Osage Orange (*Maclura pomifera*): History and Economic Uses[1]

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Osage orange, a tree native to Texas, Oklahoma, and Arkansas, was planted widely in the United States as a living fence from 1850–1875. It has naturalized over much of its planted range and is an early successional species. Economically the tree has had a wide number of uses including for bows, yellow dye, and building materials. It is used for fence posts and is a potential source for a proteolytic enzyme. Its taxonomy, anatomy, morphology, chemical constitutents, medicinal uses, and toxicity are discussed in this paper and related to its economic importance.

Osage orange, *Maclura pomifera* (Raf.) Schneid., is a familiar tree native to Texas, Oklahoma, and Arkansas. Most people can easily recognize the species by its characteristic orange-like fruits. It has had a fascinating history and varied economic uses. Many workers have been interested in this species and much study has been conducted on the secondary chemical constituents, morphology, anatomy, and pests of Osage orange. The purpose of this paper is to review, summarize and augment what is known concerning the nomenclature, description, history, distribution, ecology, propagation, economic uses, medicinal uses, toxicity, diseases, pests, antifungal and biotic activity, hemagglutinins, and chemical composition of this notable species.

NOMENCLATURE AND DESCRIPTION

Osage orange belongs to the Moraceae, the mulberry family. The number of species within the genus *Maclura* is not agreed upon; Willis (1973) recognizes 12 species, while Burton (1973) recognizes only 1. In past geologic times there were many species of *Maclura*. Fossils from the interglacial periods indicate that some of the many *Maclura* species grew as far north as Ontario (Peattie, 1953). Osage orange was first named by Rafinesque, who called it *Ioxylon pomiferum* in 1817. He changed the name to *Toxylon pomiferum* in 1818 and then to *Joxylon pomiferum* in 1819 (Morton, 1967). Thomas Nuttall found a stand of the species in 1818 and named it *Maclura aurantiaca* in honor of his friend William Maclure, an early American geologist (Peattie, 1953). Because of Nuttall's prestige, his name was generally accepted (Morton, 1967). Other names that have been given this species are: *Broussonetia tinctoria*, *Toxylon aurantiacum*, and *Toxylon Maclura* (Sargent, 1947). The accepted name today, *Maclura pomifera*, is from Schneider although *Maclura aurantiaca* is frequently found in the literature.

Osage orange is the favored common name for the species, a name derived from the fruits which resemble oranges and from the Osage Indians, who frequently used the wood for bows and clubs (Burton, 1973). The use of the wood for bows led early French explorers to name the tree *bois d'arc*, or wood-of-the-bow (Peattie, 1953). Other common names include: Osage-orange (Little, 1953), bodark, hedge, hedge-apple, Osage apple, horse-apple, mock-orange, bow-wood, and yellow wood.

One hybrid of Osage orange is recognized, i.e., *Cudrania tricuspidata* × *Maclura pomifera* var. *inermis* = *Macludrania hybrida* André (Burton, 1973; Rehder, 1940), and this hybrid is sometimes planted in the United States. *Cudrania* is native to China, Korea, and Japan.

Leaves

The leaves are deciduous and alternate. Their shape ranges from broad-ovate to ovate-lanceolate, rounded or subcordate at the base to broadly cuneate or acuminate at the apex (Vines, 1960). They are 4–12 cm long, 2–6 cm wide, and have entire margins. Leaf blades are dark green, smooth and waxy above; paler with a few hairs beneath (Stephens, 1969). Their autumn color is a clear yellow (McCurdy et al., 1972). Petioles are 1.0–2.5 cm long, slender, grooved on top, and somewhat hairy (Rogers, 1905). Stipules are triangular, small, and early deciduous.

Flowers

Osage orange is dioecious with green to greenish-yellow flowers appearing after the leaves in mid-May to June (Pool, 1919). Staminate flowers are arranged in long-peduncled axillary racemes about 2.5–4.0 cm long on the terminal leaf spur of the previous season (Rogers, 1905; Stephens, 1969). These flowers have a 4-lobed calyx with exserted stamens, but no petals (Vines, 1960). The pistillate flowers are located axillary to the leaves in dense, globular clusters, 1.5–2.5 cm in diameter (Rogers, 1905; Stephens, 1969). The calyx is 4-lobed, thick, and encloses the ovoid, compressed, 1-celled ovary (Vines, 1960). The styles are filiform, long, and exserted.

Pollen and pollination

Osage orange is wind pollinated (Peattie, 1953). The pollen grains (Fig. 1) are round, smooth, and have 1 (rarely), 2, 3, or 4 pores. Vast quantities are released, occasionally causing hay fever (Peattie, 1953).

Fruits

The "hedge-ball" is a multiple fruit consisting of many 1-seeded druplets fused into a globose, yellowish-green structure, 8–12 cm in diameter (Stephens, 1969; Vines, 1960). Fruits average 450 g in weight but range from 150–700 g. They are permeated with a milky, sticky juice that causes a dermatitis in some people. The fruits ripen in September–October and generally fall to the ground after the first hard frost. Trees may start to bear fruits at 10 yr of age. The seeds are 8–12 mm long and are embedded in the fleshy calyx (Vines, 1960). They are cream-colored at first but turn brown after aging or exposure to air.

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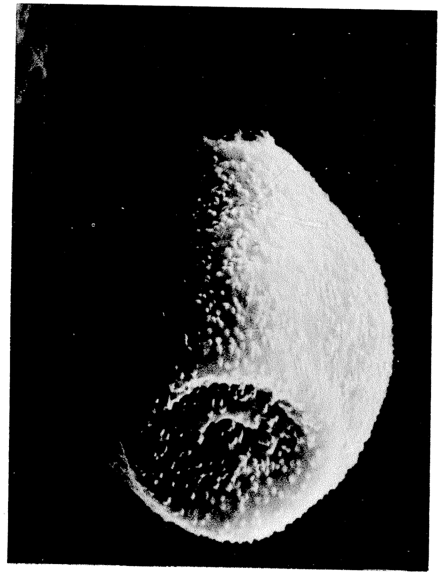

Fig. 1. SEM micrograph of Osage orange pollen (×3.77k).

Twigs, thorns, and buds

Young twigs are green and somewhat hairy. At maturity they are light brown, flecked with orange lenticels and contain an orange pith (Peattie, 1953; Pool, 1919). Modified twigs or thorns are frequently found in the leaf axils of 1-yr-old twigs (Burton, 1973). Twigs growing in full sunlight bear the sharpest thorns while the slower-growing, shaded twigs may be thornless (Burton, 1973). A thornless variety of *Maclura* is sometimes recognized (*Maclura pomifera* var. *inermis* (André) Schneid.) (Rehder, 1940; Vines, 1960).

The winter buds are depressed-globose, partly immersed in the bark, and covered by a few closely imbricated, ovate rounded, light brown, ciliated scales (Rehder, 1940; Sargent, 1933). Terminal buds are missing (Pool, 1919). Leaf scars are small and shield-shaped (Stephens, 1969).

Bark

The bark on the older branches and trunk is deeply furrowed, scaly, and dark orange-brown (Pool, 1919). It averages 2.5 cm in thickness. Root bark is bright orange-red and is composed of thin papery layers.

Wood: general description

The heartwood of Osage orange is golden yellow to golden brown when freshly cut, sometimes with reddish streaks (Record and Hess, 1943). It turns darker on exposure to air (Betts, 1953). Rays are barely visible (Burton, 1973). The sapwood

TABLE 1. CHARACTERISTICS OF OSAGE ORANGE WOOD.[a]

Specific gravity		
	Green	0.76
	Oven-dried	0.84
Kg/m^3		
	Green	99.31
	Air-dried	89.70
	Kiln-dried	86.49
Shrinkage in volume		
	Change from green to oven-dried	8.90%
Relative strength (as compared to 1.0 standard of *Quercus alba* L.)		
	Bending	1.58
	Crushing endwise	1.65
	Crushing crosswise	3.11
	Stiffness	1.01
	Hardness	1.94
	Shock resistance	2.85

[a] After Betts, 1929.

is narrow, generally not more than 2 cm wide, and light yellow in color. Annual rings are distinct, for the wood is ring-porous. Growth rings are made up of a comparatively dark, thin band of summerwood and a lighter colored, frequently narrower, band of springwood (Betts, 1953). Springwood pores are large and occluded with tyloses (Brown et al., 1949).

Characteristics that affect manufacturing quality of Osage orange wood are given in Table 1. The wood has high luster, and odor or taste are absent (Record and Hess, 1943). The wood is very hard, heavy, tough, strong, and resilient. It is difficult to work but finishes smoothly and is comparatively inert to changes in atmospheric humidity.

Wood: detailed anatomy

Osage orange wood has 10–60 vessels per mm^2. The largest vessel elements are 150–250 μ in diameter and have simple perforation plates. Spiral thickenings are present in the small vessels of the summerwood. Tyloses in the springwood vessels are small, appearing cellular en masse (Brown et al., 1949). The inter-vessel pits are obicular to oval or angular through crowding, 8–12 μ in diameter, and the orifices are frequently confluent. Parenchyma is abundant, and is usually paratracheal, paratracheal-confluent, and terminal. Fusiform parenchyma cells are occasionally intermingled with the more typical parenchyma cells. Fibers are moderately thick to thick-walled and 10–16 μ in diameter. The rays are unstoried, 1–6 (mostly 2–4) seriate, and homogeneous (Brown et al., 1949).

Morphology

Osage orange has long shoot-short shoot morphology. Terminal buds of long shoots are abscissed at the level of the last fully expanded leaf (Burton, 1973).

Short shoots exhibit monopodial growth with typical short shoot construction (Smith, 1963). Short shoots, seedlings, and young saplings continue their original line of growth. Water sprouts retain their apices longer and are positively correlated with the rate of vigorous growth (Smith, 1963).

Age

Osage orange has the potential to be fairly long lived. A specimen mentioned by Sargent (1947) was 134 yr old. McCurdy et al. (1972) estimate Osage orange longevity at 150 yr or more. Some of the oldest specimens of Osage orange in Ohio are found on the Miami University campus. Increment borings indicate that 5 of the trees are between 150–175 yr old.

Size

Osage orange trees average 9–12 m in height (Baumgardt, 1972; Betts, 1953; Hough, 1924), although specimens up to 21 m have been reported (Burton, 1973). Maximum stem diameter for this species is about 1 m (Collingwood, 1939). The champion Osage orange is located in Charlotte County, Virginia; it is 15.5 m high, 7.46 m in circumference, and has a spread of 28.2 m (American Forestry Association Social Register of Big Trees, April 1978).

Habit of growth

The trunk of Osage orange is usually short and soon divides into several prominent limbs with upwardly arching branches (Pool, 1919). This produces a low, symmetrical, rounded crown especially when the tree is growing alone or in the open. The lower branches often droop nearly to the ground, creating deep shade under the trees. Osage orange is a sun-loving species and does not tolerate shading (Schuler, 1973). Trees frequently have twisted and awkwardly positioned limbs due to competition for light. Lower branches that have died remain on a tree for years, indicating that Osage orange does not self-prune. The rooting pattern is diffuse (McCurdy et al., 1972). The roots cover large areas and their lateral spread can be extensive in shallow soils.

HISTORY

Early explorers on the Great Plains met Indians that had bows and clubs made of a very strong yet tough wood. This wood was Osage orange. So valuable were these bows that John Bradbury, a Scottish traveler, in 1810 reported their price as a horse and blanket (Peattie, 1953). The reputation of these bows was widespread among the Plains Indians as indicated by reports that the Montana Blackfeet had prized bows of Osage orange that they had obtained by barter from eastern tribes (Peattie, 1953). It is probable that no Osage orange tree was seen by the white man until the Dunbar and Hunter expedition of 1805 (Morton, 1967), although Osage orange wood had been known previously through the Indian bows. The botanist Custis recognized Osage orange as a probable new species when he collected samples of it during the Freeman and Custis scientific expedition of 1806 (Morton, 1967). Nuttall confirmed Custis' suspicions when, in 1818, he found the species growing on the flood plains of the Red River between Texas and Oklahoma.

Cultivation of Osage orange as a hedge plant was based on the suggestions of Dunbar and Hunter to President Thomas Jefferson. It was first cultivated in the Southern States, and it has many characteristics which made it a good natural hedge: it has scattered thorns set on zigzagging branches; it is hardy in drought, heat, and wind; it is easily propagated (from seeds or by cuttings); and it grows rapidly. Osage orange could be pruned to form a low, tight hedge. It met the old demand that a hedge plant should be "horse-high, bull-strong, and pig-tight" (Peattie, 1953).

There was a need on the middle western prairies when they were first settled for cheap, effective fencing. The only method of fencing available which would hold stock was a pile of long wooden stakes. Such fencing was too costly for anything but small enclosures. As a result, settlers were forced to form broken and scattered settlements on the margins of groves and streams, treating the prairies as common pasture. Social organization under these conditions was primitive.

Large scale use of Osage orange for hedges was first introduced in the 1850s (Carriel, 1961) through the efforts of John A. Wright, editor of the *Prairie Farmer*, and his friend Professor Jonathan B. Turner (Peattie, 1953). Turner was convinced that "God designed Osage orange especially for the purpose of fencing the prairies" (Steavenson et al., 1943). By 1855 Osage orange hedges made the fencing of entire farms practical. Use of Osage orange hedges spread rapidly through the prairies and even into most of the eastern states. Indeed, Osage orange hedges were the standard fence until Yankee ingenuity invented first woven, then barbed wire (Steavenson et al., 1943). From about 1875 onward, hedges were gradually supplanted by wire fencing. Even with all the strong features of Osage orange as a hedge, this change was logical because annual clippings were necessary to keep hedges within bounds and constant patching was needed to repair openings created by the death of individual plants (Rogers, 1905). In most regions the hedges were permitted to grow on farm boundaries, and these hedges played an important role in establishing the economic value and the naturalized range of the species, as will be discussed later.

DISTRIBUTION: NATURAL, PLANTED, AND NATURALIZED

Osage orange is perhaps one of the classic examples of an endemic species in North America. Although the extent of the natural range is in doubt (Fig. 2), there is little question that Osage orange grew best on the rich bottomlands of the Red River between Texas and Oklahoma (Betts, 1945; Collingwood, 1939; Sargent, 1947). Other areas of the native distribution were prairie, particularly those south of the Red River. Osage orange tended to invade the prairies forming isolated small stands either pure or in mixture with other hardwoods (Burton, 1973). Some pure stands covered as much as 100 a, but most were smaller (Betts, 1953; Burton, 1973).

The planting of Osage orange for hedges greatly extended its distribution. Osage orange can now be found from southeastern Canada to Colorado to almost all of

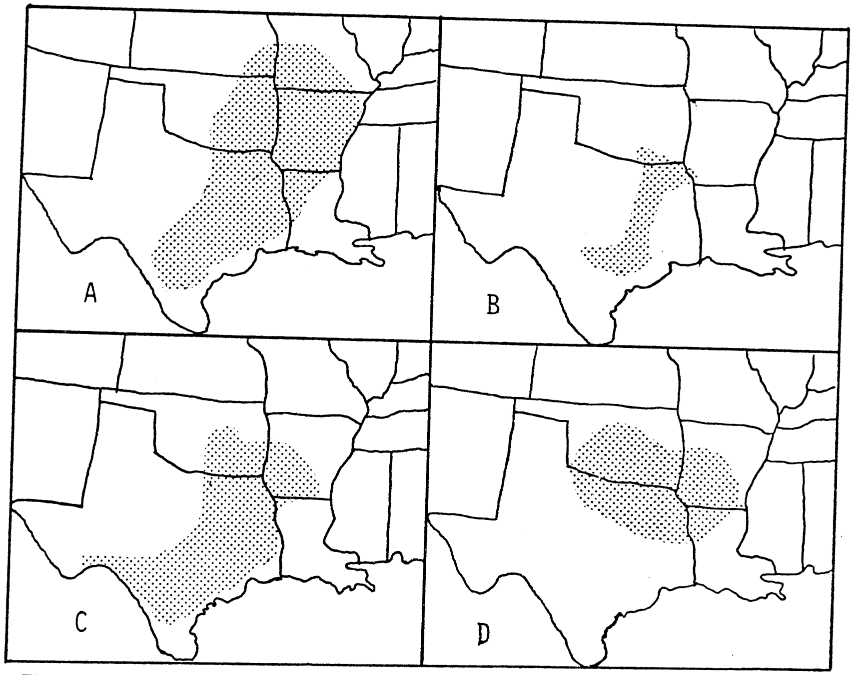

Fig. 2. Possible natural distributions for Osage orange (A—Betts, 1953; B—Burton, 1973; C—Collingwood, 1939; D—Hough, 1924).

the states east of the Mississippi, although it is occasionally winterkilled in the northern parts of this planted range (Burton, 1973; Pinchot, 1907). Osage orange has also been planted along the West Coast. Specimens are reported growing in the British Isles, France, Germany, Italy, Netherlands, Portugal, Romania, Russia, Switzerland, and Australia (Pullar, 1939; Spaulding, 1956).

With the hedgerows acting as a seed source, Osage orange has become naturalized throughout much of its planted distribution (Burton, 1973; Harmon, 1948; Peattie, 1953). It often invades abandoned fields bordering hedges and can become an important dominant in the secondary succession of such fields.

ECOLOGY OF NATURALIZED OSAGE ORANGE

Osage orange is not a constitutent of any mature forest association. It is a pioneer species forever invading exposed mineral soils, particularly overgrazed pastures and abandoned crop fields (Burton, 1973; Harmon, 1948). It can be a local dominant tree species in these fields. Other tree species frequently found in these fields include: *Juniperus virginiana*, *Robinia pseudoacacia*, *Gleditsia triacanthos*, and *Crataegus* sp. Osage orange is a good pioneer species because it can tolerate many different soil types, the thorns protect the plants from grazing, and it grows better in full sunlight than shade (Burton, 1973; McCurdy et al., 1972). In most areas, not enough time has elapsed to determine how Osage orange

TABLE 2. TYPICAL SEED YIELDS FROM OSAGE ORANGE FRUITS.[a]

Number of fruits per bushel	80
Seeds per bushel of fruit	
Number	24,500
Weight	1.02 kg
Cleaned seeds per pound	
Average	14,000
Low	7,000
High	16,000
Purity	96%
Soundness	95%

[a] After Bonner and Ferguson, 1974.

is affecting the successional pattern of the native species in its naturalized distribution. The authors know only one location where Osage orange is being replaced by the native climax species. In this case, a hedgerow of Osage orange (located on the edge of the nature preserve at Hueston Woods State Park near Oxford, Ohio) is being shaded out by the climax species of the mixed mesophytic forest (especially oaks); no Osage orange seedlings are present. Small (1972) suggested that Osage orange may be stalling succession where it has been naturalized. If this is true, then understanding the population dynamics of Osage orange and the interspecific interactions with the native species would be important in reestablishing the climax community.

PROPAGATION

Seeds

Osage orange is easy to propagate from seed. Fruits should be collected in the fall but collections can be made anytime after the fruits fall to the ground. Seeds are best extracted by macerating the fruits in water and floating off or screening out the pulp (Bonner and Ferguson, 1974; Vines, 1960). Cleaning is easiest if the fruits are stored in a moist place and allowed to decay for several months. Allowing the fruits to remain outside until spring is a good way to soften the fruits. Seed viability can be maintained for at least 3 yr by storing cleaned, air-dried seeds in sealed containers at 7°C (Engstrom and Stoeckler, 1941). The seeds germinate best when planted about 1 cm deep and covered with firmed soil.

Osage orange fruits average 200–300 seeds per fruit. They may have as few as 10 or as many as 450. Seedless fruits have been reported (Green, 1939). Typical seed yields are given in Table 2.

Since Osage orange seeds have been reported to exhibit some slight dormancy (Bonner and Ferguson, 1974; Vines, 1960) requiring mild pretreatment to overcome, the authors tested the percent germination of Osage orange seeds at weekly intervals from November to February from fruits stored in the field. Seeds were extracted and germinated on filter paper in petri dishes at room temperature for 4 wk. The results (Fig. 3) indicate that Osage orange requires a slight dormancy or maturation period before successful germination can be achieved. Seeds planted after the middle of December germinated without any pretreatment. The av-

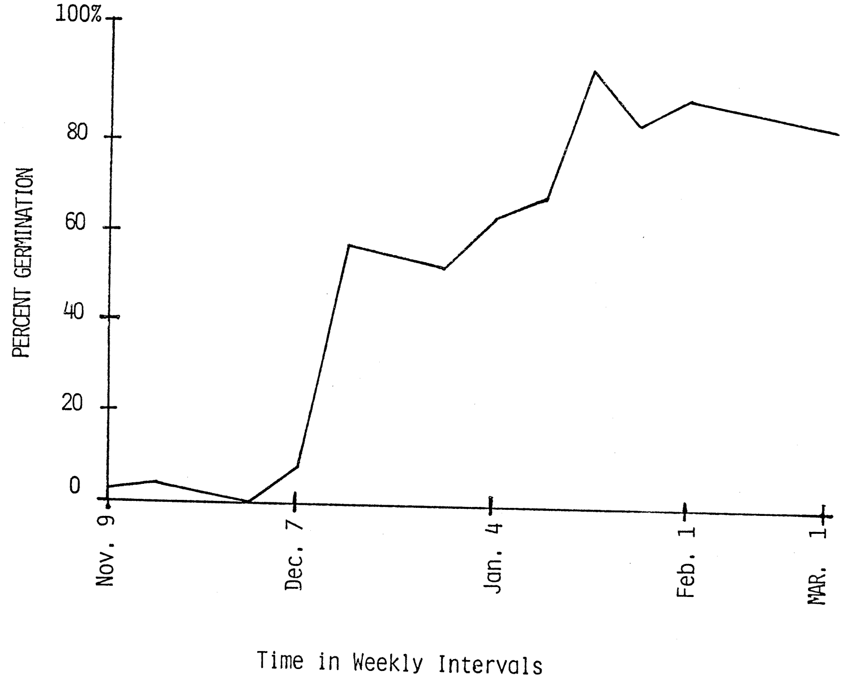

Fig. 3. Percent germination of Osage orange seeds at weekly intervals.

erage germination of Osage orange is usually 58% (Bonner and Ferguson, 1974; Vines, 1960). The authors have observed germination rates of 99% under laboratory conditions and an average of 62% under field conditions. Most seeds appear to germinate the following spring, but seed viability in soil after the first year is unknown.

Vegetative

Osage orange can be easily propagated by suckers and stump sprouts (Pinchot, 1907). It can also be propagated by root cuttings, but this is not a practical method with the large seed supply available.

ECONOMIC USES

The most important use today for Osage orange wood is fence posts. Old hedges that have grown into trees can supply up to 1,000 posts per 0.40 km of hedge (Harmon, 1948). Since Osage orange stumps sprout so readily, a continuous supply of posts is assured. About 15–20 yr are needed to grow a sprout to post size. Osage orange makes excellent posts because the untreated wood is extremely decay resistant in contact with the soil (Harmon, 1948). This decay resistance has been traced to an antifungal agent (2′,3,4′,5,7 pentahydroxyflavone) in the heartwood (Barnes and Gerber, 1955). This decay resistance, coupled with

Osage orange's great strength, has also made the wood one of the finest railway ties known (Peattie, 1953).

Historically, the wood was in great demand for making hubs and rims of wheels for horse-drawn vehicles, even though the supply was scarce. The first chuckwagon was built from Osage orange in order to withstand the terrible bumping over the Texas Panhandle (Peattie, 1953). Other major uses include: house blocks, bridge pilings, insulator pins, telephone poles, and treenails (Betts, 1953; Burton, 1973). To a lesser extent it was used for street paving blocks, machinery parts, pulley blocks, mine timbers, archery (bows), planing mill products, and parquet flooring (Burton, 1973). Osage orange wood is not a good firewood in open fireplaces because it snaps and pops, but wood left over from harvesting fence posts was sometimes used in charcoal kilns (Burton, 1973). Osage orange may be used locally as a wood for small craft items, novelties, turnings, inlay, etc. It is one of the most difficult woods to glue (Forest Products Laboratory, 1974).

Although Osage orange is rarely planted today for hedges, established hedges are maintained for windbreaks (Harmon, 1948), which are particularly important in the prairies. Fields lying on the leeward side of these windbreaks are protected from bitter winds, and the windbreaks also offer food, nesting sites, and cover for many small game animals.

The stem wood and the bark of the roots have been used in making a yellow dye. During World War I, this dye industry assumed importance as important dye sources were cut off (Burton, 1973). Most work was concentrated on using Osage orange as a substitute for fustic, a yellow dye obtained from *Chlorophora tinctoria* (Kressman, 1914, 1915). After the war and with the advent of synthetic dyes, use of Osage orange for dyewood decreased. Earlier the bark of the trunk was sometimes used in tanning leather (Saxe, 1918), but today's chemical industry has also replaced this use for Osage orange.

A potentially important economic use for Osage orange is in the proteolytic enzyme found in the fruits (Ramsbottom and Paddock, 1948; Schwimmer, 1954; Hokes et al., 1976). Proteolytic enzymes, which break down proteins into peptides or amino acids, are used in cheese making, tenderizing meats, clearing and chill-proofing of beer, bating of skin in the leather industry, and shrink-proofing of wool (Hokes et al., 1976). The enzyme resembles papain in activity. It has optimum activity in the alkaline range and is activated by cysteine and hydrogen sulfide (Hokes et al., 1976). The enzyme also appears to be heat stable. Calculations indicate that a small fruit (175 g) contains enough enzyme to coagulate 1,000 l of milk at 37°C in 30 min (Hokes et al., 1976). These high amounts of enzyme may be large enough to warrant commercial exploitation of Osage orange if the market for proteolytic enzymes continues to grow.

MISCELLANEOUS INFORMATION

Medicinal uses and toxicity

Osage orange has few medicinal uses. A boiled root solution is reported to relieve irritated eyes (Krochmal and Krochmal, 1973). A few additional drugs have been reported in the fruits, including a cardiac active principle (Waud et al., 1949).

Since the coarse pulp and sticky latex render the fruits inedible, the general

TABLE 3. DISEASES AND PESTS OF OSAGE ORANGE.[a]

Disease or pest	Part affected
Texas mistletoe	Branches
Painted hickory borers	Sapwood
San Jose scale	Twigs
Brown elm scale	Twigs
Fruit tree leaf roller	Leaves and buds
Flies (*Salva pallipes*)	Fruits
Mites (Eriophoidea)	Fruits
Viruses	Fruits
Pythium ultimum	Seedling
Rhizoctonia solani	Seedling
Ovularia maclurae	Leaves
Phyllosticta maclurae	Leaves
Sporadesmium maclurae	Leaves
Cercospora maclurae	Leaves
Sepotria angustissima	Leaves
Physopella fici	Leaves
Verticillium albo-atrum	Stems
Phoradendron serotenum	Stems
Phoradendron tomentosum	Stems
Phymatotrichum omnivorum	Roots
Poria ferrugenosa	Wood
Poria punctata	Wood
Fomes ribis	Wood

[a] As cited in Burton, 1973; Downing, 1976; Hepting, 1971; Plese and Milicic, 1973; Seymour, 1929; Styes, 1975.

assumption is that Osage orange fruits are poisonous. There is little evidence to support this notion (Kingsbury, 1964). Pullar (1939) reported that the fruits were toxic to sheep. Death of horses and cattle attributed to Osage orange are more likely the result of choking on the sticky fruits rather than to actual toxicity. Oppenheimer (1922) reported that an extract from the fruits was toxic to wheat, but Hokes et al. (1976) could not find any evidence of toxicity on a variety of organisms except at very high concentrations. The fruits are reported, however, to be repellant to cockroaches (Peattie, 1953).

Macluroxanthone and alvaxanthone isolated from the root bark has been reported to be highly toxic to goldfish and mosquito larvae (Wolfrom et al., 1963, 1964). These pigments probably serve to protect the roots from decay and pests much like the antifungal agent found in the wood.

Diseases and pests

Osage orange is one of the healthiest tree species in North America despite the variety of diseases and pests which can live on the tree (Table 3).

Antifungal and antibiotic activity

The wood of Osage orange has been found to have antifungal properties (Barnes and Gerber, 1955; Peterson and Brockemeyer, 1953; Yoshimura, 1962). It is this property that is believed to make Osage orange so decay resistant. There is also

TABLE 4. CHEMICAL COMPOSITION OF SOME OSAGE ORANGE PLANT PARTS.

Compound	Fresh fruits[a]	Dry fruits[b]	Seeds[c]	Wood[d]
Alkaloids	0.012%			
Glucosides	0.0236%			
Pectin	46.04%			
Fat	5.16%			
Resin	16.64%	21.69%		
Titratable acids	0.40%			
Sugar (before hydrolysis)	4.46%			
Sugar (after hydrolysis)	0.82%			
Vitamin C	30.4 mg/1000 g			
Moisture	80.0%			
Edible oil		18.34%	42.0%	
Nitrogen		2.56%		
Protein		16.00%		0.97%
Crude fiber		12.00%		
Amyrin		0.90%		
Lignin				41.22%
Ash				0.33%

[a] Aliev et al., 1961.
[b] Clopton and Roberts, 1949.
[c] Earle et al., 1960.
[d] Marchan, 1946.

a report of an antibiotic from the wood (Jenson, 1951). The fruits have been found to contain antioxidant properties that are useful in the food industry to prevent spoilage (Clopton, 1953, 1956; Schall and Quackenbush, 1956). The antioxidant property has been traced to the pulp of the fruits and is believed to be caused by the pigment pomiferin and several other pigments (Schall and Quackenbush, 1956).

Hemagglutinins

Seeds of Osage orange contain lectins that are direct hemagglutinins of the erythrocytes of various mammals (Jones et al., 1967a; Jones and Feldman, 1973). The molecular weight of these hemagglutinins is 100–200,000 Daltons (Ulevitch et al., 1974). The active principle is located in the epicotyl of seeds and diminishes in concentration as the seedlings mature (Jones et al., 1967b). Activity is heat stable (75°C), non-enzymatic, and the principle reacts with cells lacking terminal n-acetyl-d-galactosamine (Pardoes et al., 1970).

Hemagglutinins have been shown to be toxic to many mammals, birds, and some insects (DeMuelenaere, 1965; Swain, 1977; Toms and Western, 1971), although some of the toxicity reported for mammals was from injection of the hemagglutinins rather than ingestion. Since the active principle is located in the epicotyl, the hemagglutinins may serve as a defensive mechanism against predators.

Chemical composition

A great deal of literature exists on the chemical composition of Osage orange. Table 4 lists these chemicals by plant part. Many secondary constituents are

TABLE 5. SECONDARY CONSTITUENTS IN OSAGE ORANGE.

Compound	Part	Reference
Osajin	Fruits, leaves, bark	26, 31, 84, 88, 96, 97, 98, 104, 105, 106, 107
Isoosajin	Fruits	31, 98
Dihydroisoosajin	Fruits	108
Pomiferin	Fruits	26, 31, 68, 84, 88, 92, 96, 97, 98, 104, 105, 106, 107
Isopomiferin	Fruits	31, 98
Dihydroisopomiferin	Fruits	108
Disain	Fruits	52
Lupeol	Fruits	1, 26, 31, 44, 80, 85, 87
19 α-H lupeol	Fruits	26
Lupeol benzoate	Fruits	87
Lupane-3 β, 20 diol	Fruits	1, 26, 45
Lupane-3 β, 20 diol 3-monacetate	Root bark	20
Lupenyl acetate	Fruits, root bark	20, 87
Lurenyl	Fruits	84, 85
Lurenyl acetate	Fruits	85
Lurenyl benzoate	Fruits	88
Butyrospermol	Fruits	26, 54
Butyrospermyl acetate	Root bark	20
Osajaxanthone	Wood, root bark	19, 31, 95, 97
Dihydroosajaxanthone monomethyl ether	Root bark	101
Toxyloxanthone A	Trunk bark	19
Toxyloxanthone B	Trunk bark	19
Toxyloxanthone C	Trunk bark	19
Toxyloxanthone D	Trunk bark	19
Macluraxanthone	Wood, root bark	31, 95, 99, 100
1, 3, 6, 7 Tetrahydroxyxanthone	Wood	31, 94
Alvaxanthone	Root bark	31, 95, 99, 100
Morin	Heartwood	19, 31, 94
Dihydromorin	Heartwood	19, 43
Kampferol	Heartwood	19, 31
Dihydrokampferol	Heartwood	19, 43
Kampferol, 7-glucoside	Leaves, flowers, bark, wood, fruits	54
Quercetin	Heartwood	19
Dihydroquercetin	Heartwood	43
3,6,7,2′-Tetramethoxy 4,5′-dihydroxyflavone	Root bark	51
8-Deoxygartanin	Wood	19
6-Deoxyjacareubin	Wood	19
Resorcenol	Heartwood	19
Oxyresveratrol	Wood	19
β-sitosteryl acetate	Root bark	20
18 α-Oleomane-3 β, 19 α-diol	Fruits	44
2,3′,4,5′-Tetrahydroxystilbene	Heartwood	29, 43, 91, 94
Rutin	Wood	5, 11
Maclurin	Fruits	31

known for the species (Table 5). In addition, the composition of the rubber in the latex has been studied for possible commercial use (Fox, 1913; Maxon and Whitehead, 1943). The latex contains d-glucose, d-fructose, and pectin (Wagner and Harris, 1952a,b; Wagner, 1958), but the rubber is too waxy and has too low a yield for commercial exploitation.

CONCLUSION

This synopsis and summary of Osage orange shows that much is known about this species; however, much is yet to be learned. Since man has increased the range of Osage orange, it will be important to learn what interactions the species is having with the native species and how it is affecting the secondary succession pattern in its naturalized distribution. The function of the large number of secondary constitutents is another field needing investigation.

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1980 Lawrence Memorial Award

The Award Committee of the Lawrence Memorial Fund is pleased to announce the selection of Mr. James M. Affolter of the University of Michigan as recipient of the 1980 Lawrence Memorial Award. A student of Dr. William R. Anderson, Mr. Affolter is investigating the taxonomy, evolution and phytogeography of the genus *Lilaeopsis* (Umbelliferae). He will be using the proceeds of the Award in travel to Australia and Tasmania for field studies.

The Lawrence Memorial Fund has been established at the Hunt Institute for Botanical Documentation, Carnegie-Mellon University to commemorate the life and achievements of Dr. George H. M. Lawrence, founding Director of the Institute. Proceeds from the Fund are used to make annual awards of $1,000 to outstanding doctoral candidates for travel in support of dissertation research in any of Dr. Lawrence's fields of special interest: systematic botany or horticulture, or the history of the plant sciences, including bibliography and exploration. The Fund has been constituted initially by contributions from the Lawrence family and The Hunt Foundation, augmented by donations from many of Dr. Lawrence's friends and colleagues.

1980 Jesse M. Greenman Award

The 1980 Jesse M. Greenman Award has been won by John J. Furlow for his publication "The systematics of the American species of *Alnus* (Betulaceae)" (Rhodora 81: 1–121; 151–248. 1979). This monographic study is based on a Ph.D. dissertation from the Department of Botany and Plant Pathology, Michigan State University.

The Greenman Award, a cash prize of $250, is presented each year by the Alumni Association of the Missouri Botanical Garden. It recognizes the paper judged best in vascular plant or bryophyte systematics based on a doctoral dissertation which was published during the *previous* year. Papers published during *1980* are now being considered for the 14th annual award, which will be presented in the summer of 1981. Reprints of such papers should be sent to: Greenman Award Committee, Department of Botany, Missouri Botanical Garden, P.O. Box 299, St. Louis, MO. 63166, U.S.A. In order to be considered for the 1981 award, reprints must be received by 1 July 1981.