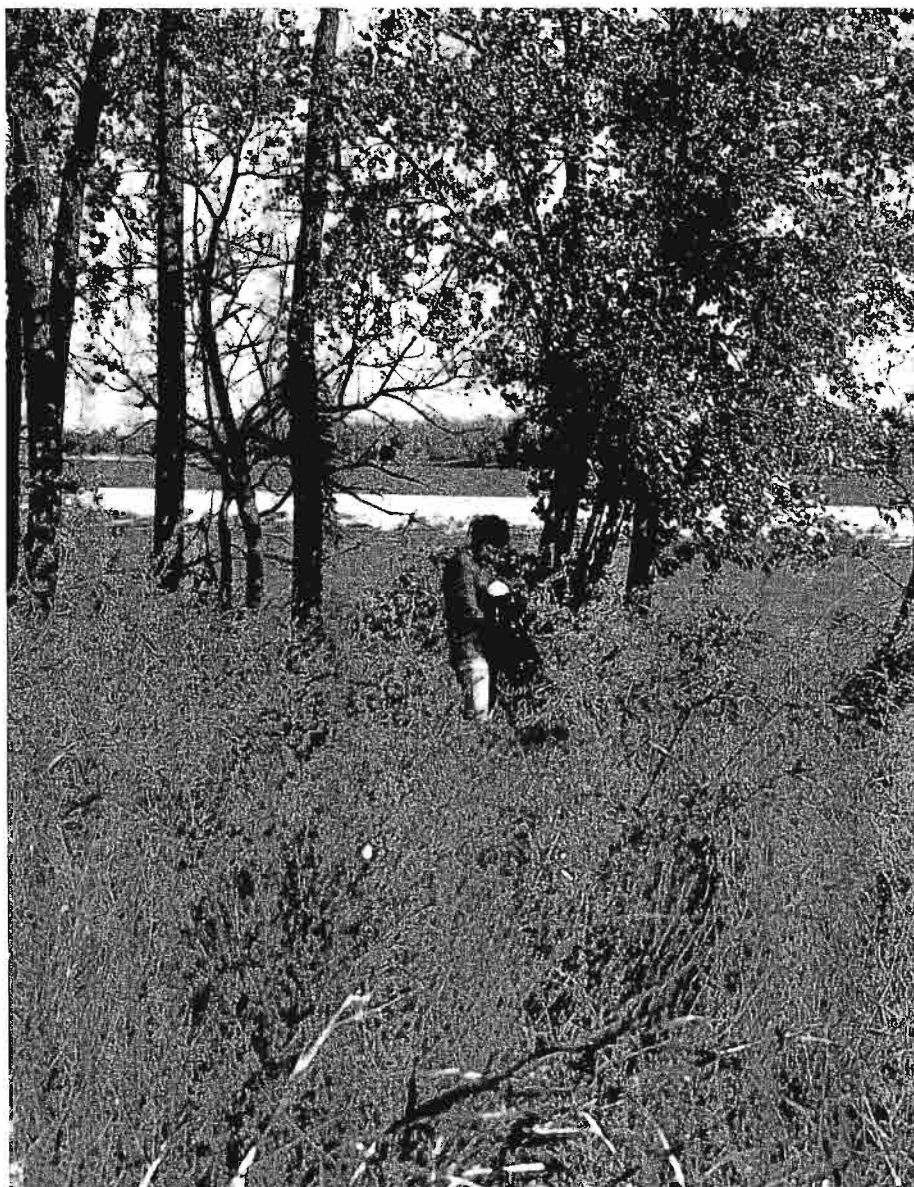


FIG. 9.—The dense weedy growth setting of *Chenopodium berlandieri* stand 94. An exposed sand bar of the main channel of the Mississippi River is visible in the background.

harvest yield levels for *C. berlandieri*—what might be expected from poorly maintained and overgrown fields. A relatively conservative range estimate of 750-1500 kg/ha for prehistoric yield levels for *C. berlandieri* is proposed (Fig. 8).

Harvest rate values obtained during this study also showed considerable variation, with stands 97 and 91 again providing minimum (.41 kg/ha) and maximum (1.6 kg/hr) values, respectively. Variability in harvest rate values was due primarily to differences in the size and degree of compactness, and terminalization of infructescences of harvested plants. The light shade plants of stand 97 had numerous small and diffuse infructescences which took far longer to locate and to strip than the large compact fruit clusters of stands 91-92 and 94-95 (Fig. 10). Surrounding chenopod plants and weeds, particularly wild bean (*Strophostyles helvola*) also substantially decreased harvest rates by making it more difficult to see and reach infructescences. A relatively conservative harvest rate range estimate of 0.7-1.1 kg/hr. is proposed for *Chenopodium berlandieri* in the prehistoric Eastern Woodlands (Fig. 8).

Harvest Yield Comparisons.—In order to make any harvest yield comparisons between *C. berlandieri* and other crop plants of the prehistoric eastern woodlands of North America, it is first necessary to take into consideration the thick seed coat of the modern wild/weedy populations of *C. berlandieri* harvested in the present study. Ranging in thickness from 40-70 microns (Smith 1985b), the seed coat of wild/weedy fruits consists largely of non-nutritive fiber, and accounts for at least 30% of the seed weight (Seeman and Wilson 1984).

Of the two prehistoric domesticated varieties of *C. berlandieri* cultivated in the prehistoric eastern woodlands, one, *C. berlandieri* ssp. *jonesianum*, had a thin (20 microns) testa (Smith and Funk 1985), and the other lacked a testa entirely (Wilson 1981, Fritz 1986). Harvest yield rates, at least 30% lower could therefore be expected for prehistoric cultivated stands producing the same number of fruits per hectare as modern wild/weedy stands. Reducing harvest yield values obtained during the present study by 30% (from 750-1500 kg/ha to 525-1050 kg/ha) results in a closer approximation of the nutritive yield of thin testa and testa-less prehistoric cultigen varieties (Fig. 11).

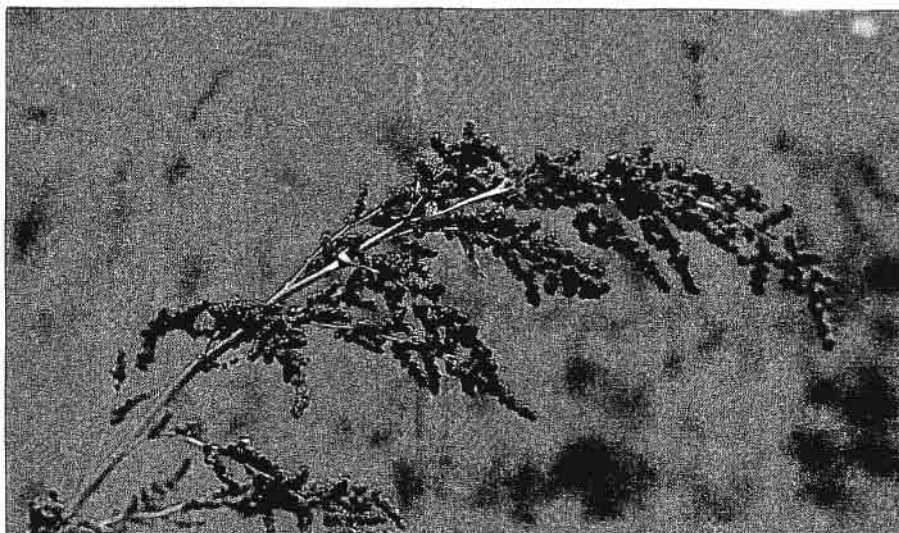


FIG. 10.—The typical infructescence form of *Chenopodium berlandieri* plants growing in full sun.

CHENOPODS

Chenopodiumberlandieri^aambrosioides^bmissouriense^cquinoa^dquinoa^equinoa^f

EASTERN CULTIGENS

Iva annua^g

(sumpweed)

Polygonum erectum^h

(knotweed)

Helianthus annuusⁱ

(sunflower)

OTHER SEED PLANTS

Zea mays^j

(maize)

Zea mexicana^k

(teosinte)

Triticum dicoccoides^l

(wild emmer wheat)

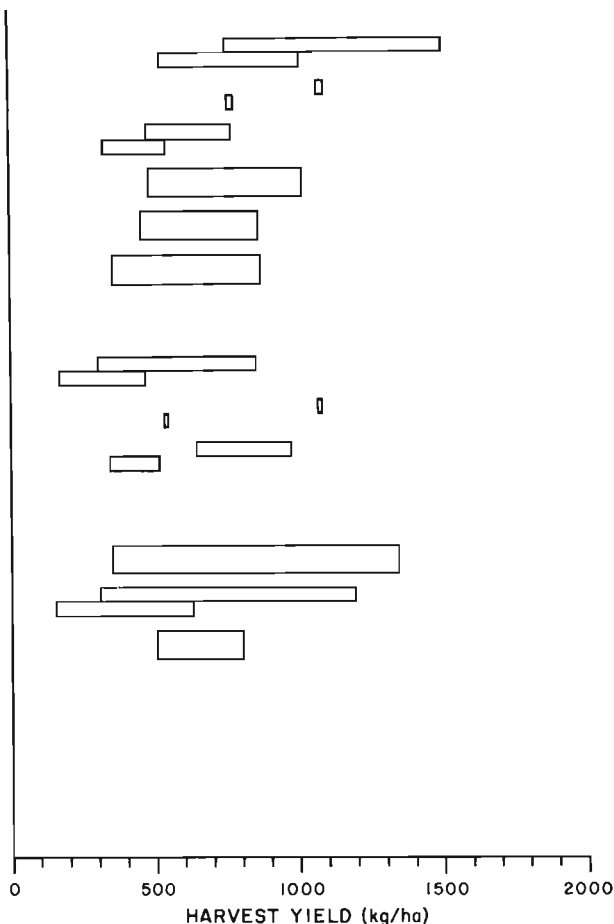


FIG. 11.—Range estimate harvest yield values for ten seed plants. To facilitate comparison of yield estimates, paired bar graphs are presented for those species with thick "seed coats", indicating harvest yield range values with and without seed coats.

(a) Results of this study. Plants hand stripped, weights represent clean seed. Range values 750 - 1500 kg/ha and 525 - 1050 when corrected for 30% seed coat weight.

(b) Containing ascaridole, which kills internal parasites, *C. ambrosioides* is cultivated and machine harvested in Carroll County, Maryland for its oil. Yields of 1000 pounds of seed per acre (1120 kg/ha) have been reported (Seeman and Wilson 1984:307).

(c) Hand stripping, cutting, and mass collecting (whole plants cut, bundled, dried, and threshed, with fruits then winnowed) harvesting methods employed. Yields ranged from 473 - 769 kg/ha, 331 - 539 kg/ha when corrected for seed coat weight [Seeman and Wilson 1984].

(d) Quinoa plants cut, dried, flailed, and fruit winnowed (Mass collecting method). Yields ranged from 504 - 1008 kg/ha (Elmer 1942).

- (e) Mass collecting method (White *et al.* 1955).
- (f) Mass collecting method, machine threshed (Johnson and McCamant 1986).
- (g) Best seven of eight 1 m² plots. Hand stripping method employed. Kernal considered 55% of total achene weight. Yields ranged from 300 - 850 kg/ha, 165 - 468 kg/ha when corrected for achene shell weight (Asch and Asch 1978).
- (h) A single stand occupying 25 ft² (2.29 m²) harvested by hand stripping. Assuming achene "shells" accounted for 50% of total achene weight, harvest yield values of 1115 and 557 kg/ha (corrected for achene shell weight) were derived (Murry and Sheehan 1984).
- (i) Martin and Leonard (1967:932) report that the 627 farms growing sunflower commercially in the United States in 1959 produced 623,000 bushels of seed from 25,732 acres, for an average yield of 24.2 bushels (576 pounds of seed) per acre (645 kg/ha). Assuming that achene shells comprise 46% of total achene weight, Asch and Asch (1978:314) derived a hulled clean seed yield value of 350 kg/ha. Martin and Leonard also reported typical yields of 784 - 1120 kg/ha for the major producing states (Minnesota and North Dakota), and noted yields of 2016 kg/ha from California. In addition they provide an average world production level of 979 kg/ha for the 17 million acres under cultivation in 1959. The average U.S. and World production levels (645 kg/ha and 979 kg/ha are employed to define a range estimate, with associated range estimate yield values for cleaned seed being 348 kg/ha and 528 kg/ha.
- (j) Harvest yield estimates reported by Will and Hyde (1917) for Indian groups of the Upper Missouri during the 1860s and 1870s. Yields of 8 - 30 bushels per acre (unshelled) allowed a range estimate of 358 - 1344 kg/ha to be derived.
- (k) Yields of 305 - 1254 kg/ha reported by Robson *et al.* (1967:247). Assuming the fruit capsule (involucure) accounts for 50% of seed yield (Robson *et al.* 1967), a range estimate of 152 - 617 kg/ha was derived for clean seed.
- (l) Hand stripped, clean grain, range estimate for optimum yield, rainy year (Zohary 1969).

Application of the same 30% reduction factor to two other modern thick testa chenopods (*C. ambrosioides* and *C. missouriense*) results in harvest yield estimates of 784 kg/ha and 331-538 kg/ha respectively (Fig. 11). While *C. missouriense* falls at the lower end of the range of values obtained for *C. berlandieri*, *C. ambrosioides* falls within the *C. berlandieri* range.

The modified range estimate of 525-1050 kg/ha for *C. berlandieri* is also quite comparable to harvest yield values reported for *C. quinoa*, the (testa-less) domesticated chenopod of South America. Elmer (1942) reports average yields of 504-10008 kg/ha, and White *et al.* (1955:535) present production figures of 493-896 kg/ha. Recent initial plantings of *C. quinoa* (varieties 407 and 407 black) in Colorado have resulted in yields of 331-805 kg/ha. Yields of 997 kg/ha were also obtained from 5 1m² plots of *C. quinoa* variety 407 grown at Vadito, Colorado in 1985 (Johnson and McCamant 1986). Optimal yields in the 3,000-5,000 kg/ha range for *C. quinoa* have also been reported or projected (Elmer 1942:21; White *et al.* 1955:535; Johnson and McCamant 1986).

Because the harvest yield range estimate for *C. berlandieri* presented here is so comparable to the large acreage cultivated harvest yield estimates available for *C. quinoa*,

it would not seem unreasonable to propose a harvest yield range estimate of 500-1000 kg/ha for prehistoric chenopod cultivated in the eastern woodlands of North America. This range estimate of 500-1000 kg/ha can in fact be considered rather conservative, if differential efficiency of harvest methods are considered. The cutting of either infructescences (cutting method) or whole plants (mass collection method) for subsequent drying and flailing for seed recovery have been shown to be more effective methods for harvesting *Chenopodium* than simple hand stripping (Seeman and Wilson 1984:308-309) in that they result in higher harvest yields. Mass collection is the harvest method employed today in South America by Quechua Groups (Elmer 1942, Gade 1970), and may also have been the preferred prehistoric method in the east, judging from the stored sheaves of *C. berlandieri* recovered from dry caves and rock shelters (Seeman and Wilson 1984:309).

Nevertheless, the proposed harvest yield range estimate of 500-1000 kg/ha for *C. berlandieri* is considerably higher than available harvest yield values for other pre-maize crop plants of the eastern woodlands. Asch and Asch obtained harvest yield values of 77-468 kg/ha from 8 1m² plots of *Iva annua* (1978:310). Murry and Sheehan (1984) report a harvest yield value of 1115 kg/ha for *Polygonum erectum*, based on the collection of a 2.29 m² stand. Assuming that the achene "shell" accounts for 50% of total knotweed achene weight, *P. erectum* would have a corrected harvest yield value of 557 kg/ha, at the lower end of the range proposed for *C. berlandieri* (Fig. 11). Similarly, employing the 1959 United States and world average production figures for sunflower (645 kg/ha, 979 kg/ha; Martin and Leonard 1967:932) to define a harvest yield range estimate, and assuming that the achene "shell" accounts for 46% of the total achene weight (Asch and Asch 1978:314), the corrected harvest yield range estimate of 348-528 kg/ha would only slightly overlap with that of *C. berlandieri*.

Against the backdrop provided by the comparatively lower harvest yield levels of other prehistoric eastern cultigens, the hand-stripped yields of *C. berlandieri* stands underscore both its value as an uncultivated prehistoric plant food source and its pre-eminent potential as a cultigen in pre-maize gardens and fields. The high harvest yield levels of present day uncultivated stands of *C. berlandieri* may help to explain why it was initially brought under domestication prehistorically, as well as its ubiquitous presence and abundance in otherwise regionally variable pre-maize plant husbandry systems of the Eastern Woodlands (Smith 1985a:52). Although having a far thicker seed coat than the prehistoric thin-testa domesticated form of chenopod that was cultivated prehistorically in the Eastern Woodlands, the present day wild-weedy form of *C. berlandieri* in the Eastern United States—the subject of this study—represents an appropriate analog for the prehistoric domesticate in that it retains a number of characteristics of domestication (simultaneous inflorescence, extended seed retention) that strongly suggest that it represents the weedy descendant of the prehistoric domesticate (Wilson 1981).

The seeds of *C. berlandieri* and other "starchy-seeded" crops have relatively low protein and fat content when compared to the "oily-seeded" crops—sumpweed and sunflower (Table 3)—and are high in carbohydrates. As a result, they have been considered to have been less important nutritionally than the "oily-seeded" annuals and to have been roughly comparable to maize in terms of food value. Analysis of the essential amino acid pattern of *C. quinoa*, however, has shown it to be exceptionally high in two essential amino acids (lysine and methionine), which make it extremely attractive as a source of protein and as a general source of human nutrition (White *et al.* 1955; Cusak 1984:23). Although it is yet to be documented, it is quite likely that *C. berlandieri* has a similar amino acid pattern to that of *C. quinoa*.

In addition to shedding light on its initial domestication and subsequent development as an important crop in pre-maize plant husbandry systems of the Eastern United States, the documented economic potential and likely nutritional qualities of *C. berlandieri* also invite a comparison between *C. berlandieri* and maize, which came to

TABLE 3.—*The Nutritive Value of Seed of Cultigens of the Prehistoric Eastern Woodlands of North America (Percent dry basis).*

| Species | Protein | Fat | Carb. | Fiber | Ash |
|-----------------------|---------|-------|-------|-------|------|
| <i>Starchy-seeded</i> | | | | | |
| Goosefoot (a) | | | | | |
| <i>C. berlandieri</i> | 19.12 | 1.82 | 47.55 | 28.01 | 3.50 |
| Maygrass (b) | | | | | |
| <i>P. caroliniana</i> | 23.7 | 6.4 | 54.3 | 3.0 | 2.14 |
| Knotweed (a) | | | | | |
| <i>P. erectum</i> | 16.88 | 2.41 | 65.24 | 13.33 | 2.34 |
| <i>Oily-seeded</i> | | | | | |
| Sumpweed (c) | | | | | |
| <i>I. annua</i> | 32.25 | 44.47 | 10.96 | 1.46 | 5.80 |
| Sunflower (d) | | | | | |
| <i>H. annuus</i> | 24.00 | 47.30 | 16.10 | 3.80 | 4.00 |
| <i>Tropical crops</i> | | | | | |
| Maize (c) | | | | | |
| <i>Z. mays</i> | 8.9 | 3.9 | 70.20 | 2.0 | 1.2 |
| Squash (c) | | | | | |
| <i>C. pepo</i> | 29.0 | 46.7 | 13.10 | 1.9 | 4.9 |
| Bean (e) | | | | | |
| <i>P. vulgaris</i> | 22.0 | 1.6 | 60.8 | 4.3 | 3.6 |
| Quinoa (f) | | | | | |
| <i>C. quinoa</i> | 12.5 | 6.0 | 72.5 | 5.6 | 3.4 |

(a) Asch and Asch 1985:361; (b) Crites and Terry 1984; (c) Asch and Asch 1978; (d) Watt and Merrill 1963; (e) Wu Leung 1961; (f) White et al. 1955.

dominate prehistoric eastern agricultural economies after A.D. 1000. Estimating prehistoric harvest yield values for maize is particularly difficult, due to the lack of documented analog situations involving non-hybrid maize cultivated and harvested without the benefit of fertilizers, draft animals, or machinery. Will and Hyde (1917:103, 108, 142) provide maize yield statistics for the 1860s and 1870s for Indian groups of the Upper Missouri area (South Dakota, North Dakota) which range from 8-30 bushels per acre (1867 Kansa, 19 bushels per acre; 1867 Yanktons, 30 bushels per acre; 1874 Sac and Fox, 20 bushels per acre; 1878 Kansa, 8 bushels per acre; 1878 Santee Sioux, 26 bushels per acre; 1878 average for Upper Missouri groups, 20 bushels per acre). While a bushel of shelled corn weighs 56 pounds (Martin and Leonard 1967:965) it is likely that the statistics extracted by Will and Hyde from historical records referred to bushels of corn on the ear. Since 70 pounds of corn on the ear yields 50 pounds of shelled corn (at a 15% moisture level—Martin and Leonard 1967), each "bushel" of the 1860s-1870s likely contained about 40 pounds of shelled corn. Employing this figure of 40 pounds of shelled corn per bushel, a range estimate of 358-1344 kg/ha can be derived from Will and Hyde's 8-30 bushel per acre range (Fig. 11). While acknowledged as being "no doubt

generous as an estimate of prehistoric yields", average production figures of 10-45 bushels per acre (shelled) have been reported for the pre-hybrid maize grown prior to 1925 in the Black Warrior River valley of west-central Alabama [Peebles 1978:402-403], providing a harvest yield range estimate of 627-2822 kg/ha. The Will and Hyde maize yield data for the northern Plains in the 1860s-1870s probably represents a closer approximation than the Black Warrior River valley values to the prehistoric Woodland levels of maize production in the eastern woodlands.

It will, of course, be difficult to establish with any degree of confidence the economic potential and actual yield of maize in the eastern woodlands during the A.D. 1000 - A.D. 1200 period of transition to maize agriculture. But yields in excess of 1000 kg/ha [about 17 bushels per acre] would have been necessary before maize would represent an attractive alternative to *C. berlandieri* in terms of harvest yield alone. Potential yield obviously was not the only factor influencing crop selection, and maize would likely have required considerably less commitment of time and energy to harvest than *C. berlandieri* during the critical fall period of intensive hunting of deer and collecting of wild plant resources. While maize cobs could be picked, stripped, dried, and stored, *C. berlandieri* would have required cutting and drying of whole plants, followed by flailing and winnowing prior to storage. The continued cultivation of *C. berlandieri* after A.D. 1200 as a secondary field crop within maize dominated field systems is not surprising, given its high yield and nutritional profile and the nutritional shortcomings of maize [Robson *et al.* 1976:246-247].

The obvious next step in pursuing the issue of harvest yield levels for *C. berlandieri* and the other prehistoric cultigens of the Eastern Woodlands is to grow them in relatively large cultivated stands in order to establish their economic potential in well controlled field plot settings. When combined with ongoing morphological and quantitative analysis of archaeobotanical assemblages of these early prehistoric cultigens, such modern experimental studies should provide substantial illumination of the nature and importance of pre-maize food production systems in the Eastern Woodlands of North America.

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NOTES

¹Assignable to subsection *Cellulata* of the genus *Chenopodium* on the basis of its reticulate-alveolate pericarp, the species *Chenopodium berlandieri* subsumes an extensive geographical variety of wild, weedy, and domesticated forms of chenopod. Although still frequently referred to as a distinct species within subsection *Cellulata*, *Chenopodium bushianum*, a large fruited chenopod of the Northeast, Midwest, and mid-latitude Southeast, has been shown to have considerable genetic affinity with *C. berlandieri*, rather than being biologically distinct (Wilson and Heiser 1979; Wilson 1980:260).

As the systematics of eastern North American chenopods belonging to subsection *Cellulata* is revised, it is highly likely that *C. bushianum* will be relegated to subspecific taxonomic status within *C. berlandieri*. In anticipation of this reassessment and reassignment of *C. bushianum*, the species designation *C. berlandieri* is used throughout this article, even when geographical location and fruit size would suggest the species label *C. bushianum*.

²*Chenopodium* produces small indehiscent "seed-like" fruits, each consisting of a seed enclosed by a very thin adherent pericarp. Since this thin pericarp is the only thing distinguishing fruits from

seeds, the terms "seed" and "fruit" are used interchangeably. Winnowing was accomplished in a two step process. Collected infructescence material was first rubbed between the palms of the hands to dislodge fruits from attached perianths, and the material was then distributed along the top edge of an inclined cotton sheet. The lighter and more angular perianth, leaf and stem fragments would adhere to the sheet while fruits would roll down the angled sheet to be collected at its base.

Chemotaxonomie der Pflanzen, Bd. 7: Nachträge zu Band 1 und Band 2. [Plant Chemotaxonomy, Vol. 7: Addenda to Vols. 1 and 2] R. Hegnauer. Basel: Birkhäuser Verlag, 1986. Pp. 804. \$278.91 [cloth].

This is the seventh volume in an immensely valuable series of reference books unequalled in any language. It and two planned future works attempt to update and expand upon the original six volumes, published between 1962 and 1973. Volume 7 supplements volumes 1 (algae, fungi, bryophytes, pteridophytes, and gymnosperms) and 2 (monocots). Volume 8 will augment the material on dicots contained in volumes 3-6 and provide indices for the entire set. Volume 9 will deal exclusively with legumes.

The set as a whole is a systematic, voluminous compilation of the available information on the chemistry of plant constituents. Despite the title, the primary emphasis of the series is on the chemical makeup of various plant taxa rather than on the direct application of chemical evidence in taxonomy. Various diagrams and discussions are presented highlighting diverse theories on the phylogenetic relationships among taxa, but this is done in a superficial way and does not represent the main thrust of the books.

The original volumes surveyed the plant (and fungal) kingdoms family by family, presenting a description of each taxon followed by a discussion of organic constituents which have been isolated from various species in each family. Organic acids, alkaloids, carbohydrates, lipids, and many more compounds are discussed in some detail. The pages are studded with numerous diagrams of chemical structures and tables listing the results of quantitative analyses. There are also frequent charts showing the interrelatedness of various compounds and outlining the biochemical pathways by which some compounds are synthesized.

Perhaps the strongest point of the series is the extensive encyclopedic referencing which will permit the reader to follow up on any line of information contained therein. Volume 7, for example, includes a 195-page annotated bibliography of works in English, French, German, Spanish, and several other languages, this in addition to the reference listing at the end of each chapter. Ethnobiologists seeking information on the makeup of plants used by native peoples can do little better than to start the literature search here.

Those of us fortunate enough to read German will gain even more from this useful reference work as a starting point from which to draw information on chemical botany. I am looking forward to the remaining volumes.

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