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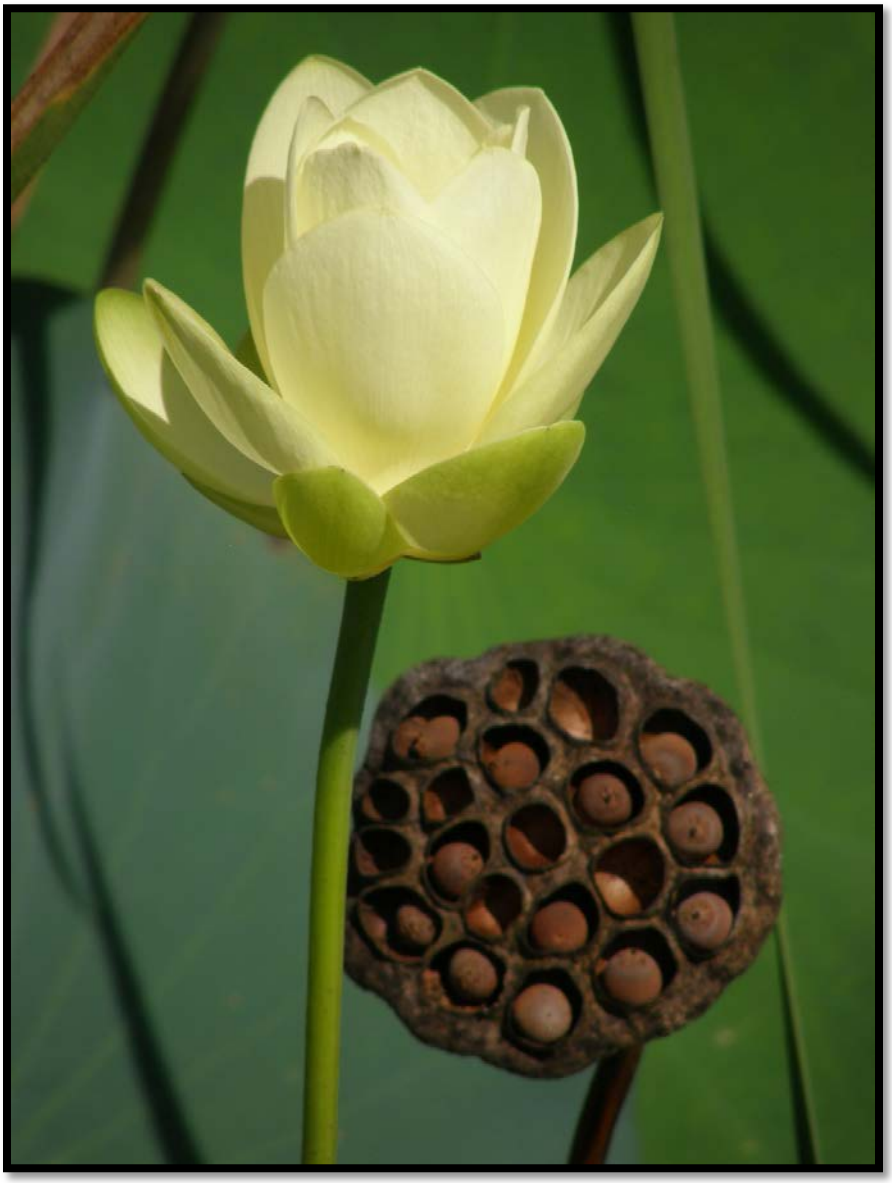
# *Oklahoma Native Plant Record*



**Journal of the Oklahoma Native Plant Society**
**Volume 17, December 2017**

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Cover photo: *Nelumbo lutea* Willd. (American lotus) by Sally Webb for the 2016 ONPS Photo Contest


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# *Oklahoma Native Plant Record*
## *Volume 17*

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† Indicates an author who is deceased

# Foreword

The search for historic articles that would be important to botanical research often leads us down surprising pathways to sources that are sometimes hidden in plain sight. Lynn Nabb mentioned her grandmother's 1959 Master's thesis from the University of Tulsa in a Facebook post that honored her work and her life. Until then, Maxine Clark's "A Study of the Flowering Plants of Tulsa County, Oklahoma" had been quietly sitting in the university library for almost 60 years. Maxine was a student of Dr. Ralph Kelting and a friend of Dr. Harriet Barclay. We are grateful to the University's library staff who helped us obtain the thesis.

This year *The Record* offers a number of important works from a wide variety of sources. It brings together several articles that have to do with species interactions and a couple of articles that offer readers the opportunity to know something "first."

We chose Paul Buck's "Allelopathy" from a previous issue of *The Gaillardia* for our "Critic's Choice Essay," because it explores deeply the "War in the Garden" and the "vicious world in nature." Dr. Buck's 2004 article may help us better understand several issues discussed in "Laboratory Studies of Allelopathic Effects of *Juniperus virginiana* on Five Species of Native Plants" by Erica Corbett and Andrea Lashley. This work involved undergraduate students in an important research opportunity and explores possible negative interactions between plant species.

As for the firsts, urban species have historically been overlooked by botanists because their habitats had been altered by human activity. Researchers have changed that perspective. Urban studies are now valued because they address the effects that humans have had on species. Urban parks can be surprisingly biodiverse. "Vascular Flora of E. C. Hafer Park, Edmond, Oklahoma" is from Gloria Caddell and students Katie Christoffel, Carmen Esqueda, and Alonna Smith at the University of Central Oklahoma. It is the first species list for Edmond's Hafer Park, which was established in 1979.

For another first, Clark Ovrebo reports on an interesting earth star fungus that, until now, was known only in Texas and Japan! Be on the lookout for it. Evidently, it has a much wider distribution than previously thought. Speaking of wide distribution… *The Oklahoma Native Plant Record* is getting more widely distributed every year. Because it is listed in the Directory of Open Access Journals and abstracted by the Centre for Agricultural Bioscience International, it can be accessed by researchers around the world.

And here's another "first." *The Record* has a new editor this year. Gloria Caddell is joining the editorial board as Co-Editor. It's time for a change of leadership, and she has graciously agreed to begin taking over the helm and her new responsibilities.

Sheila Strawn and Gloria Caddell
Co-Editors

# A STUDY OF THE FLOWERING PLANTS OF TULSA COUNTY, OKLAHOMA, EXCLUSIVE OF THE GRASSES, SEDGES, AND RUSHES

**Master's Thesis**
**University of Tulsa**
**Tulsa, Oklahoma**
**1959**

**Maxine B. Clark†**
**1905–1988**

*Keywords: riparian, prairie, limestone, flora, historical, ecology*

## ABSTRACT

A taxonomic study of the flowering plants of Tulsa County, Oklahoma, exclusive of the grasses, sedges, and rushes, was made from 1955 to 1959. A total of 585 species, representing 99 families and 335 genera, were identified and are on file in the herbarium of the University of Tulsa. The largest families in order of number of species are: Compositae [Asteraceae], 110 species; Leguminosae [Fabaceae], 50 species; Euphorbiaceae, 22 species; Cruciferae [Brassicaceae], 21 species; Rosaceae, 19 species; Scrophulariaceae [Linderniaceae, Orobanchaceae, Phrymaceae, Plantaginaceae, Scrophulariaceae], 18 species; Labiateae [Lamiaceae], 16 species; Polygonaceae, 16 species; and Onagraceae, 15 species. The number of plants found is comparable to similar collections in Muskogee County by Little (1938) and in Pontotoc County by McCoy (1958). The plant list of Tulsa County may be increased by further study.

Editor's Note: Where nomenclature has been updated using ITIS-Integrated Taxonomic Information Service (http://www.itis.gov), the revised name is in brackets [ ], as are other updates.

## INTRODUCTION

### *Statement of Problem*

A taxonomic study of the flowering plants of Tulsa County, Oklahoma, exclusive of the grasses, sedges, and rushes, was initiated by the author in the spring of 1956. One hundred twenty-five plants were collected from April 21 through November 7. Intensive field work began March 1, 1957, with 700 plants collected through November 17. Additional collections were made in 1958 and 1959. A total of 828 specimens were collected. Most plants were taken in triplicate for the herbaria of the University of Tulsa, the University of Oklahoma, and Oklahoma State University. An attempt was made to collect all plants at anthesis, but fruiting specimens were also collected whenever possible. Classification of the oaks was not attempted without the acorns. All plants were identified and pressed by the author. A few additional specimens on file in the herbarium of the University of Tulsa have been included in the list of species. Classification of the plants was established through the use of all available manuals applicable to the area, through references in *Rhodora*, and comparison with specimens at the Bebb Herbarium at the University of Oklahoma and the herbarium of Oklahoma State University. Some plants, collected at flowering time, lacked diagnostic varietal


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characteristics, and in such cases the variety name was omitted. Whenever possible, the nomenclature as given in *Gray's Manual of Botany*, 8th ed., has been followed. In a few cases in which reference material was not available for the checking of varieties and only one variety was listed for Oklahoma, the varietal designations were taken from Waterfall (1952a).

### *Physical Aspects of Tulsa County*

Tulsa County is located in northeastern Oklahoma (Figure 1). The northern border of the county is approximately 40 mi [64.37 km] south of the Kansas line and its eastern border is about 70 mi [112.65 km] west of the Arkansas line. The county has a total area of 593 $mi^2$ [1535.86 $km^2$] and is included in Tps 16–22 N, Rs 10–14 E, Indian Meridian (Figure 2). It extends north and south 39 mi [62.76 km] and east and west from 10.5–15 mi [16.9–24.14 km], exclusive of an arm 6 mi [9.66 km] wide, which extends 15 mi [24.14 km] westward from the central portion (see Figure 2). The city of Tulsa occupies 43.5 $mi^2$ [112.67 $km^2$] and has a population of 265,000 people.

The elevation varies from 550 ft [167.64 m] in the bed of the Arkansas River at the southeast corner of the county to slightly more than 950 ft [289.56 m] at points northwest of Turley and 6 mi [9.66 km] west of Sand Springs. The greatest local topographic relief is approximately 300 ft [91.44 m]. The portion of the county east of a line drawn north-south through the city of Tulsa is generally of low relief. The underlying rock is mainly shale with intermittent slopes supported by beds of sandstone or limestone which dip westward at a rate of 40 ft [12.19 m] to the mile. These slopes rise eastward until they are terminated by east-facing escarpments. The portion of the county west of the city of Tulsa is deeply dissected by streams with narrow valleys. An exception is the broad valley of the Arkansas River. The drainage of Tulsa County is by the Arkansas River and its tributaries, although Bird Creek and the Caney River are tributaries of the Verdigris River whose waters reach the Arkansas River east of the boundaries of Tulsa County. All of the large streams are muddy.

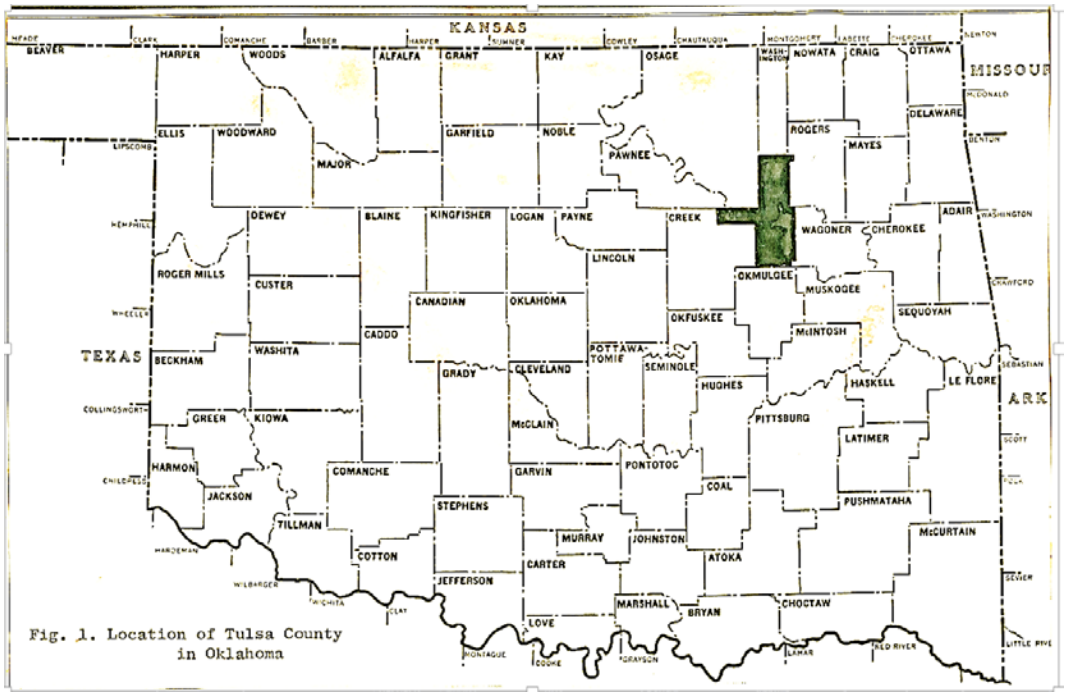


Figure 1 Location of Tulsa County in Oklahoma

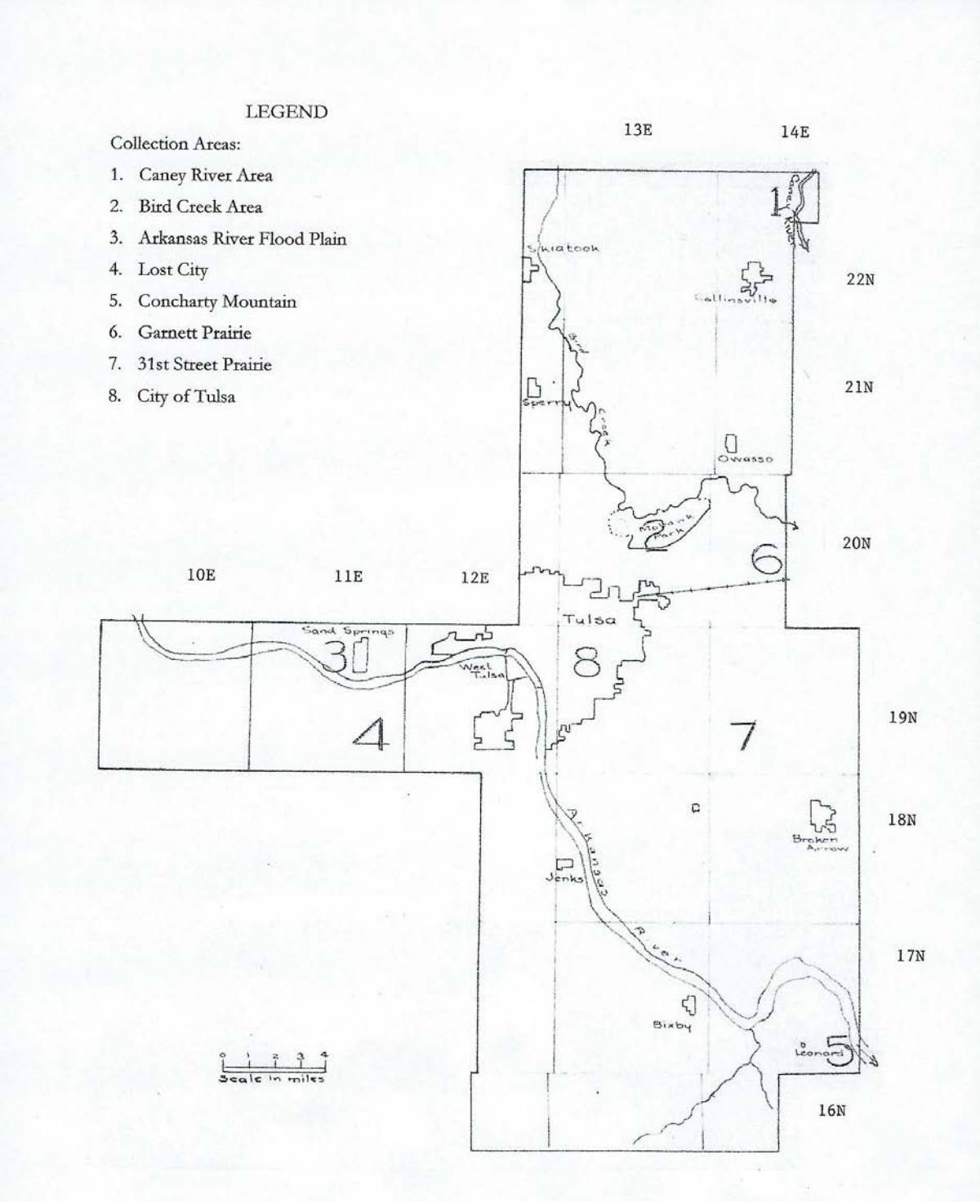


Figure 2 Map of collection areas, Tulsa County, Oklahoma [Map by J. M. Clark]

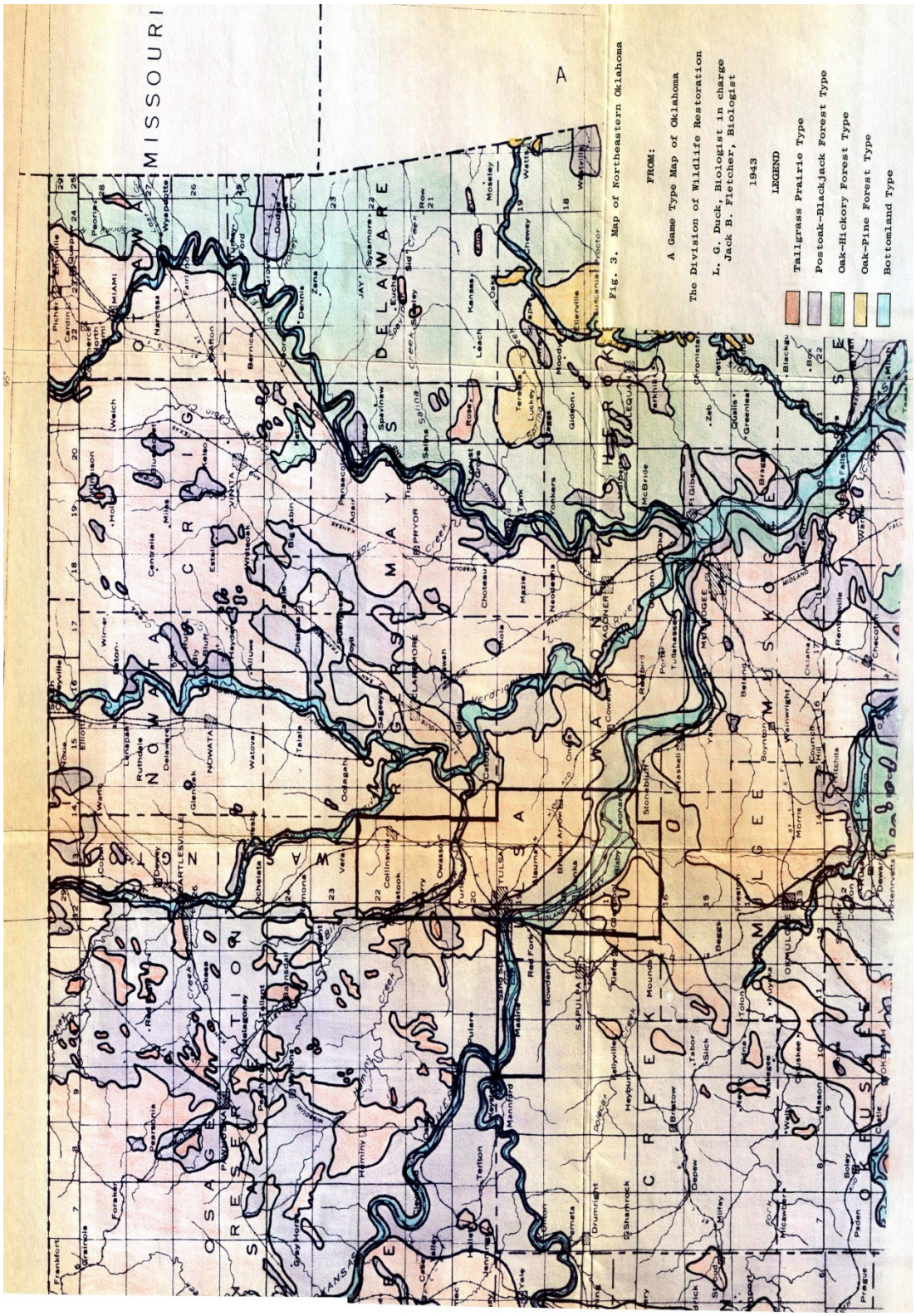


Figure 3 Map of northeastern Oklahoma [Reproduced in 2017 with the help of Michael Larson, Coordinator, Department of Geography Cartography Services, Oklahoma State University]

### *Climate*

The climate of Tulsa County may be described as continental as there are no large water surfaces or mountains to affect climatic conditions. Data for 49 years, 1905–1955 inclusive, from the climatological records of the United States Department of Commerce Weather Bureau, located at the Tulsa Municipal Airport, indicate the average growing season is 219 days. The longest growing season on record, 258 days, occurred in 1907. The shortest season, 178 days, was in 1921. The average date of the last freezing temperature, 32° F [0ºC] or lower, in the spring is March 28 with the latest occurrence on record being April 20, 1953. The average date of the first freezing temperature in the fall is November 2, and the earliest occurrence on record is October 8, 1952. The temperature may frequently climb to 100º F [37.78ºC] or more in July, August, and September, the highest on record being 112º F [44.44ºC] in July 1954. The high temperatures are usually accompanied by low humidity and high evaporation. ZeroºF [-17.78ºC] temperatures may be experienced for a few days in January, February, and occasionally in March. The lowest temperature recorded in the 49 year period was -8ºF [-22.22ºC] in January 1947.

The mean annual rainfall is 37.16 in [94.39 cm]. The lowest annual precipitation recorded during the 1905–1955 period was 24.07 in [61.14 cm] in 1910, and the highest, 62.82 in [159.56 cm], was recorded in 1915. Rainfall is greatest in the spring months and least in the winter months. Records for the 49-year period show an average of 5.23 in [13.28 cm] of rainfall in May, 4.71 in [11.96 cm] in June, and 4.18 in [10.62 cm] in April. February averages 1.59 in [4.04 cm]; January, 1.74 in [4.42 cm]; and December, 1.83 in [4.65 cm]. Snowfall is slight and remains on the ground for a very short time.

Of particular interest are the collection years of 1956 and 1957. Unfortunately, the summary data from the weather bureau does not include these years. Some information, not in summary form, is available, however. In 1956, the growing season was 253 days in length with the last spring freeze occurring on March 20 and the first fall freeze on November 28. In 1957, the growing season was 223 days in length with the last spring freeze occurring on April 14 and the first fall freeze on November 23. The freeze of April 14 did much damage, particularly to the oaks, which formed few acorns. The precipitation of 23.24 in [59.03 cm] in 1956 was the lowest ever recorded in Tulsa County. In sharp contrast, the precipitation in 1957 measured 46.50 in [118.11 cm] with 9.80 in [24.89 cm] in May, 8.74 in [22.2 cm] in April, and 7.25 in [18.42 cm] in June.

Prevailing surface winds are southerly except during the months of December, January, and February. Sudden drops in temperature may accompany rapid change in wind direction in winter and spring.

### *Ecology*

The major portion of Tulsa County is located in the Tall Grass Prairie region by Duck and Fletcher (1943; Figure 3). The long westward arm and the southeastern portion are in the Post Oak-Blackjack area. This type of vegetation also borders the alluvial flood plains of the streams. The ecological description given by Blair and Hubbell (1938) coincides with that given by Duck and Fletcher although they name the grassland the Cherokee Prairie Biotic District and the woodland the Osage Savannah Biotic District. Bruner (1931) sets the flood plain vegetation apart as a separate plant community. His description of the woody species of the flood plains of central Oklahoma is typical of that of Tulsa County as observed by the author.

Blair and Hubbell further describe the Cherokee Biotic District as an extension of the grasslands of eastern Kansas and western Missouri. The area is essentially

composed of shale soils and limestone escarpments. The vegetation of the shale soils is described as composed of big bluestem (*Andropogon gerardii*), little bluestem (*A. scoparius* [*Schizachyrium scoparium* (Michx.) Nash]), Indian grass (*Sorghastrum nutans)*, and switchgrass (*Panicum virgatum*). Representative forbs associated with the grasses are false indigo (*Baptisia leucophaea*), blazing stars (*Liatris punctata* and *L. aspera*), starwort (*Aster ericoides* [*Symphyotrichum ericoides* (L.) G.L. Nesom]), sunflower (*Helianthus mollis*), and sage (*Salvia azurea*). Recent collections of blazing stars on the prairie in Tulsa County are *Liatris aspera*, *L. angustifolia*, *L. mucronata* [*L. punctata* var. *mucronata* (DC.) B.L. Turner], and *L. pycnostachya*. *L. squarrosa* was found in the wooded sandstone area and was not common. Blair and Hubbell described areas where the sod had been destroyed and is replaced by crabgrass (*Digitaria sanguinalis*, windmill grass (*Chloris verticillata*), and weeds such as broom-snakeroot (*Gutierrezia dracunculoides* [*Amphiachyris dracunculoides* (DC.) Nutt.]) and croton (*Croton capitatus*). On the limestone escarpments is found a mixture of tall grasses and shorter grasses such as side-oats grama (*Bouteloua curtipendula*), buffalo grass (*Buchloe dactyloides* [*Bouteloua dactyloides* (Nutt.) J.T. Columbus]), and silver beardgrass (*Andropogon saccharoides* [*Bothriochloa laguroides* (DC.) Herter]). Forbs are blue false indigo (*Baptisia minor* [*Baptisia australis* (L.) R. Br. var. *minor* (Lehm.) Fernald]), stone-crop (*Sedum pulchellum*), gaillardia (*Gaillardia pulchella*), prickly pears (*Opuntia humifusa* and *O. tortispina*), and yucca (*Yucca glauca*). Widely scattered groves of small persimmon trees (*Diospyros virginiana*) dot the prairie, and persimmon and indigo bush (*Amorpha fruticosa*) may be found along the small prairie drains. The present author noted that areas with outcropping rocks frequently are covered with thickets of Chickasaw plum (*Prunus angustifolia*) and rough-leaved dogwood (*Cornus drummondii*). American elm (*Ulmus americana*), hawthorn (*Crataegus* spp.) and wooly buckthorn (*Bumelia lanuginosa* [*Sideroxylon lanuginosum* Michx.]) are found along the larger drains. Bruner describes the eastern grassland as subclimax since it occurs in an area with potential forest climate. He further states that the forest has not developed because of the recurrence of prairie fires, but forest areas are increasing with the settlement of the area and the cessation of fires.

The Osage Savannah District is an area underlain by sandstone and is described by Blair and Hubbell as an open woodland with post oak (*Quercus stellata*), blackjack (*Q. marilandica*), and black hickory (*Carya texana*) as the dominant vegetation. Grasses in this association are of the prairie type, mainly bluestems. Shrubs are sumacs (*Rhus glabra* and *R. copallina*) and coralberry (*Symphoricarpos orbiculatus*). On the north-facing slopes and the flood plains, a more mesic type of vegetation, similar to that of the Ozark area, will be found. Blair and Hubbell list red spotted oak (*Quercus shumardii*) as dominant in an association with redbud (*Cercis canadensis*), juneberry (*Amelanchier arborea*), and winged elm (*Ulmus alata*). Grasses conspicuous in this situation are spangle grass (*Uniola latifolia* [*Chasmanthium latifolium* Michx.]), wild rye (*Elymus canadensis*), and Japanese chess (*Bromus japonica*). The present author observed that chestnut oak (*Quercus muehlenbergii*), green ash (*Fraxinus pennsylvanica* var. *integerrima* [*Fraxinus pennsylvanica* Marsh. var. *lanceolata* (Borkh.) Sarg.]), white ash (*F. americana*), big-tree plum (*Prunus mexicana*), deciduous holly (*Ilex decidua*), and shrubs: black-haw (*Viburnum rufidulum*), fragrant sumac (*Rhus aromatica*), and poison ivy (*R. toxicodendron* [*Toxicodendron radicans* (L.) Kuntze]) occur with the red oaks, redbud, and juneberry on the north-facing slopes. In densely wooded areas are found wild-oat grass (*Danthonia spicata*), low twining legumes such as milk-pea (*Galactia volubilis*), wild bean (*Strophostyles*

*leiosperma*), and beggars ticks (*Desmodium glutinosum*).

The woody vegetation of the flood plains of Tulsa County consists of black willow (*Salix nigra*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), American elm (*Ulmus americana*), slippery elm (*U. rubra*), silver maple (*Acer saccharinum*), pecan (*Carya illinoensis* [*Carya illinoinensis* (Wangenh.) K. Koch]), red oaks (*Quercus rubra* and *Q. shumardii*), and the ashes. Pin oak (*Q. palustris*) is found at Mohawk Park on the Bird Creek flood plain. River birch (*Betula nigra*) and black walnut (*Juglans nigra*) were noted but are not prominent. Occasional black walnut trees were seen on all the major flood plains. River birches were observed on the Bird Creek flood plain and along a small tributary of the Arkansas River. Buttonbush (*Cephalanthus occidentalis*) and American elder (*Sambucus canadensis* [*Sambucus nigra* L. ssp. *canadensis* (L.) R. Bolli]) may be found along the streams. Common vines are trumpet vine (*Campsis radicans*), poison ivy (*Rhus radicans* [*Toxicodendron radicans*]), green briar (*Smilax bona-nox*), and members of the grape family: woodbine (*Parthenocissus quinquefolia* and *Ampelopsis cordata*) and grapes (*Vitis aestivalis* Michx. var. *argentifolia* and *V. vulpina*). Among the herbaceous plants are the rank growing composites which flower in late summer. Representative of these are ragweed (*Ambrosia trifida*), frost weed (*Verbesina virginica*), wingstem (*Actinomeris alternifolia* [*Verbesina alternifolia* (L.) Britton ex Kearney]), bearsfoot (*Polymnia uvedalia* [*Smallanthus uvedalia* (L.) Mack. ex Small]), green-stemmed Joe-Pye-weed (*Eupatorium purpureum* [*Eutrochium purpureum* (L.) E.E. Lamont]), white snakeroot (*E. rugosum* [*Ageratina altissima* (L.) King & H. Rob. var. *altissima*]), cup-plant (*Silphium perfoliatum*), goldenrods (*Solidago* spp.), and asters (*Aster* [*Symphyotrichum*] spp.).

Man and his domestic animals are of ecological significance in Tulsa County. With the fast growing population of the city of Tulsa and the consequent construction of homes, industries, and highways, many of the indigenous plants are being destroyed. As the periphery of the city increases, more suburban homes and shopping centers are being built. Prairie areas are replaced by homes with mowed lawns; small streams are routed through conduits and covered, destroying the habitat of plants with high moisture requirement. Construction of water reservoirs and dams, currently the Keystone Dam on the Arkansas River, destroys much of the lowland vegetation. Limestone quarries to satisfy the increased need for concrete are destroying the Garnett Prairie, northeast of Tulsa. In the remaining farming areas, over-grazing and trampling by domestic animals, particularly in drouth years, has effected the replacement of many native grasses and legumes by undesirable weeds. A rapid increase in the urban aspect of Tulsa County is evident.

## COLLECTION AREAS

### *Caney River Area*

Definite collection areas which might produce a variation in the flora due to ecological differences were established and visited regularly. The Caney River area, located in the northeastern corner of the county and two and one-half miles [4.02 km] northeast of Collinsville, T 22 N, R 14 E, [Indian Meridian] (see Figure 2; Figure 4), consists of alluvium deposited on sandstone and shale. Of special interest are the wooded area surrounding an ox bow lake and the vegetation on the east-facing slope of the sandstone escarpment west of the Caney River. Difficulty was encountered in collecting vernal specimens due to excessive flooding of the Caney River. Specimens located here and not found by the author elsewhere in the county are *Dicentra cucullaria*, *Paronychia canadensis*, *Staphylea trifolia*, *Forestiera acuminata*, *Myosurus minimus*, *Heliotropium indicum*, and *Abutilon theophrasti*.

### *Bird Creek Area*

The Bird Creek area, located at T 20 N, R 13 E, [Indian Meridian] (see Figure 2), consists of alluvium and forms the north boundary of Mohawk Park. This area is of particular interest because of the undisturbed areas designated as wildflower and bird sanctuaries. Species collected here and not found elsewhere in the county are *Quercus palustris*, *Lindera benzoin*, *Dentaria laciniata* [*Cardamine concatenata* (Michx.) Sw.], *Impatiens capensis*, *Phryma leptostachya, Sicyos angulatus*, and *Lysimachia ciliata*. In general, there is much similarity between the plants of the Bird Creek area and the Caney River area. The only specimens of *Asimina triloba* and *Campanula americana* var. *illinoensis* were found in these two areas.

### *Arkansas River Flood Plain*

The Arkansas River flood plain, characterized by alluvial sands shifted by a variable volume of water and wind, enters the county at Keystone, T 19 N, R 10 E, [Indian Meridian], extends east and southeastwardly and leaves the county at T 17 N, R 14 E (see Figure 2; Figure 5). Among the species collected on the sandflats of the river bed and bank in August during the drouth of 1956 are *Dalea lanata*, *Cycloloma atriplicifolium*, *Chenopodium murale*, and *Urtica dioica*. *Chenopodium murale* is listed in Waterfall (1952a) with the notation "none seen." *Urtica dioica*, a perennial urtica, had not been previously collected in Oklahoma. The only other known Oklahoma collection of this species was made by C. S. Wallis in 1957 in the Ozark area.

### *Lost City Area*

Escarpments, created by the Arkansas River flowing over westward dipping beds of unequal hardness, are made up of the more resistant limestones and sandstones. Of these is the area known as Lost City, which is south of the Arkansas River, slightly east of Sand Springs in T 19 N, R 11 E, [Indian Meridian], on a road called Scenic Drive, an extension of West 21 Street (see Figure 2; Figure 6). Massive bluffs of Hogshooter Limestone face north and provided a favorite collecting area. *Cotinus obovatus*, *Celastrus scandens*, *Aquilegia canadensis* var. *latiscula*, *Ribes odoratum* [*Ribes aureum* Pursh var. *villosum* DC.], and *Zigadenus nuttallii* [*Toxicoscordion nuttallii* (A. Gray) Rydb.] are among the plants located here and not collected elsewhere in the county.

### *Concharty Mountain Area*

In the southeast corner of the county, south of the Arkansas River flood plain and southeast of Leonard, T 17 N, R 14 E, [Indian Meridian], is located the north-facing slope of Concharty Mountain [(Figure 7)]. The mountain is underlain by sandstone and has a relief of about 300 feet [91.44 m]. Plants collected here and not found elsewhere in the county are *Saxifraga texana* [*Micranthes texana* (Buckley) Small], *Lonicera flava*, *Ascyrum hypericoides* var. *multicaule* [*Hypericum hypericoides* (L.) Crantz ssp. *multicaule* (Michx. ex Willd.) N. Robson], *Gerardia grandiflora* var. *cinerea* [*Aureolaria grandiflora* (Benth.) Pennell], *Pycnanthemum tenuifolium*, and *Centunculus minimus* [*Anagallis minima* (L.) E.H.L. Krause].

### *Prairie Areas*

Prairie areas [(Figures 8, 9)] which were visited regularly are: Garnett Prairie, located two miles [3.22 km] north and two miles east of the traffic circle on State Highway 33 in T 20 N, R 14 E [Indian Meridian] (see Figure 2); a section of the Saint Louis-San Francisco Railroad right-of-way located one and one-half miles [2.41 km] north and two miles east of the traffic circle in T 20 N, R 14 E, [Indian Meridian] (see Figure 2); and an area known as the 31st Street Prairie, six miles [9.66 km] east of Harvard Avenue on 31st Street, T 19 N, R 14 E [Indian Meridian] (see Figure 2). All the above are underlain by the Oolagah Limestone. These afford a wealth of specimens typical of the

Tall Grass Prairie region. The area known as Garnett Prairie is currently about to be destroyed by the encroachment of a commercial plant for crushing limestone. The railroad right-of-way was not burned, mowed, or trampled by domestic animals during the collection period. The 31st Street Prairie was annually mowed on about July 20. Prominent among the plant families represented are the Compositae [Asteraceae], Leguminosae [Fabaceae], Cruciferae [Brassicaceae], Euphorbiaceae, and Labiatae [Lamiaceae]. Plants collected in the Garnett Prairie area, including the railroad right-of-way, and not found elsewhere are *Eriogonum longifolium*, *Cucurbita foetidissima*, *Isanthus brachiatus* [*Trichostema brachiatum* L.], *Hybanthus linearis* [*Hybanthus verticillatus* (Ortega) Baill.], and *Nama hispidum*.

### *Other Collection Areas*

No attempt was made to visit other collection areas regularly, but roadside ditches and bordering fields traversed coincidental to traveling to collection sites were kept under observation. Occasional trips were taken to the areas west of Sand Springs, north of the Arkansas River to the Osage County line; southwest of Sand Springs, south of the Arkansas River to an area near the Creek County line; and south of Bixby to the Okmulgee County line. Some weeds from Tulsa city streets and lawns were collected. Of these is a small plant, *Veronica hederaefolia* [*Veronica hederifolia* L.], which had not previously been collected in Oklahoma. *Gray's Manual* (Fernald 1950) lists the range of this plant as New York and Ohio to North Carolina. The plant was found under a mulberry tree which was a favorite feeding place for migratory birds.

## SUMMARY OF SPECIES

The list of plants of Tulsa County consists of 99 families made up of 335 genera and 585 species. The largest families in order of number of species are: Compositae [Asteraceae], 53 genera and 110 species; Leguminosae [Fabaceae], 33 genera and 50 species; Euphorbiaceae, 7 genera and 22 species; Cruciferae [Brassicaceae], 16 genera and 21 species; Rosaceae, 9 genera and 19 species; Scrophulariaceae [Linderniaceae, Orobanchaceae, Phrymaceae, Plantaginaceae, Scrophulariaceae], 12 genera and 18 species; Labiatae [Lamiaceae], 13 genera and 16 species; Polygonaceae, 4 genera and 16 species; and Onagraceae, 4 genera and 15 species. Twenty-eight families are represented by one species each.

Figure 4 Caney River Area. The flood plain forest is in the background. *Polygonum longistylum* [*Persicaria bicornis* (Raf.) Nieuwl.] covers a recently flooded field in the foreground.

Figure 5 Sand Flats of the Arkansas River. Photograph was taken in October, 1957. The river recedes after spring flooding, and large quantities of sand are deposited in the channel.

Figure 6 Lost City Area. Massive blocks of Hogshooter Limestone rise above the Arkansas River flood plain and provide a north-facing habitat.

Figure 7 Concharty Mountain. The north-facing slope of the mountain rises 300 feet [91.44 m] above the Arkansas River flood plain.

Figure 8 Forbs of the Tall Grass Prairie Area. In the foreground is the composite, *Liatris aspera*, which measures 4 ft [1.22 m] in height and is common on the Tall Grass Prairie. A flood plain forest is visible in the background.

Figure 9 Garnett Prairie Area. The rock outcrop is the Oolagah Limestone. Cactus (*Opuntia macrorhiza*) and flameflower (*Talinum calycinum* [*Phemeranthus calycinus* (Engelm.) Kiger]) are rooted between the rocks.

## ACKNOWLEDGMENTS

The author wishes to express her appreciation to Dr. Ralph W. Kelting for directing this study, for assistance in collecting plants, and for the many hours spent in rechecking specimens. She also wishes to thank Dr. Harriet G. Barclay for stimulating an interest in field botany, Dr. A. P. Blair for assistance in finding unusual specimens, and Dr. George J. Goodman and Dr. U. T. Waterfall for offering the facilities of the herbaria of the University of Oklahoma and Oklahoma State University. She also wishes to thank her husband, J. M. Clark, for providing the maps which appear in this thesis, for interpreting the geology of Tulsa County, and for his patience during the past three years.

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# APPENDIX

## List of Species Found in Tulsa County

Editor's Note: Where nomenclature has been updated using ITIS–Integrated Taxonomic Information Service (http://www.itis.gov), the revised name is in brackets [ ]. Unless otherwise indicated, the numbers in parentheses following the species are the collection numbers of the author.

MONOCOTYLEDONEAE

Typhaceae
*Typha latifolia* L. (414)

Zosteraceae [Potamogetonaceae]
*Potamogeton diversifolius* Raf. (Kelting 1038A)

Alismataceae
*Echinodorus cordifolius* (L.) Griseb. (626)
*Echinodorus rostratus* (Nutt.) Engelm. [*Echinodorus berteroi* (Spreng.) Fassett] (482)
*Sagittaria graminea* Michx. (458)
*Sagittaria platyphylla* (Engelm.) J.G. Sm. (619)

Araceae
*Arisaema atrorubens* (Ait.) Blume [*Arisaema triphyllum* (L.) Schott.] (236)
*Arisaema dracontium* (L.) Schott. (214)

Lemnaceae [Araceae]
*Lemna minor* L. (666)
*Spirodela polyrhiza* (L.) Schleid (667)

Commelinaceae
*Commelina communis* L. var. *ludens* (Miguel) Clarke [*Commelina communis* L.] (23)
*Commelina erecta* L. var. *angustifolia* (Michx.) Fern. [*Commelina erecta* L.] (375)
*Tradescantia occidentalis* (Britt.) Symth (241)
*Tradescantia ohiensis* Raf. (321)

Pontederiaceae
*Heteranthera limosa* (Sw.) Willd.

Liliaceae
*Allium canadense* L. var. *hyacinthoides* (Bush) Ownbey [Amaryllidaceae] (908)
*Allium drummondii* Regel [Amaryllidaceae] (Barclay unnumbered)
*Camassia scilloides* (Raf.) Cory [Asparagaceae] (219)
*Erythronium albidum* Nutt. var. *mesochoreum* (Knerr) Rickett [*Erythronium mesochoreum* Knerr] (129)
*Nothoscordum bivalve* (L.) Britton [Amaryllidaceae] (166)
*Polygonatum canaliculatum* (Muhl.) Pursh [*Polygonatum biflorum* (Walter) Elliott] [Asparagaceae] (315)
*Smilax bona-nox* L. [Smilacaceae] (662)

*Smilax herbacea* L. [Smilacaceae] (396A, 562, 873)
*Yucca glauca* Nutt. var. *glauca* [*Yucca glauca* Nutt.] [Asparagaceae] (280)
*Zigadenus nuttallii* Gray [*Toxicoscordion nuttallii* (A. Gray) Rydb.] [Melanthiaceae] (240)

Amaryllidaceae
*Cooperia drummondii* Herb. [*Zephyranthes chlorosolen* (Herb.) D. Dietr.] (568, 641, 981, 983)
*Hypoxis hirsuta* (L.) Coville (216, 228)

Iridaceae
*Nemastylis geminiflora* Nutt. (243)
*Sisyrinchium angustifolium* Mill. (245)
*Sisyrinchium campestre* Bickn. (Kelting 1007)

Orchidaceae
*Spiranthes cernua* (L.) Richards (355, 671, 720)

DICOTYLEDONEAE

Salicaceae
*Populus deltoides* Marsh. [*Populus deltoides* W. Bartram ex. Marshall] (775, 885)
*Salix interior* Rowlee (110, 883)
*Salix nigra* Marsh. [*Salix nigra* Marshall] (792, 885)

Juglandaceae
*Carya cordiformis* (Wang.) K. Koch (689)
*Carya illinoensis* (Wang.) K. Koch [*Carya illinoinensis* (Wang.) K. Koch] (515)
*Carya texana* Buckl. var. *texana* [*Carya texana* Buckl.] (866)
*Juglans nigra* L. (727)

Corylaceae [Betulaceae]
*Betula nigra* L. (729)

Fagaceae
*Quercus macrocarpa* Michx. (733)
*Quercus marilandica* Muench. (716)
*Quercus muehlenbergii* Engelm. (875, 880)
*Quercus palustris* Muench. (664)
*Quercus prinoides* Willd. (Kelting 1008A)
*Quercus rubra* L. (665, 732, 798)
*Quercus shumardii* Buckl. var. *shumardii* [*Quercus shumardii* Buckl.] (724, 725)
*Quercus shumardii* Buckl. var. *schneckii* (Britton) Sarg. [*Quercus shumardii* Buckl.] (723)
*Quercus stellata* Wang. var. *stellata* [*Quercus stellata* Wang.] (874)
*Quercus velutina* Lam. (728)

Ulmaceae
*Celtis laevigata* Willd. var. *laevigata* [*Celtis laevigata* Willd.] [Cannabaceae] (100, 869, 871)
*Ulmus alata* Michx. (135)

*Ulmus americana* L. (130)
*Ulmus rubra* Muhl. (138)

Moraceae
*Morus rubra* L. (789)

Urticaceae
*Laportea canadensis* (L.) Wedd. (551)
*Parietaria pennsylvanica* Muhl. [*Parietaria pensylvanica* Muhl. ex Willd.] (311)
*Urtica chamaedryoides* Pursh (397)
*Urtica dioica* L. (95)

Loranthaceae [Santalaceae]
*Phoradendron flavescens* (Pursh) Nutt. [*Phoradendron serotinum* ssp. *serotinum* (Raf.) M.C. Johnst.] (757)

Aristolochiaceae
*Aristolochia tomentosa* Sims (249)

Polygonaceae
*Eriogonum annuum* Nutt. (498)
*Eriogonum longifolium* Nutt. (572)
*Polygonum aviculare* L. var. *aviculare* [*Polygonum aviculare* L.] (113, 373, 508A)
*Polygonum convolvulus* L. [*Fallopia convolvulus* (L.) Á. Löve] (372)
*Polygonum cristatum* Engelm. & Gray [*Fallopia scandens* (L.) Holub] (613, 661)
*Polygonum hydropiperoides* Michx. var. *hydropiperoides* [*Persicaria hydropiperoides* (Michx.) Small] (486, 602, 734)
*Polygonum hydropiperoides* Michx. var. *bushianum* Stanford [*Persicaria hydropiperoides* (Michx.) Small] (621)
*Polygonum lapathifolium* L. [*Persicaria lapathifolia* (L.) Gray] (628, 636, 685)
*Polygonum longistylum* Small [*Persicaria bicornis* (Raf.) Nieuwl.] (527, 714)
*Polygonum pennsylvanicum* L. var. *pennsylvanicum* [*Persicaria pensylvanica* (L.) M. Gómez] (611)
*Polygonum punctatum* var. *punctatum* [*Persicaria punctata* (Elliott) Small] (462)
*Polygonum tenue* Michx. (674)
*Rumex altissimus* Wood (268)
*Rumex crispus* L. (317)
*Rumex hastatulus* Baldw. (863)
*Tovara virginiana* (L.) Raf. [*Persicaria virginiana* (L.) Gaertn.] (554, 633)

Chenopodiaceae [Amaranthaceae]
*Chenopodium album* L. (756)
*Chenopodium ambrosioides* L. var. *ambrosioides* [*Dysphania ambrosioides* (L.) Mosyakin & Clemants] (687)
*Chenopodium hybridum* L. var. *gigantospermum* (Aellen) Rouleau [*Chenopodium simplex* (Torr.) Raf.] (519)
*Chenopodium leptophyllum* Nutt. [*Chenopodium leptophyllum* (Moq.) Nutt. ex S. Watson] (27)
*Chenopodium murale* L. (107)
*Cycloloma atriplicifolium* (Spreng) Coult. (96)
*Salsola kali* L. var. *tenuifolia* Tausch [*Salsola tragus* L.] (15)

Amaranthaceae
*Acnida tamarascina* (Nutt.) Wood [*Amaranthus tuberculatus* (Moq.) J.D. Sauer] (625)
*Amaranthus hybridus* L. (700)
*Amaranthus palmeri* S. Wats. (750)
*Froelichia floridana* (Nutt.) Moq. var. *campestris* (Small) Fern. [*Froelichia floridana* (Nutt.) Moq.] (125, 593)
*Froelichia gracilis* (Hook.) Moq. (52)
*Iresene rhizomatosa* Standl. [*Iresine rhizomatosa* Standl.] (637)

Nyctaginaceae
*Mirabilis albida* (Walt.) Heimerl. (92, 410)
*Mirabilis nyctaginea* (Michx.) MacM. (289, 578, 857)

Phytolacaceae
*Phytolacca americana* L. (737)

Aizoaceae [Molluginaceae]
*Mollugo verticillata* L. (369)

Portulacaceae
*Claytonia virginica* L. [Montiaceae] (154)
*Portulaca mundula* I.M. Jtn. [*Portulaca pilosa* L.] (102, 359)
*Portulaca oleracea* L. (85)
*Talinum calycinum* Engelm. [*Phemeranthus calycinus* (Engelm.) Kiger] [Montiaceae] (345)
*Talinum parviflorum* Nutt. [*Phemeranthus parviflorus* (Nutt.) Kiger] [Montiaceae] (Barclay unnumbered)

Caryophyllaceae
*Arenaria patula* Michx. [*Minuartia patula* (Michx.) Mattf.] (189)
*Arenaria stricta* Michx. var. *texana* Robinson [*Minuartia michauxii* (Fenzl) Farw.] (293)
*Cerastium brachypodum* (Engelm.) Robinson [*Cerastium brachypodum* (Engelm. ex A. Gray) B.L. Rob.] 168, 173, 186, 190)
*Cerastium viscosum* L. [*Cerastium glomeratum* Thuill.] (172)
*Paronychia canadensis* (L.) Woods (384)
*Paronychia fastigata* (Raf.) Fern. (503)
*Silene antirrhina* L. (209)
*Silene stellata* (L.). Ait. f. var. *scabrella* (Niewl.) Palm. & Steyerm. [*Silene stellata* (L.) Ait. f.] (50, 53)
*Stellaria media* (L.) Cyrill (991)
*Stellaria nuttallii* T. & G. [*Minuartia drummondii* (Shinners) McNeill] (247, 258)

Nymphaceae [Nymphaeaceae]
*Nelumbo lutea* (Willd.) Pers. [Nelumbonaceae] (607)
*Nymphea tuberosa* Paine [*Nymphaea odorata* Aiton ssp. *tuberosa* (Paine) Wiersema & Hellq.] (496)

Ranunculaceae
*Anemone caroliniana* Walt. (163, 164)
*Aquilegia canadensis* L. var. *latiscula* (Greene) Munz [*Aquilegia canadensis* L.] (237)
*Clematis pitcheri* T. & G. [*Clematis pitcheri* Torr. & A. Gray] (68, 387)

*Delphinium virescens* Nutt. var. *virescens* [*Delphinium carolinianum* Walter ssp. *virescens* (Nutt.) R.E. Brooks] (11)
*Isopyrum biternatum* (Raf.) T & G. [*Enemion biternatum* Raf.] (Kelting 1004)
*Myosurus minimus* L. (204)
*Ranunculus abortivus* L. var. *abortivus* [*Ranunculus abortivus* L.] (183)
*Ranunculus fascicularis* Muhl. var. *fascicularis (155, 199)*
*Thalictrum dasycarpum* Fisch.& Lall. var. *hypoglaucum* (Rydb.) Boivin [*Thalictrum dasycarpum* Fisch. & Lall.] (54)

Berberidaceae
*Podophyllum peltatum* L. (787)

Menispermaceae
*Cocculus carolinus* (L.) DC. (437)
*Menispermum canadense* L. (648, 657)

Annonaceae
*Asimina triloba* Dunal [*Asimina triloba* (L.) Dunal] (224, 390, 653, 788)

Lauraceae
*Lindera benzoin* (L.) Blume var. *pubescens* (Palmer and Steyerm.) Rehd. [*Lindera benzoin* (L.) Blume] (559)
*Lindera benzoin* (L.) Blume var. undetermined [*Lindera benzoin* (L.) Blume] (769)

Papaveraceae
*Argemone intermedia* Sweet [*Argemone polyanthemos* (Fedde) G.B. Ownbey] (248)
*Corydalis crystallina* Engelm. (207)
*Corydalis micrantha* (Engelm.) Gray [*Corydalis micrantha* (Engelm. ex A. Gray) A. Gray] (181)
*Dicentra cucullaria* (L.) Bernh. (208, 778)

Cruciferae [Brassicaceae]
*Brassica nigra* (L.) Koch (227)
*Camelina microcarpa* Andrz. [*Camelina microcarpa* DC.] (188, 215)
*Capsella bursa-pastoris* (L.) Medic. (201)
*Cardamine parviflora* L. var. *arenicola* (Britt.) O.E. Schulz [*Cardamine parviflora* L.] (160)
*Cardamine pennsylvanica* Muhl. [*Cardamine pensylvanica* Muhl. ex Willd.] (784)
*Conringia orientalis* (L.) Dumort. (167)
*Dentaria laciniata* Muhl. [*Cardamine concatenata* (Michx.) Sw.] (772)
*Descurainia pinnata* (Walt.) Britt. [*Descurainia pinnata* (Walter) Britton] (146)
*Draba brachycarpa* Nutt. [*Draba brachycarpa* Nutt. ex Torr & A. Gray] (174)
*Draba cuneifolia* Nutt. var. *cuneifolia* [*Draba cuneifolia* Nutt. var. *cuneifolia* Nutt. ex Torr. & A. Gray] (147)
*Draba reptans* (Lam.) Fern. var. *reptans* [*Draba reptans* (Lam.) Fernald] (127, 156)
*Erysimum asperum* DC. (212, 231, 570)
*Erysimum repandum* L. (170)
*Iodanthus pinnatifidus* (Michx.) Steud. (649)
*Lepidium densiflorum* Schrad. (257)
*Lepidium virginicum* L. (865)
*Lesquerella gracilis* (Hook.) Wats. var. *repanda* (Nutt.) Payson [*Physaria gracilis* (Hook.) O'Kane & Al-Shehbaz ssp. *nuttallii* (Torr. & A. Gray) O'Kane & Al-Shehbaz] (165, 232)

*Rorippa sessiliflora* (Nutt.) Hitchc. (627)
*Selenia aurea* Nutt. (148)
*Sibara virginica* (L.) Rollins [*Planodes virginica* (L.) Greene] (131, 161)
*Thlaspi arvense* L. (779)

Crassulaceae
*Sedum nuttallianum* Raf. [*Sedum nuttallii* Torr. & E. James ex Eaton] (906)
*Sedum pulchellum* Michx. (260)

Saxifragaceae
*Penthorum sedoides* L. [Penthoraceae] (574, 616)
*Ribes odoratum* Wendland f. [*Ribes aureum* Pursh var. *villosum* DC.] [Grossulariaceae] (158)
*Saxifraga texana* Buckl. [*Micranthes texana* (Buckley) Small] (194)

Platanaceae
*Platanus occidentalis* L. (758)

Rosaceae
*Agrimonia pubescens* Wallr. (663)
*Agrimonia rostellata* Wallr. (416, 589)
*Amelanchier arborea* (Michx. f.) Fern. [*Amelanchier arborea* (Michx. f) Fernald] (144)
*Crataegus mollis* (T. & G.) Scheele [*Crataegus mollis* (Torr. & A. Gray) Scheele] (790)
*Crataegus reverchonii* Sarg. var. undetermined (856)
*Fragaria virginiana* Duchesne (795)
*Geum canadense* Jacq. var. *camporum* (Rydb.) Fern. & Weath. [*Geum canadense* Jacq.] (309, 596)
*Geum vernum* (Raf.) T & G. [*Geum vernum* (Raf.) Torr. & A. Gray] (794)
*Prunus americana* Marsh. [*Prunus americana* Marshall] (773)
*Prunus angustifolia* Marsh. var. undetermined [*Prunus angustifolia* Marshall var. undetermined] (150)
*Prunus gracilis* Engelm. & Gray [*Prunus gracilis* Engelm. & A. Gray] (Kelting 1008)
*Prunus hortulana* Bailey (791)
*Prunus mexicana* Wats. [*Prunus mexicana* S. Watson] (137, 140, 141, 142)
*Prunus serotina* Ehrh. (867, 887)
*Rosa arkansana* Porter var. *suffulta* (Greene) Cockerell [*Rosa arkansana* Porter] (474)
*Rosa carolina* L. (288, 404, 742)
*Rosa setigera* Michx. var. *tomentosa* T. & G. [*Rosa setigera* Michx.] (36)
*Rubus mollior* Bailey [*Rubus pensylvanicus* Poir.] (868)
*Sanguisorba annua* Nutt. [*Poteridium annuum* (Nutt.) Spach.] (287)

Leguminosae [Fabaceae]
*Acacia angustissima* (Mill.) Kuntze var. *hirta* (Nutt.) Robinson (Latting 101)
*Amorpha canescens* Pursh var. *canescens* [*Amorpha canescens* Pursh] (37)
*Amorpha canescens* Pursh var. *glabrata* Gray [*Amorpha canescens* Pursh] (722)
*Amorpha fruticosa* L. var. *fruticosa* (448)
*Amphicarpa bracteata* (L.) Fern. var. *bracteata* [*Amphicarpaea bracteata* (L.) Fernald var. *bracteata*] (658)
*Astragalus canadensis* L. (470)
*Astragalus caryocarpus* Ker [*Astragalus carassicarpus* Nutt. var. *crassicarpus*] (*297)*
*Astragalus nuttallianus* DC. var. *nuttallianus* [*Astragalus nuttallianus* DC.] (286)

*Baptisia leucantha* T. & G. [*Baptisia lactea* (Raf.) Thieret var. *lactea*] (41)
*Baptisia leucophaea* Nutt. var. *leucophaea* [*Baptisia leucophaea* Nutt.] (859)
*Baptisia minor* Lehm. [*Baptisia australis* (L.) R. Br. var. *minor* (Lehm.) Fernald] (255)
*Cassia fasciculata* Michx. [*Chamaecrista fasciculata* (Michx.) Greene var. *fasciculata*] (362, 426)
*Cassia marilandica* L. [*Senna marilandica* (L.) Link.] (526)
*Cassia nictitans* L. [*Chamaecrista nictitans* (L.) Moench var. *nictitans*] (466, 595)
*Cercis canadensis* L. var. *canadensis* (786)
*Clitoria mariana* L. (531)
*Crotalaria sagittalis* L. (379)
*Dalea lanata* Spreng. (101)
*Desmanthus illinoensis* (Michx.) MacM. (43, 400)
*Desmodium canescens* (L.) DC. (523, 582, 654)
*Desmodium glutinosum* (Muhl.) Wood [*Desmodium glutinosum* (Muhl.) Alph. Wood] (408)
*Desmodium illinoense* Gray [*Desmodium illinoense* A. Gray] (407)
*Galactia volubilis* (L.) Britt. var. *mississippiensis* Vail [*Galactia volubilis* (L.) Britton] (473, 533, 754)
*Gleditsia triacanthos* L. (884)
*Glycyrrhiza lepidota* (Nutt.) Pursh (478)
*Gymnocladus dioica* (L.) Koch (391, 759)
*Indigofera leptosepala* Nutt. [*Indigofera miniata* Ortega] (374)
*Lathyrus pusillus* Ell. [*Lathyrus pusillus* Elliott] (259)
*Lespedeza stuevei* Nutt. var. *angustifolia* Britt. [*Lespedeza X neglecta* Mack. & Bush (pro sp.)] (598, 753)
*Lespedeza violacea* (L.) Pers. (620)
*Medicago hispida* Gaertn. [*Medicago polymorpha* L.] (318)
*Medicago sativa* L. (465)
*Melilotus alba* Desv. [*Melilotus albus* Medik.] (26)
*Melilotus officinalis* (L.) Lam. (16)
*Neptunia lutea* (Leavenw.) Benth. (442)
*Petalostemum candidum* (Willd.) Michx. [*Dalea candida* Michx. ex Willd.] (38)
*Petalostemum multiflorum* Nutt. [*Dalea multiflora* (Nutt.) Shinners] (488)
*Petalostemum purpureum* (Vent.) Rydb. [*Dalea purpurea* Vent.] (24)
*Prosopis juliflora* (Swartz) DC. var. *torreyana* Benson [*Prosopis glandulosa* Torr. var. *torreyana* (L.D. Benson) M.C. Johnson] (440, 973)
*Psoralea esculenta* Pursh [*Pediomelum esculentum* (Pursh) Rydb.] (294)
*Psoralea tenuiflora* Pursh [*Psoralidium tenuiflorum* (Pursh) Rydb.] (273, 337, 463)
*Robinia pseudo-acacia* L. (860)
*Schrankia nuttallii* (DC.) Standl. [*Mimosa nuttallii* (DC. ex Britton & Rose) B.L. Turner] (7)
*Sesbania exaltata* (Raf.) Cory [*Sesbania herbacea* (Mill.) McVaugh] (89, 561, 631)
*Strophostyles helvola* (L.) Ell. [*Strophostyles helvola* (L.) Elliott] (109, 475, 495)
*Strophostyles leiosperma* (T. & G.) Piper [*Strophostyles leiosperma* (Torr. & A. Gray) Piper] (108, 468)
*Stylosanthes biflora* (L.) BSP. var. *hispidissima* (Michx.) Pollard & Ball [*Stylosanthes biflora* (L.) Britton, Sterns & Poggenb.] (46)
*Tephrosia virginiana* (L.) Pers. var. *holosericea* (Nutt.) T. & G. [*Tephrosia virginiana* (L.) Pers. var. *holosericea* (Nutt.) Torr. & A. Gray] (22)
*Trifolium repens* L. (735)
*Vicia micrantha* Nutt. [*Vicia minutiflora* D. Dietr.] (780)
*Vicia villosa* Roth. (300)

Linaceae
*Linum lewisii* Pursh var. *pratense* Norton [*Linum pratense* (Norton) Small] (217, 346)
*Linum medium* (Planch.) Britton var. *texanum* (Planch.) Fern. [*Linum medium* (Planch.) Britton var. *texanum* (Planch.) Fernald] (328)
*Linum sulcatum* Riddell (45, 298, 423)

Oxalidaceae
*Oxalis europaea* Jord. var. *europaea* [*Oxalis stricta* L.] (690)
*Oxalis stricta* L. (483)
*Oxalis violacea* L. var. *violacea* [*Oxalis violacea* L.] (4)

Geraniaceae
*Geranium carolinianum* L. (19)

Zygophyllaceae
*Kallstroemia intermedia* Rydb. *[Kallstroemia parviflora* Norton] (116)
*Tribulus terrestris* L. (39)

Rutaceae
*Xanthoxylum americanum* Mill. [*Zanthoxylum americanum* Mill.] (145)

Simaroubaceae
*Ailanthus altissima* (Mill.) Swingle (Kelting 1050)

Polygalaceae
*Polygala incarnata* L. (301, 348, 406)

Euphorbiaceae
*Acalypha gracilens* Gray var. *gracilens* [*Acalypha gracilens* A. Gray] (86)
*Acalypha ostryaefolia* Riddell [*Acalypha ostryifolia* Riddell] (87, 492)
*Acalypha rhomboidea* Raf. (493)
*Acalypha virginica* L. (312)
*Cnidoscolus texanus* (Muell. Arg.) Small (361)
*Croton capitatus* Michx. (93)
*Croton glandulosus* L. var. *septentrionalis* Muell. Arg. [*Croton glandulosus* L.] (78, 487)
*Croton monanthogynus* Michx.
*Crotonopsis linearis* Michx. [*Croton michauxii* G.L. Webster] (464)
*Euphorbia chamaesyce* L. [A misidentification, as this species does not occur in North America.] (119)
*Euphorbia corollata* L. var. *corollata* [*Euphorbia corollata* L.] (82, 405)
*Euphorbia dentata* Michx. (60, 73, 447)
*Euphorbia dictyosperma* Fisch. & Mey. [*Euphorbia spathulata* Lam.] (262)
*Euphorbia heterophylla* L. (411, 550)
*Euphorbia hexagona* Nutt. [*Euphorbia hexagona* Nutt. ex Spreng.] (103, 686)
*Euphorbia maculata* L. (83)
*Euphorbia marginata* Pursh (608)
*Euphorbia missurica* Raf. var. *calcicola* (Shinners) Waterfall [*Euphorbia missurica* Raf.] (99, 120, 565)
*Euphorbia serpens* HBK. [*Euphorbia serpens* Kunth] (104, 684)

*Euphorbia supina* Raf. [*Euphorbia maculata* L.] (77, 105)
*Stillingia sylvatica* L. (276)
*Tragia urticifolia* Michx. (14)

Callitrichaceae [Plantaginaceae]
*Callitriche heterophylla* Pursh (Kelting 997)

Anacardiaceae
*Cotinus obovatus* Raf. (239, 881, 882)
*Rhus aromatica* Ait. var. undetermined (136)
*Rhus aromatica* Ait. var. *aromatica* (743)
*Rhus copallina* L. var. *latifolia* Engler [*Rhus copallinum* L. var. *copallinum*]
*Rhus glabra* L. (314)
*Rhus radicans* L. [*Toxicodendron radicans* (L.) Kuntze ssp. *radicans*] (observed)
*Rhus toxicodendron* L. [*Toxicodendron pubescens* Mill.] (observed)

Aguifoliaceae [Aquifoliaceae]
*Ilex decidua* Walt. [*Ilex decidua* Walter] (193, 223)

Celastraceae
*Celastrus scandens* L. (415, 699)
*Euonymus atropurpureus* Jacq. (436)

Staphyleaceae
*Staphylea trifolia* L. (203)

Aceraceae [Sapindaceae]
*Acer negundo* L. var. *negundo* (143)
*Acer saccharinum* L. (774)

Hippocastanaceae [Sapindaceae]
*Aesculus glabra* Willd. var. *sargentii* Rehd. [*Aesculus glabra* Willd. var. *glabra*] (185)

Sapindaceae
*Sapindus drummondi* H. & A. [*Sapindus saponaria* L. var. *drummondii* (Hook. & Arn.) L.D. Benson] (726)
*Cardiospermum halicacabum* L. (580, 751)

Balsaminaceae
*Impatiens capensis* Meerburg [*Impatiens capensis* Meerb.] (432)

Rhamnaceae
*Ceanothus americanus* L. var. *pitcheri* T. & G. [*Ceanothus americanus* L. var. *pitcheri* Torr. & A. Gray] (69)

Vitaceae
*Ampelopsis arborea* (L.) Koehne (585)
*Ampelopsis cordata* Michx. (438, 563)
*Cissus incisa* (Nutt.) Des Moulins [*Cissus trifoliatus* (L.) L.] (500, 547)

*Parthenocissus quinquefolia* (L.) Planch. (876)
*Vitis aestivalis* Michx. var. *argentifolia* (Munson) Fern. [*Vitis aestivalis* Michx. var. *bicolor* Deam] (250)
*Vitis vulpina* L. (870)

Malvaceae
*Abutilon theophrasti* Medic. (634)
*Callirhoe alceoides* (Michx.) Gray [*Callirhoe alcaeoides* (Michx.) A. Gray] (233)
*Callirhoe involucrata* (T. & G.) Gray var. *involucrata* [*Callirhoe involucrata* (Torr. & A. Gray) A. Gray var. *involucrata*] (59)
*Hibiscus lasiocarpos* Cav. [*Hibiscus moscheutos* L. spp. *lasiocarpos* (Cav.) O.J. Blanch.] (579)
*Hibiscus militaris* Cav. [*Hibiscus laevis* All.] (522)
*Sida spinosa* L. (517)
*Sphaeralcea angusta* (Gray) Fern. [*Malvastrum hispidum* (Pursh) Hochr.] (380, 424)

Guttiferae [Hypericaceae]
*Ascyrum hypericoides* L. var. *multicaule* (Michx.) Fern. [*Hypericum hypericoides* (L.) Crantz ssp. *multicaule* (Michx. ex Willd.) N. Robson] (467)
*Hypericum drummondii* (Grev. & Hook.) T. & G. [*Hypericum drummondii* (Grev. & Hook) Torr. & A. Gray] (472, 494, 502)
*Hypericum gymnanthum* Engelm. & Gray [*Hypericum gymnathum* Engelm. & A. Gray] (670)
*Hypericum sphaerocarpum* Michx. (31, 381)

Tamaricaceae
*Tamarix gallica* L. (98)

Cistaceae
*Lechea tenuifolia* Michx. var. *tenuifolia* [*Lechea tenuifolia* Michx.] (329)

Violaceae
*Hybanthus linearis* (Torr.) Shinners [*Hybanthus verticillatus* (Ortega) Baill.] (281)
*Viola kitaibeliana* R. & S. var. *rafinesquii* (Greene) Fern. [*Viola bicolor* Pursh] (151)
*Viola missouriensis* Greene [*Viola sororia* Willd. var. *missouriensis* (Greene) L.E. McKinney] (152, 153, 793)
*Viola pensylvanica* Michx. var. *pensylvanica* [*Viola pubescens* Aiton var. *scabriuscula* Torr. & A. Gray] (771)

*Viola pensylvanica* Michx. var. *leicarpa* (Fern. & Wieg.) Fern. [*Viola pubescens* Aiton var. *scabriuscula* Torr. & A. Gray] (182)
*Viola sororia* Willd. [*Viola sororia* Willd. var. *sororia*] (770)
*Viola triloba* Schwein var. *dilatata* (Ell.) Brainerd [*Viola palmata* L.] (197)

Passifloraceae
*Passiflora incarnata* L. (51, 528)
*Passiflora lutea* L. var. *glabriflora* Fern. [*Passiflora lutea* L.] (549, 560)

Loasaceae
*Mentzelia oligosperma* Nutt. [*Mentzelia oligosperma* Nutt. ex Sims] (334, 571)

Cactaceae

*Neobessya similis* (Engelm.) Br. & Rose [*Escobaria missouriensis* (Sweet) D.R. Hunt var. *missouriensis*] (observed)
*Opuntia macrorhiza* Engelm. (742A)

Lythraceae

*Ammannia auriculata* Willd. (81, 421)
*Ammannia coccinea* Rothb. (703A)
*Cuphea petiolata* (L.) Koehne [*Cuphea viscocissima* Jacq.] (600)
*Lythrum lanceolatum* Ell. [*Lythrum alatum* Pursh var. *lanceolatum* (Elliott) Torr. & A. Gray ex Rothr.] (62, 358, 377)
*Rotala ramosior* (L.) Koehne var. *interior* Fern. & Grisc. [*Rotala ramosior* (L.) Koehne] (552)

Onagraceae

*Gaura biennis* L. var. *pitcheri* Pickering [*Oenothera filiformis* (Small) W.L. Wagner & Hoch] (74, 497, 545, 640)
*Gaura parviflora* Dougl. [*Oenothera curtiflora* W.L. Wagner & Hoch] (484)
*Gaura suffulta* Engelm. [*Oenothera suffulta* (Wngelm.) W. L. Wagner & Hoch] (254, 382)
*Gaura tripetala* Cav. var. *triangulata* (Buckl.) Munz. [*Oenothera triangulata* (Buckley) W.L. Wagner & Hoch] (339, 383)
*Jussiaea decurrens* (Walt.) DC. [*Ludwigia decurrens* (DC.) Walter] (581)
*Jussiaea repens* L. var. *glabrescens* Ktze. [*Ludwigia peploides* (Kunth) P.H. Raven ssp. *glabrescens* (Kuntze) P.H. Raven] (55, 388, 534)
*Ludwigia alternifolia* L. (490, 577, 614)
*Ludwigia palustris* (L.) Ell. var. *americana* (DC.) Fern. & Grisc. [*Ludwigia palustris* (L.) Elliott] (434, 573)
*Oenothera biennis* L. var. *canescens* T. & G. [*Oenothera villosa* Thunb. ssp. villosa] (618)
*Oenothera biennis* L. var. *hirsutissima* Gray [*Oenothera elata* Kunth. ssp. *hirsutissima* (A. Gray ex S. Watson) W. Dietr.] (601)
*Oenothera laciniata* Hill var. *laciniata* [*Oenothera laciniata* Hill] (278)
*Oenothera linifolia* Nutt. (242)
*Oenothera rhombipetala* Nutt. [*Oenothera rhombipetala* Nutt. ex Torr. & A. Gray] (360)
*Oenothera serrulata* Nutt. (265, 279)
*Oenothera speciosa* Nutt. (285)
*Oenothera triloba* Nutt. (187, 210)

Umbelliferae [Apiaceae]

*Ammoselinum butleri* (Engelm.) Coult. & Rose [*Ammoselinum butleri* (Engelm. ex S. Watson) J.M. Coult. & Rose] (820)
*Bifora americana* (DC.) Wats [*Bifora americana* Benth. & Hook. f. ex S. Watson] (290, 338)
*Chaerophyllum texanum* C. & R. [*Chaerophyllum tainturieri* Hook. var. *tainturieri*] (200)
*Cicuta maculata* L. (530)
*Cynosciadium pinnatum* DC. [*Limnosciadium pinnatum* (DC.) Mathias & Constance] (295)
*Daucus pusillus* Michx. (418)
*Eryngium leavenworthii* T. & G. [*Eryngium leavenworthii* Torr. & A. Gray] (121)
*Eryngium yuccifolium* Michx. var. *synchaetum* Gray [*Eryngium yuccifolium* Michx. var. *synchaetum* A. Gray ex J.M. Coult. & Rose] (357)

*Lomatium foeniculaceum* (Nutt.) Coulter & Rose [*Lomatium foeniculaceum* (Nutt.) J.M. Coulter & Rose] (128, 162)
*Polytaenia nuttallii* DC. var. *nuttallii* [*Polytaenia nuttallii* DC.] (34)
*Ptilimnium nuttallii* (DC.) Britton (44, 389)
*Sanicula canadensis* L. var. *canadensis* (308, 444)
*Sanicula gregaria* Bicknell [*Sanicula odorata* (Raf.) K.M. Pryer & L.R. Phillippe] (253)
*Spermolepis echinata* (Nutt.) Heller [*Spermolepis echinata* (Nutt. ex DC.) A. Heller] (325)
*Torilis japonicus* (Houtt.) DC. [*Torilis japonica* (Houtt.) DC.] (67, 417)
*Zizia aurea* (L.) Koch (222, 461)

Cornaceae
*Cornus drummondii* Meyer (271)

Ericaceae
*Vaccinium arboreum* Marsh. var. *arboreum* [*Vaccinium arboreum* Marsh] (719)

Primulaceae
*Androsace occidentalis* Pursh (159)
*Centunculus minimus* L. [*Anagallis minima* (L.) E.H.L. Krause] (323)
*Dodecatheon meadia* L. [*Primula meadia* (L.) A.R. Mast & Reveal] (176, 251, 252)
*Lysimachia ciliata* L. (433)
*Samolus parviflorus* Raf. [*Samolus valerandi* L.] (Kelting 1009)

Sapotaceae
*Bumelia lanuginosa* (Michx.) Pers. var. *oblongifolia* (Nutt.) R.B. Clark [*Sideroxylon lanuginosum* Michx. var. *oblongifolium* (Nutt.) T.D. Penn] (446)

Ebenaceae
*Diospyros virginiana* L. var. *virginiana* [*Diospyros virginiana* L.] (905)
*Diospyros virginiana* L. var. undetermined [*Diospyros virginiana* L.] (741)

Oleaceae
*Forestiera acuminata* (Michx.) Poir. (777)
*Fraxinus americana* L. (157)
*Fraxinus pennsylvanica* Marsh. var. *subintegerrima* [*Fraxinus pennsylvanica* Marshall] (195, 878)
*Fraxinus quadrangulata* Michx. (139)

Gentianaceae
*Sabatia campestris* Nutt. (347, 354, 399)

Apocynaceae
*Apocynum cannabinum* L. var. *cannabinum* [*Apocynum cannabinum* L.] (739)

Asclepiadaceae [Apocynaceae]
*Ampelamus albidus* (Nutt.) Britt. [*Cynanchum laeve* (Michx.) Pers.] (485)
*Asclepiadora viridis* (Walt.) Gray [*Asclepias viridis* Walter] (33)
*Asclepias amplexicaulis* J.E. Smith (70, 419)

*Asclepias auriculata* (Engelm.) Holz. [*Asclepias engelmanniana* Woodson] (320) [Probably misidentified; this species does not occur in eastern Oklahoma.]
*Asclepias hirtella* (Pennell) Woodson (639)
*Asclepias incarnata* L. (564)
*Asclepias speciosa* Torr. (972)
*Asclepias stenophylla* Gray [*Asclepias stenophylla* A. Gray] (42, 398)
*Asclepias tuberosa* L. (21)
*Asclepias verticillata* L. (40, 586)
*Asclepias viridiflora* Raf. var. *viridiflora* [*Asclepias viridiflora* Raf.] (29, 403)
*Gonolobus gonocarpus* (Walt.) Perry [*Gonolobus suberosus* (L.) R.Br. var. *suberosus]* (58, 597)

Convolvulaceae
*Convolvulus arvensis* L. (370)
*Cuscuta cuspidata* Engelm. (982)
*Cuscuta gronovii* Willd. (652)
*Ipomea hederacea* (L.) Jacq. var. *integriscula* Gray [*Ipomoea hederacea* Jacq.] (617)
*Ipomea lacunosa* L. [*Ipomoea lacunosa* L.] (610)
*Ipomea pandurata* (L.) G.F.W. Mey. [*Ipomoea pandurata* (L.) G.F.W. Mey.] (457)

Polemoniaceae
*Phlox divaricata* L. var. *laphamii* Wood [*Phlox divaricata* L. ssp. *laphamii* (Alph. Wood) Wherry] (206)
*Phlox pilosa* L. var. *ozarkana* Wherry [*Phlox pilosa* L. ssp. *ozarkana* (Wherry) Wherry] (10, 270)

Hydrophyllaceae
*Ellisia nyctelea* L. (205)
*Nama hispidum* Gray [*Nama hispida* A. Gray] **[Boraginaceae]** (283)
*Phacelia gilioides* A. Brand (220)
*Phacelia hirsuta* Nutt. (211)

Boraginaceae
*Heliotropium curassavicum* L. (97)
*Heliotropium indicum* L. (385)
*Heliotropium tenellum* (Nutt.) Torr. (282, 336)
*Lithospermum arvense* L. [*Buglossoides arvensis* (L.) I.M. Johnst.] (169)
*Lithospermum incisum* Lehm. (171)
*Myosotis verna* Nutt. (196, 235)
*Onosmodium hispidissimum* Mackenzie [*Onosmodium bejariense* DC. ex A. DC. var *hispidissimum* (Mack.) B.L. Turner] (310)

Verbenaceae
*Lippia lanceolata* Michx. var. *recognita* Fern. & Grisc. [*Phyla lanceolata* (Michx.) Greene] (66)
*Lippia nodiflora* (L.) Michx. [*Phyla nodiflora* (L.) Greene] (306)
*Verbena bracteata* Lag. & Rodr. [*Verbena bracteata* Cav. ex Lag. & Rodr.] (363)
*Verbena canadensis* (L.) Britt. [*Glandularia canadensis* (L.) Nutt.] (72, 425)
*Verbena simplex* Lehm. (342)
*Verbena stricta* Vent. (366)
*Verbena urticifolia* L. var. *urticifolia* (64, 441, 524)

Labiatae [Lamiaceae]
*Agastache nepetoides* (L.) Kuntze (698)
*Hedeoma hispida* Pursh (261)
*Isanthus brachiatus* (L.) BSP. [*Trichostema brachiatum* L.] (569)
*Lamium amplexicaule* L. (184)
*Monarda citriodora* Cerv. [*Monarda citriodora* Cerv. ex Lag.(291)
*Monarda fistulosa* L. var. *mollis* (L.) Benth. (352)
*Physostegia angustifolia* Fern. [*Physostegia angustifolia* Fernald] (47, 349)
*Prunella vulgaris* L. var. *lanceolata* (Bart.) Fern. [*Prunella vulgaris* L. ssp. *lanceolata* (W. Bartram) Hultén] (396)
*Pycnanthemum tenuifolium* Schrad. (469)
*Salvia azurea* Lam. var. *grandiflora* Benth. (529)
*Satureja arkansana* (Nutt.) Brig. [*Clinopodium glabrum* (Nutt.) Kuntze] (292)
*Scutellaria lateriflora* L. (307, 413)
*Scutellaria parvula* Michx. var. *parvula* (18, 246)
*Stachys tenuifolia* Willd. (599, 660)
*Teucrium canadense* L. var. *virginicum* (L.) Eat. [*Teucrium canadense* L. var. *canadense*] (367)

Solanaceae
*Datura stramonium* L. (35, 612)
*Physalis pendula* Rydb. [*Physalis angulata* L.] (395)
*Physalis pubescens* L. (392)
*Physalis pumila* Nutt. (8)
*Physalis subglabrata* Mackenz. & Bush [*Physalis longifolia* Nutt. var. *subglabrata* (Mack. & Bush.) Cronquist] (638)
*Solanum americanum* Mill. (409)
*Solanum carolinese* L. [*Solanum carolinense* L.] (744, 976)
*Solanum elaeagnifolium* Cav. (333)
*Solanum rostratum* Dunal (123, 747)

Scrophulariaceae
*Buchnera americana* L. [Orobanchaceae] (428)
*Castilleja purpurea* (Nutt.) G. Don [Orobanchaceae] (230, 244)
*Collinsia violacea* Nutt. [Plantaginaceae] (179)
*Conobea multifida* (Michx.) Benth. [*Leucospora multifida* (Michx.) Nutt.] [Plantaginaceae] (378)
*Gerardia grandiflora* Benth. var. *cinerea* (Pennell) Cory [*Aureolaria grandiflora* (Benth.) Pennell] [Orobanchaceae] (501, 535, 680)
*Gerardia heterophylla* Nutt. [*Agalinis heterophylla* (Nutt.) Small] [Orobanchaceae] (88, 630, 647)
*Gerardia skinneriana* Wood [*Agalinis skinneriana* (Alph. Wood) Britton] [Orobanchaceae] (678, 717)
*Linaria canadensis* (L.) Dumont var. *texana* Pennell [*Nuttallanthus texanus* (Scheele) D.A. Sutton] [Orobanchaceae] (218)
*Lindernia anagallidea* (Michx.) Pennell [*Lindernia dubia* (L.) Pennell] [Linderniaceae] (386, 420)
*Mimulus alatus* Ait. [Phrymaceae] (575, 609)
*Penstemon cobaea* Nutt. [Plantaginaceae] (267)
*Penstemon tubaeflorus* Nutt. [Plantaginaceae] (275, 313, 504)
*Seymeria macrophylla* Nutt. [*Dasistoma macrophylla* (Nutt.) Raf.] [Orobanchaceae] (435)
*Verbascum thapsus* L. (477)

*Veronica arvensis* L. [Plantaginaceae] (180)
*Veronica hederaefolia* L. [*Veronica hederifolia* L.] [Plantaginaceae] (132, 134, 175, 864)
*Veronica peregrina* L. var. *peregrina* [*Veronica peregrina* L.] [Plantaginaceae] (198)
*Veronica peregrina* L. var. *xalapensis* (HBK.) St. John & Warren [*Veronica peregrina* L.] [Plantaginaceae] (202, 796)
*Veronica polita* Fries [Plantaginaceae] (126, 133)

Bignoniaceae
*Campsis radicans* (L.) Seem. [*Campsis radicans* (L.) Seem. ex Bureau] (365)
*Catalpa speciosa* Warder [*Catalpa speciosa* (Warder) Warder ex Engelm.] (904)

Lentibulariaceae
*Utricularia biflora* Lam. [*Utricularia gibba* L.] (115)

Acanthaceae
*Dicliptera brachiata* (Pursh) Spreng. (544)
*Justicia americana* (L.) Vahl var. *subcoriacea* Fern. [*Justicia americana* (L.) Vahl] (56, 350)
*Ruellia humilis* Nutt. var. *humilis* [*Ruellia humilis* Nutt.] (5)
*Ruellia humilis* Nutt. var. *longiflora* (Gray) Fern. [*Ruellia humilis* Nutt.] (376)
*Ruellia strepens* L. (20, 594)

Phrymaceae
*Phryma leptostachya* L. (555)

Plantaginaceae
*Plantago aristata* Michx. (13, 304, 341, 351)
*Plantago purshii* R. & S. var. *purshii* [*Plantago patagonica* Jacq.] (30, 340)
*Plantago pusilla* Nutt. (191)
*Plantago rugelii* Dcne. [*Plantago rugelii* Decne.] (412, 505)
*Plantago virginica* L. (263)

Rubiaceae
*Cephalanthus occidentalis* L. var. *occidentalis* [*Cephalanthus occidentalis* L.] (63)
*Diodia teres* Walt. var. *setifera* Fern. & Grisc. [*Diodia teres* (Walter) Small] (114, 371)
*Galium aparine* L. (213)
*Galium pilosum* Ait. var. *puncticulosum* (Michx.) T. & G. [*Galium pilosum* Aiton var. *puncticulosum* (Michx.) Torr. & A. Gray] (327)
*Galium virgatum* Nutt. (234)
*Houstonia minima* Beck [*Houstonia pusilla* Schoepf] (149)
*Houstonia nigricans* (Lam.) Fern. [*Stenaria nigricans* (Lam.) Terrell var. *nigricans]* (266)
*Spermacoce glabra* Michx. (525)

Caprifoliaceae
*Lonicera flava* Sims (192)
*Sambucus canadensis* L. var. *canadensis* [*Sambucus nigra* L. ssp. *canadensis* (L.) R. Bolli] [Adoxaceae] (364)
*Symphoricarpos orbiculatus* Moench (393)
*Viburnum rufidulum* Raf. [Adoxaceae] (238)

Valerianaceae
*Valerianella radiata* (L.) Durf. var. *radiata* [*Valerianella radiata* (L.) Dufr.] (12, 862)

Cucurbitaceae
*Cucurbita foetidissima* HBK. [*Cucurbita foetidissima* Kunth] (343)
*Melothria pendula* L. (512, 557)
*Sicyos angulatus* L. (651)

Campanulaceae
*Campanula americana* L. var. *illinoensis* (Fresn.) Farw. [*Campanula americana* L.] (553, 632)
*Lobelia appendiculata* DC. (356)
*Lobelia puberula* Michx. var. *mineolana* E. Wimm. (672)
*Lobelia spicata* Lam. var. *leptostachys* (A. DC.) Mack. & Bush [*Lobelia spicata* Lam.] (299)
*Specularia biflora* (R. & P.) Fisch. & Mey. [*Triodanis perfoliata* (L.) Nieuwl. ssp. *biflora* (Ruiz & Pav.) Lammers] (305)
*Specularia leptocarpa* (Nutt.) Gray [*Triodanis leptocarpa* (Nutt.) Nieuwl.] (284)
*Specularia perfoliata* (L.) A. DC. [*Triodanis perfoliata* (L.) Niewl. ssp. *perfoliata*] (17, 274)

Compositae [Asteraceae]
*Achillea lanulosa* Nutt. [*Achillea millefolium* L.] (3)
*Actinomeris alternifolia* (L.) DC. [*Verbesina alternifolia* (L.) Britton ex Kearney] (558)
*Ambrosia artemisiifolia* L. var. *elatior* (L.) Descourtils [*Ambrosia artemisiifolia* L.] (118, 704)
*Ambrosia trifida* L. var. *texana* Scheele [*Ambrosia trifida* L.] (683, 746)
*Antennaria campestris* Rydb. [*Antennaria neglecta* Greene] (776)
*Antennaria plantaginifolia* (L.) Richards (177)
*Aphanostephus skirrobasis* (DC.) Trel. (368)
*Artemisia caudata* Michx. [*Artemisia campestris* L. ssp. *caudata* (Michx.) H.M. Hall & Clem.] (Miller unnumbered) [Probably a misidentification, as this species does not occur in Oklahoma.]
*Artemisia ludoviciana* Nutt. var. *mexicana* (Willd.) Fern. [*Artemisia ludoviciana* Nutt. ssp. *mexicana* (Willd. ex Spreng.) D.D. Keck] (90, 691, 745)
*Aster ericoides* L. [*Symphyotrichum ericoides* (L.) G.L. Nesom] (695, 702)
*Aster exilis* Ell. [*Symphyotrichum subulatum* (Michx.) G.L. Nesom var. *ligulatum* (Shinners) S.D. Sundb.] (75, 76, 622, 677)
*Aster oblongifolius* Nutt. [*Symphyotrichum oblongifolium* (Nutt.) G.L. Nesom] (701)
*Aster ontarionis* Wieg. [*Symphyotrichum ontarionis* (Wiegand) G.L. Nesom] (716A, 716B)
*Aster patens* Ait. var. *gracilis* Hook [*Symphyotrichum patens* (Aiton) G.L. Nesom var. *gracile* (Hook.) G.L. Nesom] (676, 716C, 716D)
*Aster praealtus* Poir. [*Symphyotrichum praealtum* (Poir.) G.L. Nesom] (708, 709, 710, 713)
*Aster sagittifolius* Wedemeyer var. *drummondii* (Lindl.) Shinners [*Symphyotrichum drummondii* (Lindl.) G.L. Nesom var. *drummondii*] (697, 711)
*Aster simplex* Willd. [*Symphyotrichum lanceolatum* (Willd.) G.L. Newsom var. *lanceolatum*] (730)
*Aster vimineus* Lam. var. *subdumosus* Wieg. [*Symphyotrichum racemosum* (Elliot) G.L. Newsom] (755)
*Astranthium integrifolium* (Michx.) Nutt. var. undetermined (1, 2)
*Bidens bipinnata* L. (615)
*Bidens frondosa* L. (650)
*Bidens polylepis* Blake (646)
*Boltonia latisquama* Gray [*Boltonia asteroides* (L.) L'Hér. var. *latisquama* (A. Gray) Cronquist] (506, 635)

*Cacalia plantaginea* (Raf.) Shinners [*Arnoglossum plantagineum* Raf.] (48)
*Centaurea americana* Nutt. [*Plectocephalus americanus* (Nutt.) D. Don] (344)
*Chrysopsis pilosa* Nutt. [*Bradburia pilosa* (Nutt.) Semple] (277)
*Cichorium intybus* L. (427)
*Cirsium discolor* (Muhl.) Spreng. (518)
*Cirsium undulatum* (Nutt.) Spreng. (974)
*Coreopsis grandiflora* Hogg. var. *grandiflora* (*Coreopsis grandiflora* Hogg ex Sweet.] (264)
*Coreopsis tinctoria* Nutt. (61)
*Echinacea pallida* Nutt. (269)
*Eclipta alba* (L.) Hassk. [*Eclipta prostrata* (L.) L.] (443)
*Elephantopus carolinianus* Willd. [*Elephantopus carolinianus* Raeusch.] (556, 606)
*Erigeron annuus* (L.) Pers. (591, 694)
*Erigeron canadensis* L. [*Conyza canadensis* (L.) Cronquist] (79)
*Erigeron philadelphicus* L. (861)
*Erigeron strigosus* Muhl. var. *strigosus* (*Erigeron strigosus* Muhl. ex Willd. var. *strigosus*] (6, 32, 588)
*Erigeron strigosus* Muhl. var. *beyrichii* (Fisch. & Mey.) T. & G. [*Erigeron strigosus* Muhl. ex Willd. var. *strigosus*] (303)
*Erigeron tenuis* T. & G. [*Erigeron tenuis* Torr. & A. Gray] (256)
*Eupatorium coelestinum* L. [*Conoclinium coelestinum* (L.) DC.] (659)
*Eupatorium purpureum* L. [*Eutrochium purpureum* (L.) E.E. Lamont] (668)
*Eupatorium rugosum* Houtt. var. undetermined [*Ageratina altissima* (L.) King & H. Rob. var. *altissima*] (655)
*Eupatorium serotinum* Michx. (80, 604)
*Evax prolifera* Nutt. [*Diaperia prolifera* (Nutt. ex DC.) Nutt.] (877, 907)
*Gaillardia pulchella* Foug. (28)
*Gnaphalium obtusifolium* L. [*Pseudognaphalium obtusifolium* (L.) Hilliard & B.L. Burtt] (673)
*Gnaphalium purpureum* L. [*Gamochaeta purpurea* (L.) Cabrera] (326)
*Grindelia lanceolata* Nutt. var. *lanceolata* [*Grindelia lanceolata* Nutt.] (489, 703)
*Grindelia squarrosa* (Pursh) Dunal var. *squarrosa* [*Grindelia squarrosa* (Pursh) Dunal] (122)
*Gutierrezia dracunculoides* (DC.) Blake [*Amphiachyris dracunculoides* (DC.) Nutt.]
*Happlopappus ciliatus* (Nutt.) DC. [*Grindelia ciliata* (Nutt.) Spreng.] (693)
*Happlopappus divaricatus* (Nutt.) Gray [*Croptilon divaricatum* (Nutt.) Raf.] (476)
*Helenium tenuifolium* Nutt. [*Helenium amarum* (Raf.) H. Rock var. *amarum*] (696)
*Helianthus annuus* L. (451, 566)
*Helianthus besseyi* Bates [*Helianthus tuberosus* L.] (510, 521, 623)
*Helianthus hirsutus* Raf. var. *hirsutus* (322)
*Helianthus hirsutus* Raf. var. *trachyphyllus* T. & G. [*Helianthus hirsutus* Raf. var. *trachyphyllus* Torr. & A. Gray] (546, 587, 590)
*Helianthus laetiflorus* Pers. var. *rigidus* (Cass.) Fern. [*Helianthus pauciflorus* Nutt. var. *pauciflorus*] (430)
*Helianthus maximiliani* Schrad. (642)
*Helianthus mollis* Lam. (431)
*Helianthus petiolaris* Nutt. (499)
*Heliopsis helianthoides* (L.) Sweet var. *scabra* (Dunal) Fern. [*Heliopsis helianthoides* (L.) Sweet var. *scabra* (Dunal) Fernald] (583)
*Heterotheca subaxillaris* (Lam.) Britt. & Rusby [*Heterotheca subaxillaris* (Lam.) Britton & Rusby] (106, 592)
*Hieracium gronovii* L. var. undetermined (319)
*Hieracium longipilum* Torr. (422)

*Hymenopappus corymbosus* T. & G. [*Hymenopappus scabiosaeus* L'Hér. var. *corymbosus* (Torr. & A. Gray) B.L. Turner] (9)
*Iva ciliata* Willd. [*Iva annua* L.] (112, 644)
*Krigia dandelion* (L.) Nutt. (872)
*Kuhnia eupatorioides* L. var. *corymbulosa* T. & G. [*Brickellia eupatorioides* (L.) Shinners var. *corymbulosa* (Torr. & A. Gray) Shinners] (645)
*Lactuca canadensis* L. var. *latifolia* Ktze. [*Lactuca canadensis* L.] (509)
*Lactuca scariola* L. [*Lactuca serriola* L.] (480)
*Liatris angustifolia* (Bush) Gaiser [*Liatris punctata* Hook. var. *mucronata* (DC.) B.L. Turner] (Kelting 861H)
*Liatris aspera* Michx. var. *aspera* [*Liatris aspera* Michx.] (679)
*Liatris aspera* Michx. var. *intermedia* (Lunell) Gaiser [*Liatris aspera* Michx.] (491)
*Liatris mucronata* DC. [*Liatris punctata* Hook. var. *mucronata* (DC.) B.L. Turner] (643)
*Liatris pycnostachya* Michx. (454)
*Liatris squarrosa* (L.) Michx. var. *glabrata* (Rydb.) Gaiser (718)
*Pluchea purpurascens* (Sw.) DC. [*Pluchea odorata* (L.) Cass. var. *odorata*] (111)
*Polymnia uvedalia* L. var. *densipilis* Blake [*Smallanthus uvedalia* (L.) Mack. ex Small] (656)
*Pyrrhopappus carolinianus* (Walt.) DC. (335, 738)
*Pyrrhopappus scaposus* DC. [*Pyrrhopappus grandiflorus* (Nutt.) Nutt.] (226, 879)
*Ratibida columnifera* (Nutt.) W. & S. [*Ratibida columnifera* (Nutt.) Woot. & Standl.] (25)
*Rudbeckia amplexicaulis* Vahl (57)
*Rudbeckia bicolor* Nutt. [*Rudbeckia hirta* L. var. *pulcherrima* Farw.] (49, 401)
*Rudbeckia triloba* L. var. *triloba* (460)
*Senecio aureus* L. [*Packera aurea* (L.) Á. Löve & D. Löve] (178)
*Senecio glabellus* Poir. [*Packera glabella* (Poir.) C. Jeffrey] (221)
*Senecio plattensis* Nutt. [*Packera plattensis* (Nutt.) W.A. Weber & Á. Löve] (229)
*Serinia oppositifolia* (Raf.) Kuntze [*Krigia caespitosa* (Raf.) K.L. Chambers] (225)
*Silphium asperrimum* Hook. [*Silphium astericus* L. var. *astericus*] (402, 455)
*Silphium laciniatum* L. var. *lanciniatum* [*Silphium laciniatum* L.] (450, 567)
*Silphium perfoliatum* L. (520, 629, 669)
*Solidago altissima* L. (707, 736)
*Solidago bootii* Hook. [*Solidago arguta* Aiton var. *boottii* (Hook.) Palmer & Steyerm.] (508)
*Solidago canadensis* L. var. *canadensis* (624, 712)
*Solidago gigantea* Ait. var. *leiophylla* Fern. [*Solidago gigantea* Aiton] (511)
*Solidago missouriensis* Nutt. var. *fasciculata* Holzinger [*Solidago missouriensis* Nutt.] (516, 576, 603)
*Solidago mollis* Bartl. (675)
*Solidago petiolaris* Ait. var. *petiolaris* [*Solidago petiolaris* Aiton] (716E)
*Solidago petiolaris* Ait. var. *wardii* (Britt.) Fern. [*Solidago petiolaris* Aiton] (706)
*Solidago rigida* L. (692, 740)
*Solidago rugosa* Mill. var. *celtidifolia* (Small) Fern. [*Solidago rugosa* Mill. ssp. *aspera* (Aiton) Cronquist] (688)
*Sonchus asper* (L.) Hill (731)
*Taraxacum erythrospermum* Andrz. [*Taraxacum erythrospermum* Andrz. ex Besser] (785)
*Taraxacum officinale* Weber [*Taraxacum officinale* F.H. Wigg] (797)
*Tragopogon porrifolius* L. (888)
*Verbesina encelioides* (Cav.) B. & H. var. *exauriculata* Robins. & Greenm. [*Verbesina encelioides* (Cav.) Benth. & Hook. f. ex A. Gray] (752)
*Verbesina virginica* L. (605)
*Vernonia baldwinii* Torr. var. *interior* (Small) Schub. [*Vernonia baldwinii* Torr.] (84, 445, 471, 507, 514)

*Vernonia crinita* Raf. [*Vernonia arkansana* DC.] (94, 449, 479)
*Xanthium chinense* Mill. [*Xanthium strumarium* L.] (715)
*Xanthium italicum* Mor. [*Xanthium strumarium* L.] (124, 681, 705, 749)
*Xanthium pennsylvanicum* Wallr. [*Xanthium strumarium* L.] (682, 748)

# LABORATORY STUDIES OF ALLELOPATHIC EFFECTS OF *JUNIPERUS VIRGINIANA* L. ON FIVE SPECIES OF NATIVE PLANTS

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## ABSTRACT

*Juniperus virginiana* L. (eastern redcedar) is known as an encroaching native plant species. It poses particular problems in the Great Plains, where fire suppression in the 20th century has led to the expansion of its population and the area it affects. There is some evidence that the genus *Juniperus* contains members that are allelopathic; work with western species of juniper have demonstrated negative effects of litter on seedling growth. We established laboratory experiments to test the effect of a water leachate of eastern redcedar litter (100 g litter per liter DI water; steeped 8 h) and eastern redcedar litter on the growth and germination of five native herbaceous species. We saw no clear negative effect of leachate or litter; in fact, there is limited evidence that the leachate increased percent germination, and the presence of litter may have led to greater height growth in inland sea-oats. There was no evidence of the litter or leachate acidifying the soil, at least over the short course of the experiment. It is possible the main negative effect of the presence of eastern redcedar on herbaceous species is through light or nutrient competition by mature trees. We are repeating this study in a field setting.

## INTRODUCTION

*Juniperus virginiana* L. (eastern redcedar), while a native plant in the U.S., has encroached throughout much of the Great Plains region following fire suppression and extensive land-use changes in the 20th century (van Els et al. 2010; Linneman et al. 2011). Eastern redcedar had invaded 600,000 acres in Oklahoma by 1950; that number had increased to 1,400,000 acres in 1985 (Engle et al. 1987). It can change a prairie into a closed woodland in less than 100 years (Limb et al. 2010) and is considered a weed tree throughout much of its range, including Oklahoma. Eastern redcedar tends to invade both abandoned land and high-diversity, non-degraded native grassland because of high seed production and rapid seed dispersal (Holthuizen and Sharik 1984; Linneman et al. 2011). *Juniperus* species in general are a common woody invader in many grassland ecosystems (Limb et al. 2010; Alford et al. 2012). Eastern redcedar can also affect soil properties, raising pH and leading to an increase in calcium content (Pierce and Reich 2010). When junipers come to dominate a site, they greatly reduce the ground cover layer (Horman and Anderson 2003). The reduction of ground cover is evidenced by the bare patches that often develop below its crown and dripline; there are five possible contributing factors (not


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necessarily mutually exclusive) for this, listed by Horman and Anderson (2003):

1. The litter (bark, needles, shed branches, cones) of the cedar trees change soil pH and change its properties to prevent germination or growth of seeds.
2. The shade cast by the crown of the tree is deep enough to hinder survival of herbaceous plants and prevents germination.
3. The tree competes strongly for water with other species.
4. The depth of the litter smothers or prevents water from reaching herbaceous plants and seedlings.
5. The tree itself (roots or litter) is allelopathic and hinders seedling germination and/or survival.

Many western juniper species show this sort of reduction: Horman and Anderson (2003) demonstrated that Utah juniper (*Juniperus osteosperma* (Torr.) Little) litter did seem to have a negative effect on seedling growth and survival but more from the standpoint of drying than of allelopathy (i.e., the litter prevented the seeds from properly imbibing water in order to germinate). Schott and Pieper (1985) found that shading by one-seeded juniper (*Juniperus monosperma* (Engelm.) Sarg.) in New Mexico had a major effect on grass growth, and that litter and allelopathy had secondary effects. Ashe juniper (*Juniperus ashei* J. Buchholz) also has a zone of reduced understory growth beneath its dripline, and furthermore, growth of vegetation may be stunted in areas where junipers were present but had been removed (Yager and Smeins 1999). However, Engle et al. (1987) observed that the zonation noted around the base of western juniper species was not as clear around eastern redcedar. They examined the effect of eastern redcedar on herbage standing crop in tallgrass prairie. Their measurements were taken 1 m and 3 m beyond the dripline of trees. They demonstrated an effect of proximity to the tree; biomass of herbaceous vegetation was reduced close to the dripline of the cedar. They concluded this was a result of shading or possibly water competition rather than allelopathy. Also, in general, the effect on herbaceous vegetation under eastern redcedar in Oklahoma was less than the effect under other *Juniperus* species in the arid southwest (Engle et al. 1987). Alford et al. (2012) demonstrated that removal of eastern redcedar from grassland areas in Oklahoma increased herbaceous plant species diversity and biomass, likely because of reduced competition for light. The effect was stronger the more heavily-invaded the area had been.

Van Els et al. (2010) proposed possible changes *J. virginiana* could cause in grassland: increased litter depth, increased soil pH, changes in soil N and C balance, and decreased light availability. Apparently redcedars increase, rather than decrease, soil pH, unlike the litter of some other conifers. Van Els et al. (2010) also proposed that the effects of redcedar encroachment would be different on prairie than in forest. Smith and Stubbendieck (1990) determined that in tallgrass prairie, grass biomass was reduced underneath redcedar canopy, and that water content under the tree canopy was reduced. They concluded competition for soil water was the most important factor. Linnemann et al. (2011) demonstrated in a field experiment that removal of redcedar litter and trees increased herbaceous cover and species diversity, with removal of the trees having a bigger effect on forb and prairie grass cover. In a laboratory experiment, Stipe and Bragg (1989) demonstrated that only one prairie species among those studied (*Coreopsis palmata* Nutt.*)* showed a statistically significant decrease in germination when grown in soil from underneath redcedar. However, the seeds were watered with tapwater, so there was no further influence of litter after its removal.

Our objectives for this study were to determine to what extent eastern redcedar

affected selected prairie species. In particular, we were interested in the possible effects of remaining eastern redcedar litter in areas where prairie restorations might be attempted. We examined litter and leachate; future studies will examine the effects of dripline, proximity, and shading on plant growth. In this study, we focus on determining whether leachate from litter reduces prairie plant germination and growth. We hypothesize that there will be reductions in germination and/or growth of the selected plant species (two prairie grasses, two prairie forbs, one woodland grass) when watered with leachate from redcedar leaves and that the presence of litter will make that effect stronger.

## METHODS AND MATERIALS

In early October 2016, approximately 30 pounds of *Juniperus virginiana* branches were collected from pastureland just outside of Durant, Oklahoma. These bags were transported to Southeastern Oklahoma State University and maintained at roughly 20ºC. On October 8, leachate was prepared: redcedar needles were picked clean of branches and woody material. One hundred grams of this "cedar litter" were steeped for 8 h in 1000 mL deionized water (similar to the 10% leachate as prepared by Horman and Anderson 2003). At the end of the time period, the leachate was filtered through a 50 mesh sieve, bottled, and frozen at 0ºC until needed.

Natural soil was collected from a disturbed grassland on Lake Texoma, Bryan County, Oklahoma (33.999687°N, -96.587678°W). The site was dominated by several species of panic-grasses (*Dichanthelium*), crowngrasses (*Paspalum*), and with forbs, *Lespedeza cuneata* (Dum. Cours.) G. Don (sericea lespedeza) and *Rudbeckia hirta* L. (black-eyed Susan). There was a stand of *Ulmus alata* Michx. (winged elm) within 15 m of where the soil was collected. The soil is in the Boxville Fine Sandy Loam series (USDA 1978). Approximately the top 20 cm of soil was collected and transported to Southeastern Oklahoma State University.

Cone-tainers size SC-10 (21 cm deep and roughly 4 cm in diameter) (Ray Leach Company) were set up in racks. There was a total of four treatments and five species, and nine replicates of each species by treatment combination, resulting in 180 Cone-tainers. Each Cone-tainer was filled with soil, and a standard-sized marble (Cardinal Industries' "Marble Bonanza") was placed in the bottom of each Cone-tainer to allow for drainage and prevent excessive leakage of soil. Each Cone-tainer was planted with 2–3 seeds of one of the focal species. As the seeds germinated, excess individuals were removed to leave one plant per Cone-tainer. The focal species were: little bluestem (*Schizachyrium scoparium* (Michx.) Nash), Indian grass (*Sorghastrum nutans* (L.) Nash), inland sea-oats (*Chasmanthium latifolium* (Michx.) H.O. Yates), partridge-pea (*Chamaecrista nictitans* (L.) Moench), and black-eyed Susan. Seeds were purchased from Native American Seeds in Junction, Texas.

The racks of Cone-tainers were set under a fluorescent-light fixture having six fluorescent tubes (GE Plant and Aquarium 40 Watt T12 Warm Linear Fluorescent Tubes). These light fixtures were suspended from PVC frames so that the tubes were approximately 20 cm above the tops of the Cone-tainers. The lights were set on a timer to give a 14 h daylength. Two identical fluorescent fixtures were used because there was not enough room for both racks under a single fixture.

Four treatments were applied: Control (10 ml of deionized water once a week, no litter), Leachate only (10 ml of eastern redcedar leachate once a week), Litter only (~ 3 cm of eastern redcedar litter on top of soil surface), and Litter plus leachate (~3 cm of litter plus 10 ml leachate once a week). Between treatments, all Cone-tainers were watered every second or third day (as

needed, from examining the soil surface). Precise amounts of water given to each of the 180 Cone-tainers were not measured in these waterings; however, it was approximately the same quantity to each.

We monitored time-to-germination and percent germination of each species. At the end of the first run of the experiment (5 December 2016), we measured the height of each germinated grass individual or leaf-length of the largest leaf for the forbs. We measured leaf growth because individual plants were too small to be weighed.

In January 2017, we began a second run of the experiment with a few changes. Because of high dormancy of inland sea-oats, the seeds were subjected to 30 d of cold-wet stratification (between paper towels in a 5° C refrigerator) before planting. Additionally, partridge-pea seeds were scarified with 100 grit sandpaper before planting.

Fresh soil and cedar branches were collected from the same location as for the first experiment. In contrast to the first experiment, the soil was sieved prior to planting to give a more homogeneous substrate. Seeds were planted on 25 January 2017. Other procedures were the same as for the first experiment. The second experiment concluded on 11 April 2017, and the height of each grass and length of the longest leaf of each forb individual measured. The soil from replicates of each species and treatment combination was pooled, and a 20 g sample was analyzed for pH.

We conducted a third study in spring 2017 examining the effects of cedar leachate on seed germination. The same five species were included in this study. Two treatments were applied: Control (distilled water only) and Leachate. Ten seeds from each of the five species were placed into separate petri-dishes between layers of filter paper. For each species, treatments were applied to six petri-dishes: three received distilled water and three received leachate. There were three replicates (of ten seeds each) for each species and each treatment. Petri dishes were maintained at room temperature and were watered as needed: control dishes were watered with deionized water, and treatment dishes with leachate. Both the distilled water and eastern redcedar leachate were stored at approximately 4° C and were applied to the seeds at this temperature. Germination percentage was recorded after 30 d, and shoot extension and radicle length were measured. Inland sea-oats was dropped from further analysis because of low germination.

Analysis of the germination data was challenging because germination was typically low (Table 1). We used likelihood-ratio chi-square analysis (G-test) based on number of seeds germinating. We tested the fall 2016 and spring 2017 experiments separately. For this test and all other statistical tests, we used an alpha level of 0.05 for significance. We also grouped all species for each treatment separately for the two experiments for analysis of overall effects across species. For the combined data, we tested the data for normality using a Shapiro-Wilk test. Where data were normal, we performed a one-way analysis of variance (ANOVA) on germination by treatment. When data were not normal, we performed Kruskal-Wallis analysis. We originally planned to use two-way ANOVA to test for treatment by species interactions in germination and growth. However, because germination was low overall and the species differed in growth form (grasses vs. forbs, one forb had compound leaves and the other had simple leaves), we chose instead to do a series of one-way ANOVAs. The soil pH data (2017 experiment only) were analyzed with a one-way ANOVA following a test for normality. For the petri-plate experiment, we used chi-square and likelihood-ratio chi-square tests of germination percentages and Mann-Whitney U-tests on growth of individual species. Statistical analyses, including chi-square

Table 1 Germination results for prairie plants in Cone-tainers subjected to leachate and litter treatments in 2016 and 2017. Control = no litter, no leachate. Leachate = leachate only. Litter = litter only. Both = litter plus leachate. LB = little bluestem, IG = Indian grass, SO = inland sea-oats, PP = partridge-pea, and BS = black-eyed Susan. For all treatments, n = 9.

| Experiment 1: Fall 2016 | | |
|---|---|---|
| Treatment | Species | Percent Germination |
| Control | LB | 33.3 |
| Control | IG | 55.6 |
| Control | SO | 22.2 |
| Control | PP | 0.0 |
| Control | BS | 33.3 |
| Leachate | LB | 22.2 |
| Leachate | IG | 55.6 |
| Leachate | SO | 22.2 |
| Leachate | PP | 0.0 |
| Leachate | BS | 77.8 |
| Litter | LB | 66.7 |
| Litter | IG | 66.7 |
| Litter | SO | 11.1 |
| Litter | PP | 11.1 |
| Litter | BS | 22.2 |
| Both | LB | 77.8 |
| Both | IG | 77.8 |
| Both | SO | 33.3 |
| Both | PP | 0.0 |
| Both | BS | 66.7 |

Table 1 Continued

| Experiment 2: Spring 2017 | | |
|---|---|---|
| Treatment | Species | Percent Germination |
| Control | LB | 11.1 |
| Control | IG | 66.7 |
| Control | SO | 77.8 |
| Control | PP | 11.1 |
| Control | BS | 44.4 |
| Leachate | LB | 55.6 |
| Leachate | IG | 77.8 |
| Leachate | SO | 88.9 |
| Leachate | PP | 11.1 |
| Leachate | BS | 88.9 |
| Litter | LB | 22.2 |
| Litter | IG | 33.3 |
| Litter | SO | 100.0 |
| Litter | PP | 0.0 |
| Litter | BS | 33.3 |
| Both | LB | 22.2 |
| Both | IG | 55.6 |
| Both | SO | 100.0 |
| Both | PP | 0.0 |
| Both | BS | 88.9 |

Table 2 Growth of four species under four treatments. Growth data is plant height (grasses) or length of longest leaf (forbs) at the end of the growing period. Control = no litter, no leachate. Leachate = leachate only. Litter = litter only. Both = litter plus leachate. n = sample size. Partridge-pea is not included as germination was too low (zero for three treatments).

| Fall 2016 | | |
|---|---|---|
| Treatment | Growth (cm ± SE) | n |
| | Little Bluestem | |
| Control | 10.6 ± 2.6 | 3 |
| Leachate | 8.0 ± 0.6 | 2 |
| Litter | 13.8 ± 2. 5 | 6 |
| Both | 10.2 ± 0.4 | 7 |
| | Indian Grass | |
| Control | 12.7 ± 2.0 | 4 |
| Leachate | 13.8 ± 1. 7 | 5 |
| Litter | 21.3 ± 4.5 | 6 |
| Both | 23.6 ± 1.3 | 7 |
| | Inland Sea-oats | |
| Control | 13.9 ± 6.4 | 2 |
| Leachate | 9.5 ± 1.0 | 2 |
| Litter | 6.0 ± 0.0 | 1 |
| Both | 10.6 ± 2.0 | 3 |
| | Black-eyed Susan | |
| Control | 2.8 ± 0.7 | 3 |
| Leachate | 1.8 ± 0.2 | 7 |
| Litter | 2.6 ± 0.4 | 2 |
| Both | 3.5 ± 0.1 | 6 |

Table 2 Continued

| Spring 2017 | | |
|---|---|---|
| Treatment | Growth (cm ± SE) | n |
| | Little Bluestem | |
| Control | Only one observation, no mean | 1 |
| Leachate | 13.3 ± 1.9 | 5 |
| Litter | 17.7 ± 4.0 | 3 |
| Both | 16.5 ± 0.1 | 2 |
| | Indian Grass | |
| Control | 22.7 ± 3.2 | 6 |
| Leachate | 18.8 ± 2.6 | 7 |
| Litter | 24.5 ± 3.9 | 3 |
| Both | 20.8 ± 1.7 | 5 |
| | Inland Sea-oats | |
| Control | 9.2 ± 0.9 | 7 |
| Leachate | 7.7 ± 0.8 | 8 |
| Litter | 11.3 ± 0.7 | 9 |
| Both | 12.0 ± 0.8 | 9 |
| | Black-eyed Susan | |
| Control | 3.3 ± 0.3 | 2* |
| Leachate | 2.4 ± 0.4 | 5** |
| Litter | 2.4 ± 0.6 | 3 |
| Both | 3.0 ± 0.3 | 8 |

*One individual germinated (total germinating = 3) but died before maturity

**Three individuals germinated (total germinating = 8) but died before maturity

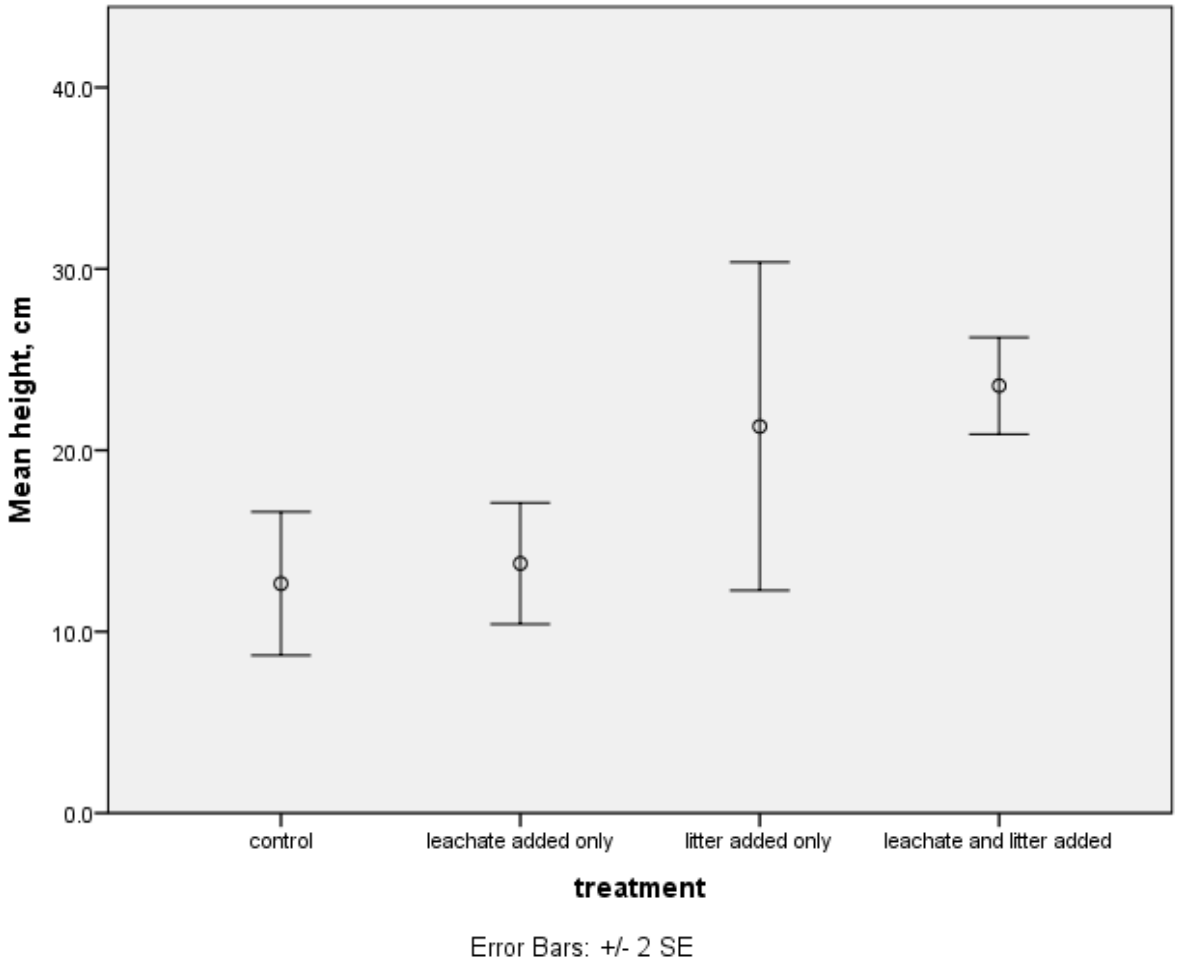


Figure 1 Average height of Indian grass for four eastern redcedar treatments in fall 2016. Sample sizes: control, n = 4; leachate, n= 5; litter, n=6; litter plus leachate, n=7. Treatment significantly affected height, but no pairwise comparisons were significantly different in post hoc tests.

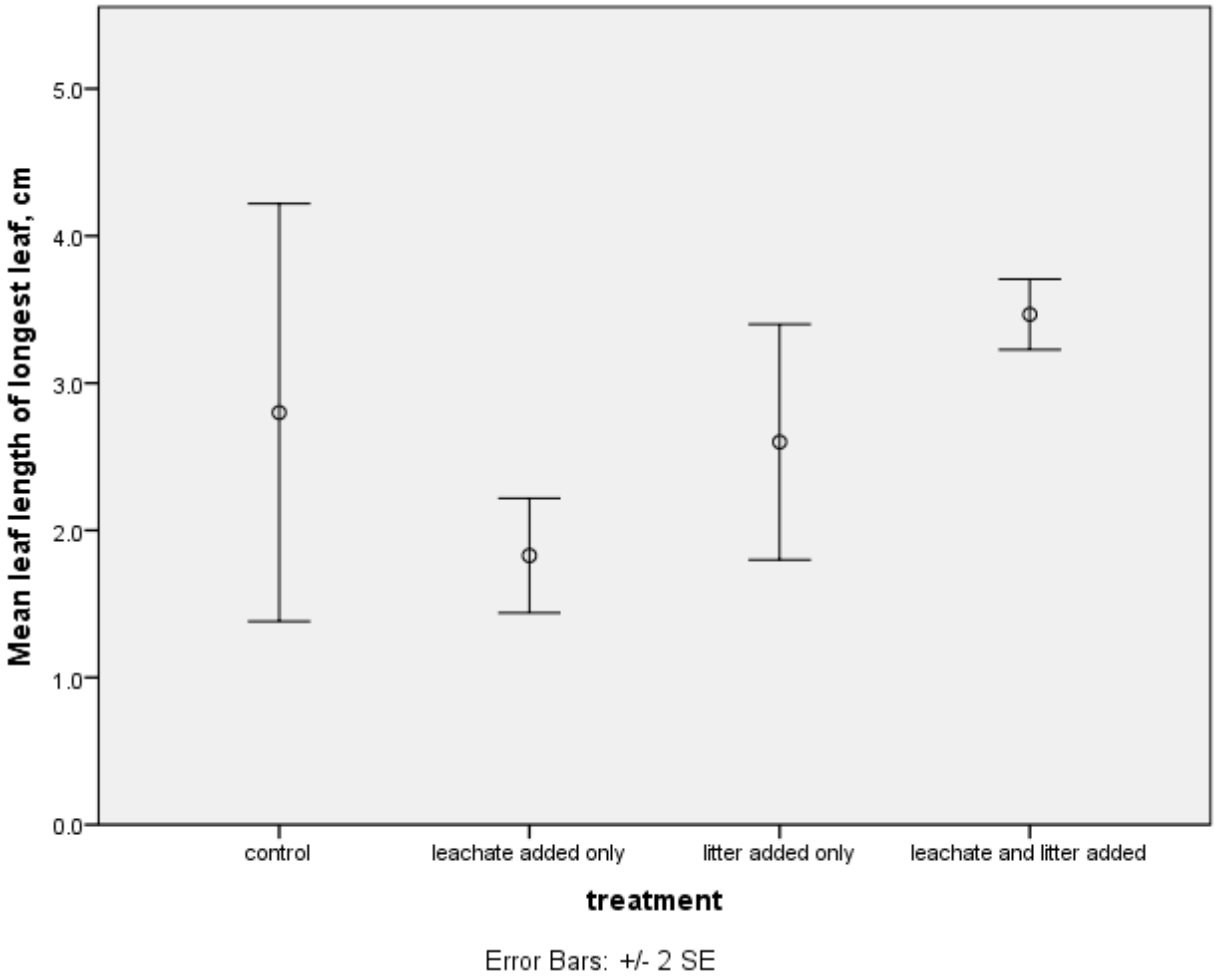


Figure 2 Average leaf length of black-eyed Susan by treatment for fall 2016 data. Control, n = 3; leachate treatment, n= 7; litter treatment, n=29; litter plus leachate treatment, n=6.

tests, ANOVAS, and Kruskal-Wallis tests, were performed using SPSS (IBM 2011).

## RESULTS

### *Fall 2016 germination and growth (Cone-tainer experiment 1)*

Germination percentages are shown in Table 1. Species-treatment combinations did not differ in germination percentages ($G = 9.161$, $df = 12$, $p=0.689$). To test treatment effects across species, we grouped the data for all species within each treatment. The data were not normal (Shapiro-Wilk test, $W_{(20)} = 0.899$, $p = 0.040$). There was no significant difference in germination among treatments for all species grouped together (Kruskal-Wallis test: $\chi^2 = 5.077$, $df = 3$, $p=0.166$).

Growth measures (i.e., the longest leaf height on the grasses or the longest leaf on the forbs) are presented in Table 2. Partridge-pea had too few germinating individuals to analyze. We analyzed each species separately because of differences in growth form. Little bluestem data were not normal ($W_{(18)}=0.853$, $p=0.009$) and showed no significant effect of treatment on growth ($G= 4.879$, $df =3$, $p = 0.181$). Normality of Indian grass data could not be rejected ($W_{(22)}= 0.981$, $p =0.927$), and Indian grass showed a significant effect of treatment (ANOVA, $F_{(3, 18)}=3.598$, $p=0.034$). There is a weak trend for litter application to result in greater height (Figure 1). However, this was not statistically significant in post-hoc tests. Normality of inland sea-oats data could not be rejected ($W_{(8)}=0.878$, $p=0.180$), and inland sea-oats did not show a significant effect of treatment (ANOVA, $F_{(3, 4)} =0.557$, $p=0.671$), perhaps because sample sizes were low due to poor germination. Normality of black-eyed Susan data could not be rejected ($W_{(18)}=0.962$, $p = 0.650$), and black-eyed Susan showed a significant effect of treatment (ANOVA, $F_{(3, 4)}=7.63$, $p=0.003$), but post-hoc tests did not find pairwise differences between treatments (Figure 2)

### *Spring 2017 germination and growth (Cone-tainer experiment 2)*

For the spring germination results (see Table 1), again there was no significant relationship between treatment, species, and germination ($G = 6.190$, $df =12$, $p = 0.906$). After grouping species within treatment, differences among were not significant ($\chi^2= 1.702$, $df=3$, $p=0.637$).

For spring growth measures (Table 2), normality of little bluestem data could not be rejected ($W_{(11)} =0.915$, $p = 0.277$), and little bluestem showed no significant effect of treatment on growth (ANOVA, $F_{(3, 7)}=1.478$, $p=0.301$). Normality of Indian grass data could not be rejected ($W_{(21)} = 0.979$, $p=0.908$), and Indian grass did not show a significant effect of treatment (ANOVA, $F_{(3, 7)}= 0.687$, $p=0.572$). Normality of inland sea-oats data could not be rejected ($W_{(34)}= 0.972$, $p=0.518$), and inland sea-oats growth was affected significantly by treatment (ANOVA, $F_{(3, 30)} = 6.211$, $p=0.002$), with individuals in treatment 4 (litter plus leachate) growing larger (Student-Newman-Keuls test) than individuals in treatment 2 (leachate alone; Figure 3). Normality of black-eyed Susan data could not be rejected ($W_{(18)} = 0.945$, $p=0.346$), and growth of black-eyed Susan did not show a significant effect of treatment (ANOVA, $F_{(3, 14)}=0.811$, $p=0.509$).

Normality of treatment pH (Table 3) could not be rejected ($W_{(20)}= 0.934$, $p=0.188$). Treatments did not affect soil pH (ANOVA, $F_{(3, 16)}=1.355$, $p=0.262$).

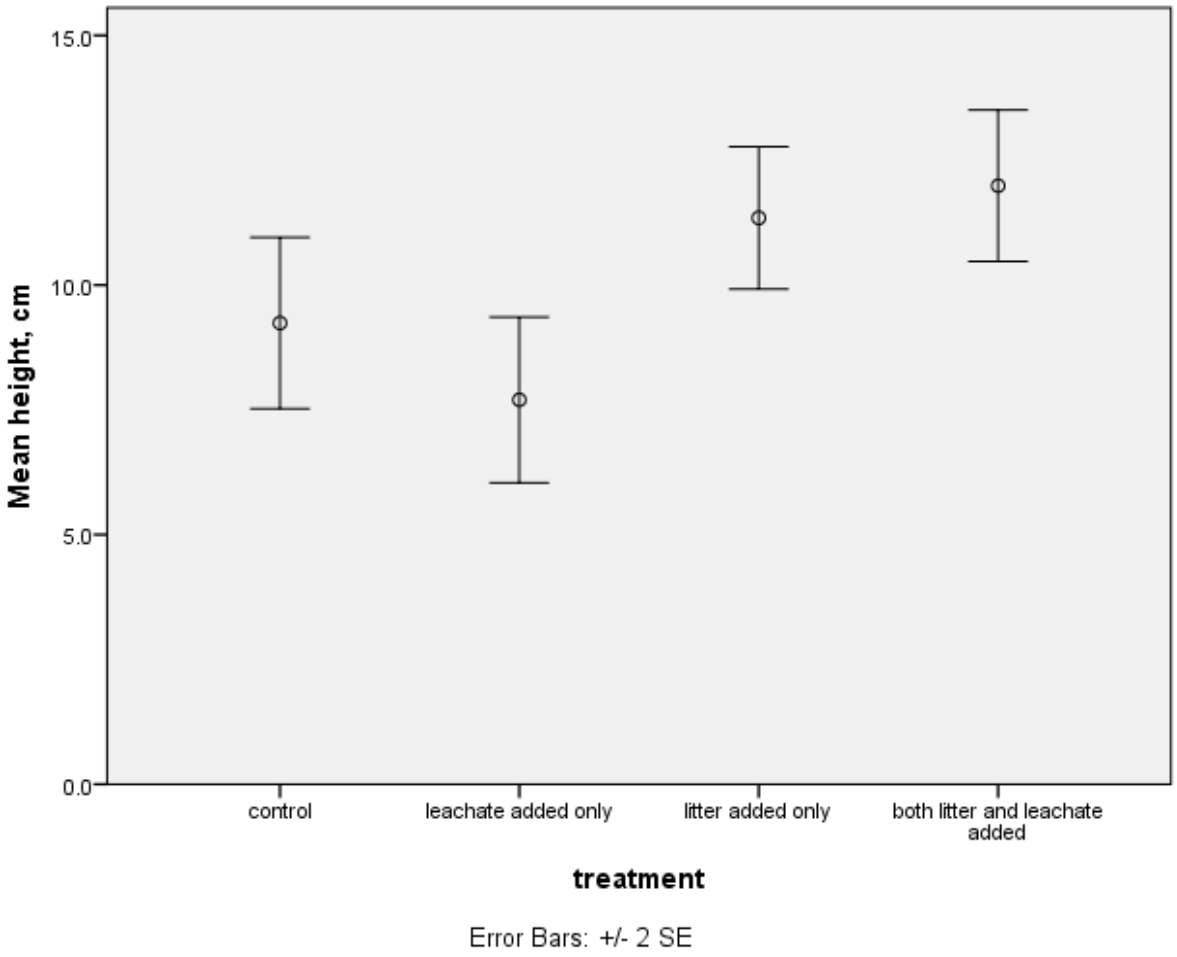


Figure 3 Average height of inland sea-oats by treatment for spring 2017 data. Control, n = 8; leachate treatment, n= 8; litter treatment, n=9; litter plus leachate treatment, n=9.

Table 3 Soil pH for five species under five treatments in spring 2017 and means across species within treatment. Control = no litter, no leachate. Leachate = leachate only. Litter = litter only. Both = litter plus leachate. LB = little bluestem, IG = Indian grass, SO = inland sea-oats, PP = partridge-pea, and BS = black-eyed Susan.

| Treatment | Species | pH |
|---|---|---|
| Control | LB | 6.4 |
| Control | IG | 6.2 |
| Control | SO | 6.3 |
| Control | PP | 6.1 |
| Control | BS | 5.7 |
| Mean (± SE) | | 6.1 ± 0.13 |
| Leachate | LB | 6.0 |
| Leachate | IG | 6.0 |
| Leachate | SO | 6.0 |
| Leachate | PP | 6.1 |
| Leachate | BS | 6.2 |
| Mean (± SE) | | 6.1 ± 0.04 |
| Litter | LB | 6.2 |
| Litter | IG | 5.9 |
| Litter | SO | 5.8 |
| Litter | PP | 6.1 |
| Litter | BS | 5.8 |
| Mean (± SE) | | 6.0 ± 0.08 |
| Both | LB | 6.0 |
| Both | IG | 6.2 |
| Both | SO | 6.2 |
| Both | PP | 6.2 |
| Both | BS | 6.2 |
| Mean (± SE) | | 6.2 ± 0.04 |

*Germination in petri-dishes*

Species and treatment combinations differed in germination percentage (Table 4, chi-square = 42.897, df=4, $p < 0.001$). This result was likely influenced by differences in germination of Indian grass (ca 27% for control vs. ca 37% for added leachate) and little bluestem (ca 10% vs. 30% ). In both cases, the presence of the cedar leachate seemed to increase germination.

For little bluestem, there was no treatment effect of leachate on radicle length (Mann-Whitney test: U=5.0, n=12, p=0.145) or shoot length (U=7.5, n=12, p=0.282). For Indian grass, there was a decrease in radicle length in response to leachate (U=11.50, n=19, p=0.005). However, there was no effect of treatment on shoot length (U=41.5. n=19, p=0.840). Black-eyed Susan showed no effect of treatment on radicle length (U=211.5, n=42, p=0.828), but had a marginally significant effect of treatment on shoot length (U=145.5, n=42, p=0.052).

Table 4 Percent germination in petri dishes under two treatments. See text for chi-square tests of treatment by species.

| Treatment | Species | Average percent germination |
|---|---|---|
| Control | little bluestem | 10.0 ± 0.0 |
| Control | Indian grass | 26.7 ± 8.8 |
| Control | inland sea-oats | 3.3 ± 3.3 |
| Control | partridge-pea | 3.3 ±3.3 |
| Control | black-eyed Susan | 66.7 ± 8.8 |
| Leachate | little bluestem | 30.0 ± 0.0 |
| Leachate | Indian grass | 36.7 ± 6.7 |
| Leachate | inland sea-oats | 0.0 ± 0.0 |
| Leachate | partridge-pea | 10.0 ± 5.8 |
| Leachate | black-eyed Susan | 73.3 ± 6.7 |

## DISCUSSION

In general, there were few effects of the application of redcedar leachate and/or litter. Treatment with leachate and/or litter did not hamper germination, and there was no clear effect of treatment on growth in the Cone-tainer experiments. There were weak trends suggesting in some cases that application of litter plus leachate might increase growth, but trends were weak. A negative effect of redcedar was not demonstrated over the months-long course of these experiments (56 d for fall 2016 and 77 d for spring 2017). There is some evidence from the petri-dish germination

experiment that the redcedar leachate may stimulate germination rate (at least in Indian grass and little bluestem) but reduce growth of seedling root in Indian grass and seedling shoot in black-eyed Susan, but it is possible that the growth reductions are a short-lived effect.

Anecdotally, we observed that the treatment receiving the cedar leachate required more frequent watering in order to maintain the same moist environment as those receiving the water only. Further study of the rate of evaporation of the water and cedar leachate may provide additional insight regarding whether water resources may be affected by an eastern redcedar population. An additional anecdotal observation was that partridge-pea was susceptible to mold growth that was possibly inhibited by the redcedar leachate. A study of the allelopathic effects of cedar leachate on mold growth may provide additional data to test this observation.

We speculate that in soils with long exposure to redcedar litter (years rather than months), perhaps effects would be greater, or there might be a negative effect. We are considering future experiments planting seeds or seedlings within the driplines of existing cedars and comparing their growth to the growth of individuals away from the dripline.

It is also possible that *Juniperus virginiana* may lack the same allelopathic compounds found in the western junipers (e.g., *Juniperus monosperma*). It would be informative to repeat the experiment on a larger scale, comparing the effects of eastern redcedar, one-seeded juniper, and Utah juniper.

It is also possible that a harmful effect of redcedar is produced by shade; future research could include planting individuals at varying distances from the trunk of the tree to determine whether shading has an effect, or if the dripline of the tree has an effect. In future work, we plan to examine the pH of soils within the dripline and 3 and 5 m beyond the dripline of redcedars. Smith and Stubbendeick (1990) suggested that the effects of red-cedar on herbaceous species in the field is mainly mediated through light and water competition from the mature trees; they demonstrated reduction in biomass for prairie species grown inside the dripline of cedar trees. It is also possible that water competition is the mechanism of limitation; many of the studies showing reduced herbaceous growth under junipers (e.g., Schott and Pieper 1985; Yager and Smeins 1999) were conducted in climates drier than that of south-central Oklahoma and certainly under more water-limited conditions than our lab experiment. However, in northeastern Oklahoma, Engle et al. (1987) did demonstrate reduction in herbaceous standing crop within the dripline of redcedar trees. Van Els et al. (2010) demonstrated reduced species richness in forest understory under *Juniperus* trees in Oklahoma; they attributed these changes to increased litter depth but did not separate what chemical or physical characteristic of the litter served as a barrier to plant germination and growth. Finally, we plan to conduct a field experiment to determine whether the greater stress of growth outdoors or over a longer time is sufficient to show effects.

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# VASCULAR FLORA OF E. C. HAFER PARK, EDMOND, OKLAHOMA

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*Keywords: floristic inventory, urban park, Cross Timbers, non-native, invasive*

## ABSTRACT

E. C. Hafer Park is located on the western edge of the Cross Timbers ecoregion, in central Oklahoma within the City of Edmond. The park contains post oak-blackjack oak forest, tallgrass prairie, riparian forest, and areas developed for recreational activities. A vascular plant inventory conducted during 2013, 2015, 2016, and 2017 yielded 270 species in 190 genera and 65 families. The largest families were the Asteraceae (46 species), Poaceae (42), and Fabaceae (27). There were 96 annuals, four biennials, and 170 perennials. Sixty species (22.2%) were not native to the United States. No rare species currently being tracked by the Oklahoma Natural Heritage Inventory were present. Compared to floristic inventories for other sites of similar size in Oklahoma, Hafer Park has a relatively high number of species. However, it also has a relatively high percentage of exotic species from other continents, some of which are invasive and are threatening the native forest, grassland, and riparian plant communities.

## INTRODUCTION

Efforts to protect biodiversity often focus on large natural habitats outside of highly urbanized locations, but efforts should also be made to preserve and promote biodiversity in urban forests and other urban green spaces that have maintained relatively high levels of biodiversity including species of conservation concern (Alvey 2006). In a literature review of species richness in urban parks on five continents, Nielsen et al. (2013) found that those with a diversity of habitats and microhabitats can be biodiversity hotspots with large components of native species of all plant and animal groups. For vascular plants, however, urban parks often have a large percentage of exotic species, sometimes over 50% (Nielsen et al. 2013).

Palmer et al. (1995) summarized the importance of floristic inventories in providing data for research on biodiversity, environmental impact assessment, and management decisions. The Floras of North America project (Palmer 2017) promotes the compilation of floras, emphasizing their importance as "baselines for understanding patterns of, and threats to, modern biodiversity".

We conducted a floristic inventory of E. C. Hafer Park, an urban park in central Oklahoma, from 2013 to 2017. Our


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objectives were to 1) document the vascular plant richness of a central Oklahoma urban park; 2) contribute to our knowledge of plant distributions in Oklahoma; 3) assess the threat that exotic species, i.e., from other continents, pose to the biodiversity of this urban park; and 4) provide a resource that can be used by the City of Edmond to conserve the biodiversity of Hafer Park and to educate the public.

## STUDY AREA

E. C. Hafer Park is located in the City of Edmond, Oklahoma County, Oklahoma (T14N, R2W, SW1/4 of Sec 31). Latitudinal extent is from 35° 38'17" N to 35° 38' 44" N, and longitudinal extent is from 97° 27' 6" W to 97° 27' 37" W. The park consists of approximately 49 hectares (=121 acres). Spring Creek flows west to east along the southern edge of the park. Elevation ranges from approximately 326 m to 345 m. Soils are Stephenville-Darnell-Niotaze shallow, sandy and loamy soils that are moderately acidic and humus-poor, and occur on steep slopes up to 18% (Carter and Gregory 2008).

The climate is continental. According to climate data for the past 15 years (2002–2016) from Mesonet stations in Oklahoma County (Oklahoma Climatological Survey 2017b), average annual precipitation was 89.8 cm. The mean annual temperature for 2002–2016 was 16.1°C, with daily average temperatures ranging from 3.9°C in January to 27.8° C in July. Temperatures ranged from an average low temperature of -1.7°C in January to an average daytime high of 33.3°C in July. Average wind speed was 8 mph.

The climate averages for the past 15 years differ somewhat from longer-term historical trends. For example, from 2002–2016 spring and summer had the highest average precipitation, but historically fall and spring have been the wettest seasons (Oklahoma Climatological Survey 2017a). Annual precipitation for Oklahoma County varied considerably for the four years during which this vascular plant survey was conducted, ranging from 75.4 cm to 131.3 cm.

E. C. Hafer Park is in the Central Red-Bed Plains physiographic province, in which "Permian red shales and sandstone form gently rolling hills and broad, flat plains" (Curtis et al. 2008). It is on the western edge of the Cross Timbers ecoregion (Oklahoma Forestry Services 2017) and is in the Northern Cross Timbers Level III Ecoregion (Environmental Protection Agency 2017). The dominant potential vegetation is post oak-blackjack oak woodland (Duck and Fletcher 1943).

King and Cheek (2015) documented the land-use history of the site. From the early 1900s to the 1940s, historical documents indicate that it was privately owned and farmed. From 1952 to 1972, a portion of the site housed a sewage treatment facility operated by the City of Edmond. Following decommissioning of the facility in 1972 and the acquisition of additional small tracts of land, the site was commissioned as E. C. Hafer Park in 1979. Paved trails, playgrounds, picnic areas, and pavilions have been constructed, but the eastern half of the park is primarily post oak-blackjack oak forest with tallgrass prairie in the northeast corner.

## METHODS

We surveyed the park during the growing seasons (March through October) of 2013, 2015, 2016, and 2017. During those years, we visited the site 23 times, with 6 collecting dates in the spring, 10 in the summer, and 7 in the fall. We recorded the vascular plant species encountered and collected voucher specimens. We collected non-native and exotic species only from naturalized populations, excluding cultivated species in flower beds, picnic areas, playgrounds, etc. A few species were

identified by sight and documented only by photographs because of their rarity at the site or because the steep slope of Spring Creek made a collection impossible. References used for specimen identification included Great Plains Flora Association (1986), Diggs et al. (1999), Yatskievyich (1999), Barkworth et al. (2007), and Tyrl et al. (2015). In addition to our collections, we searched the University of Central Oklahoma Herbarium (CSU) database and added a few previously collected species from the park. Specimens were identified only to the species level.

The organization of taxa in our species list is based on Angiosperm Phylogeny Group (APG III) recommendations (Stevens 2017). Nomenclature follows the Integrated Taxonomic Information System (2017). The PLANTS Database (USDA NRCS 2017) was used for common names and to determine whether each species was native to the United States, its duration (annual, biennial, or perennial), and its growth form (forb, graminoid, shrub, tree, or woody vine). If duration varied or if more than one growth form was listed in the PLANTS Database, the duration and growth form listed for Oklahoma by Taylor and Taylor (1994) was used. Voucher specimens were deposited in the University of Central Oklahoma (CSU) Herbarium. Our reporting of site location and geography, taxonomy, voucher specimens, botanical effort, exotic species, taxonomic list, and summary table follows recommendations by Palmer and Richardson (2012) for published floras. An "invasive species", as defined by Executive Order 13112, is one that is "1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (USDA National Agricultural Library 2017).

**Table 1 Summary of floristic collections from E. C. Hafer Park in Edmond, Oklahoma***

| Taxonomic Group | Families | Genera | Species | Native spp. | Non-native spp. |
|---|---|---|---|---|---|
| Monilophyta | 1 | 1 | 1 | 1 | 0 |
| Pinophyta | 1 | 1 | 1 | 1 | 0 |
| Magnoliophyta | | | | | |
| Eudicots | 55 | 146 | 206 | 162 | 44 |
| Monocots | 8 | 42 | 62 | 46 | 16 |

* Table format follows Palmer (1995)

## RESULTS AND DISCUSSION

We identified 270 species in 190 genera and 65 families (Table 1; Appendix). These included one monilophyte, one gymnosperm, 206 eudicots, and 62 monocots. Species in the Asteraceae (46), Poaceae (42), and Fabaceae (27) far outnumbered those in other families. Only six other families were represented by more than five species: Euphorbiaceae (9), Cyperaceae (8), Rosaceae (8), Rubiaceae (7), Plantaginaceae (6), and Polygonaceae (6). The largest genera, each with five species, were *Quercus*, *Solidago*, and *Bromus*. Ninety-six species (35.5%) were annuals, four (1.5%) were biennials, and 170 (63%) were perennials. Thirty-eight species were trees, 12 were shrubs, and 10 were woody vines. There were 157 forbs and 53 graminoids.

No rare species tracked by the Oklahoma Natural Heritage Inventory (2017) were present. Sixty species (22.2%) in 26 families were not native to the United States. These included 13 species of Poaceae, 10 species of Fabaceae, and 5 species of Asteraceae. All but one non-native species (*Torilis arvensis*) were exotic to North America. Eight exotic species (*Albizia julibrissin*, *Bromus japonicus*, *Bromus tectorum*, *Lespedeza cuneata*, *Ligustrum sinense*, *Lonicera japonica*, *Rosa multiflora*, *Sorghum halepense*) are listed as Oklahoma Problem Species by the Oklahoma Invasive Plants Council (2017). Five of these species (*B. tectorum*, *L. cuneata*, *L. sinense*, *L. japonica*, *S. halepense*) and one native species (*Juniperus virginiana*) are on the OKIPC's "Dirty Dozen" list of the worst invasive species in the state. Four species (*Erodium cicutarium, Lonicera maackii*, *Melilotus officinalis*, *Pyrus calleryana*) are on the Oklahoma Watch List, and an additional 19 species are listed as problem species in states bordering Oklahoma (Oklahoma Invasive Plants Council 2017). Other species may become problems in the future. For example, *Koelreuteria paniculata*, *Nandina domestica*, and *Pistacia chinensis* were found in the forest, and these cultivated species are considered invasive in Texas and other southeastern states (Texas Invasives 2017).

The major plant communities at Hafer Park and brief descriptions of common species are as follows:

1. ***Quercus stellata-Quercus marilandica/Schizachyrium scoparium* woodland association** (Hoagland 2000)

Post oak/blackjack oak woodland is the predominant vegetation association in the park. Common species included *Celtis* spp., *Cornus drummondii, Juniperus virginiana, Morus rubra*, *Quercus muehlenbergii*, *Sideroxylon lanuginosum*, *Symphoricarpos orbiculatus,* and *Ulmus* spp. *Fraxinus pennsylvanica*, *Prunus mexicana, Quercus shumardii, and Viburnum rufidulum* were occasionally encountered. Exotic woody plants found in this community included *Ligustrum sinense*, *Lonicera maackii*, *Pyrus calleryana*, and *Rosa multiflora*.

2. ***Schizachyrium scoparium-Sorghastrum nutans* herbaceous association** (Hoagland 2000)

This tallgrass prairie community was found in the northeast corner of the park. Commonly encountered species included *Acacia angustissima*, *Ambrosia psilostachya*, *Asclepias verticillata*, *Asclepias viridis*, *Bouteloua* spp., *Chamaecrista fasciculata*, *Coreopsis tinctoria*, *Dichanthelium* spp., *Eragrostis* spp., *Gaillardia aestivalis*, *Lespedeza* spp., *Liatris punctata*, *Panicum virgatum*, *Psoralidium tenuiflorum*, *Sabatia campestris*, *Solidago* spp., *Symphyotrichum ericoides*, and *Xanthisma texanum*. *Rhus glabra* has spread into much of this area. The invasive native *Juniperus virginiana* and the invasive exotic *Lespedeza cuneata* are threatening this community.

3. **Riparian forest**

Riparian forest was found on the steep banks of Spring Creek. Common woody species included *Catalpa speciosa*, *Celtis* spp.,

*Cercis canadensis*, *Cornus drummondii*, *Juglans nigra*, *Juniperus virginiana*, *Morus rubra*, *Populus deltoides*, *Salix nigra*, *Sapindus saponaria*, *Ulmus americana*, and *Ulmus rubra*. *Quercus macrocarpa*, *Q. muehlenbergii*, *Acer negundo*, *Gymnocladus dioicus*, and *Equisetum laevigatum* were occasionally encountered. Common vines included *Cocculus carolinus*, *Parthenocissus quinquefolia*, *Smilax* spp., and *Toxicodendron radicans*. Exotic woody plants found in this community included *Albizia julibrissin* and *Ulmus parvifolia*.

4. **Disturbed areas**

This type of vegetation was found predominately in mowed lawns around picnic areas and playgrounds and along paved trails. Common species included *Ambrosia trifida*, *Arenaria serpyllifolia*, *Bromus* spp., *Cerastium pumilum*, *Cruciata pedemontana*, *Cynodon dactylon*, *Erodium cicutarium*, *Geranium pusillum*, *Lamium amplexicaule*, *Lonicera japonica*, *Medicago lupulina*, *Scleranthus annuus*, *Stellaria media*, *Sherardia arvensis*, *Sorghum halepense*, *Trifolium repens*, and *Veronica* spp. Disturbed areas of Spring Creek have been invaded by exotic species such as *Phragmites australis*, *Parthenium hysterophorus*, and *Clematis terniflora*.

A comparison with the species-area relationship for 59 Oklahoma floras published by Palmer (2007) indicates the flora of Hafer Park is among the richest for areas of a similar size. However, of all the floras listed, only one (Vance Air Force Base) had a higher proportion of non-native species (46.8%) than Hafer Park (22.2%). The next highest is for a checklist of plants in Cleveland County, at 17.5%. The percentage of non-native taxa from grassland-dominated sites (Buthod and Hoagland 2016) in Oklahoma ranged from 8.8% to 15%. The percentage of non-native taxa for Alabaster Caverns State Park, a heavily-visited park in the Cimarron Gypsum Hills of Woodward County, Oklahoma, was 15.3% (Caddell and Rice 2012). Inventories of natural areas in Oklahoma generally exclude cultivated plants that have not become naturalized, and those plants have been excluded in the inventory reported here. However, the proportion of non-native species for Hafer Park would be much higher if those plants were included.

This inventory indicates that Hafer Park has a rich vascular plant community, in spite of the development of large portions for recreational use. It has a variety of habitats that support high plant diversity within the rapidly developing City of Edmond. However, the native plant communities at Hafer Park are threatened by an increase in exotic, invasive plants that are already reported as invasive within the state, as well as perhaps by others that are considered invasive in adjacent states. The diversity of the understory of the post oak-blackjack oak forest is being threatened particularly by the invasion of Chinese privet (*Ligustrum sinense*), and the tallgrass prairie in the northeast corner of the park is being threatened particularly by encroachment of the native invader eastern red cedar (*Juniperus virginiana*) and by the exotic invasive *Lespedeza cuneata*.

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# APPENDIX

## Vascular Plant Species from E. C. Hafer Park, Edmond, Oklahoma

Annotated species list with organization based on Angiosperm Phylogeny Group (APG III) recommendations (Stevens 2017). Nomenclature is based on ITIS (2017), and common names are from the USDA PLANTS Database (USDA NRCS 2017). Duration (A=annual, B=biennial, P=perennial), growth form (F=forb, G=graminoid, S=shrub, T=tree, V=woody vine), and collection numbers follow species name. Duration, nativity, and growth form are from the USDA PLANTS Database (USDA NRCS 2017). If duration varied or if more than one growth form was listed in the PLANTS Database, the duration and growth form listed for Oklahoma by Taylor and Taylor (1994) was used. Non-native species to the United States are indicated with an asterisk (*). Collectors are AK= Aaron Kidd, AP= Alonna Price Smith, CC= Carmen Cowo Esqueda, GC=Gloria Caddell, HU=Hitomi Ushio, KC= Katie Christoffel, RC= Rachel Cotts, SD= Shahang Derakhshan, TW=T. Williams, and YS=Yukiko Shimoda. Voucher specimens were deposited in the University of Central Oklahoma Herbarium (CSU).

MONILOPHYTA
Equisetaceae
*Equisetum laevigatum* A. Braun (smooth horsetail) – P; F; GC1315

GYMNOSPERMS/PINOPHYTA
Cupressaceae
*Juniperus virginiana* L. (eastern redcedar) – P; T; AP105, CC50

ANGIOSPERMS/MAGNOLIOPHYTA
EUDICOTS
Acanthaceae
*Dicliptera brachiata* (Pursh) Spreng. (branched foldwing) – A; F; GC1316
*Ruellia humilis* Nutt. (fringeleaf wild petunia) – P; F; AP127, KC88

Adoxaceae
*Viburnum rufidulum* Raf. (rusty blackhaw) – P; T, S; KC91

Amaranthaceae
*Amaranthus arenicola* I.M. Johnst. (sandhill amaranth) – A; F; KC115, KC116
*Froelichia floridana* (Nutt.) Moq. (plains snakecotton) – A; F; AP107

Anacardiaceae
**Pistacia chinensis* Bunge (Chinese pistache) – P; T; KC123
*Rhus copallinum* L. (winged sumac) – P; S; AP96, CC67
*Rhus glabra* L. (smooth sumac) – P; S; AP124, SD67
*Toxicodendron radicans* (L.) Kuntze (eastern poison ivy) – P; V; KC69

Apiaceae
*Chaerophyllum tainturieri* Hook. (hairyfruit chervil) – A; F; GC 1306
*Sanicula canadensis* L. (Canadian blacksnakeroot) – B; F; AP75
**Torilis arvensis* (Huds.) Link (spreading hedgeparsley) – A; F; AP93, KC68

Apocynaceae
*Apocynum cannabinum* L. (Indianhemp) – P; F; AP122
*Asclepias verticillata* L. (whorled milkweed) – P; F; AP109
*Asclepias viridis* Walter (green antelopehorn) – P; F; RC74

Asteraceae
*Achillea millefolium* L. (common yarrow) – P; F; AP67
*Ambrosia psilostachya* DC. (Cuman ragweed) – P; F; CC49
*Ambrosia trifida* L. (great ragweed) – A; F; KC87
*Amphiachyris dracunculoides* (DC.) Nutt. (prairie broomweed) – A; F; SD69
*Antennaria parlinii* Fernald (Parlin's pussytoes) – P; F; KC139
*Artemisia ludoviciana* Nutt. (white sagebrush) – P; F; GC1300
*Bidens bipinnata* L. (Spanish needles) – A; F; KC89
*Bradburia pilosa* (Nutt.) Semple (soft goldenaster) – A; F; AP92, CC52, CC53
*Cirsium altissimum* (L.) Hill (tall thistle) – B; F; KC39
*Cirsium undulatum* (Nutt.) Spreng. (wavyleaf thistle) – P; F; AP120
*Conyza canadensis* (L.) Cronquist (Canadian horseweed) – A; F; AK1
*Coreopsis tinctoria* Nutt. (golden tickseed) – A; F; AP94
**Cosmos sulphureus* Cav. (sulphur cosmos) – A; F; KC80
*Diaperia prolifera* (Nutt. ex DC.) Nutt. (bighead pygmycudweed) – A; F; RC59
*Diaperia verna* (Raf.) Morefield (spring pygmycudweed) – A; F; GC1301
*Eclipta prostrata* (L.) L. (false daisy) – A; F; KC150
*Elephantopus carolinianus* Raeusch (Carolina elephantsfoot) – P; F; KC58
*Erigeron strigosus* Muhl. ex Willd. (prairie fleabane) – A; F; AP90
*Gaillardia aestivalis* (Walter) H. Rock (lanceleaf blanketflower) – P; F; AP99
*Gamochaeta argyrinea* G. L. Nesom (silvery everlasting) – A; F; AP53
*Gamochaeta purpurea* (L.) Cabrera (spoonleaf purple everlasting) – P; F; GC1302
*Grindelia ciliata* (Nutt.) Spreng. (Spanish gold) – A; F; KC95
*Helianthus annuus* L. (common sunflower) – A; F; KC42, KC94
*Helianthus mollis* Lam. (ashy sunflower) – P; F; KC40
*Heterotheca subaxillaris* (Lam.) Britton & Rusby (camphorweed) – A; F; SD60, KC149
*Lactuca ludoviciana* (Nutt.) Riddell (biannual lettuce) – B; F; AK3
**Lactuca serriola* L. (prickly lettuce) – A; F; AP113
*Liatris punctata* Hook. (dotted blazing star) – P; F; SD72, GC1317
**Parthenium hysterophorus* L. (Santa Maria feverfew) – A; F; KC148
*Pluchea camphorata* (L.) DC. (camphor pluchea) – P; F; KC76
*Pseudognaphalium obtusifolium* (L.) Hilliard & B.L. Burtt (rabbit-tobacco) – A; F; KC112
*Pyrrhopappus grandiflorus* (Nutt.) Nutt. (tuberous desert-chicory) – P; F; RC57
*Solidago canadensis* L. (Canada goldenrod) – P; F; KC102
*Solidago missouriensis* Nutt. (Missouri goldenrod) – P; F; KC77
*Solidago nemoralis* Aiton (gray goldenrod) – P; F; CC48
*Solidago rigida* L. (stiff goldenrod) – P; F; CC42
*Solidago speciosa* Nutt. (showy goldenrod) – P; F; CC41
*Symphyotrichum drummondii* (Lindl.) G.L. Nesom (Drummond's aster) – P; F; CC70, KC78, KC85
*Symphyotrichum ericoides* (L.) G.L. Nesom (white heath aster) – P; F; CC44
*Symphyotrichum subulatum* (Michx.) G.L. Nesom (eastern annual saltmarsh aster) – A; F; KC99, KC147, SD79

**Taraxacum officinale* F.H. Wigg. (common dandelion) – P; F; AP64
*Thelesperma filifolium* (Hook.) A. Gray (stiff greenthread) – P; F; AP108
**Tragopogon dubius* Scop. (yellow salsify) – A; F; AP104
*Verbesina virginica* L. (white crownbeard) – P; F; SD71
*Vernonia baldwinii* Torr. (Baldwin's ironweed) – P; F; KC41
*Xanthisma texanum* DC. (Texas sleepydaisy) – A; F; SD77

Berberidaceae
**Nandina domestica* Thunb. (sacred bamboo) – P; S; GC1320, KC83, SD75

Bignoniaceae
*Campsis radicans* (L.) Seem. ex Bureau (trumpet creeper) – P; V; GC 1322
*Catalpa speciosa* (Warder) Warder ex Engelm. (northern catalpa) – P; T; RC38, KC101, KC163

Boraginaceae
*Myosotis verna* Nutt. (spring forget-me-not) – A; F; GC1291

Brassicaceae
**Capsella bursa-pastoris* (L.) Medik. (shepherd's purse) – A; F; KC127
*Lepidium virginicum* L. (Virginia pepperweed) – A; F; AP71, RC48, GC1294

Cactaceae
*Opuntia humifusa* (Raf.) Raf. (devil's-tongue) – P; S; GC1319

Campanulaceae
*Triodanis perfoliata* (L.) Nieuwl. (clasping Venus' looking glass) – A; F; RC42

Cannabaceae
*Celtis laevigata* Willd. (sugarberry) – P; T; RC77
*Celtis occidentalis* L. (common hackberry) – P; T; KC59
*Celtis reticulata* Torr. (netleaf hackberry) – P; T; AP65, KC37, KC84

Caprifoliaceae
**Lonicera japonica* Thunb. (Japanese honeysuckle) – P; V; SD66, KC162
**Lonicera maackii* (Rupr.) Herder (Amur honeysuckle) – P; S; GC1285
*Lonicera sempervirens* L. (trumpet honeysuckle) – P; V; YS31
*Symphoricarpos orbiculatus* Moench (coralberry) – P; S; SD63

Caryophyllaceae
**Arenaria serpyllifolia* L. (thymeleaf sandwort) – A; F; AP74, RC82
**Cerastium pumilum* W. Curtis (European chickweed) – A; F; RC41, GC1292
**Scleranthus annuus* L. (German knotgrass) – A; F; GC1304
**Stellaria media* (L.) Vill. (common chickweed) – A; F; RC45

Celastraceae
**Euonymus europaeus* L. (European spindletree) – P; S; KC57

Cistaceae
*Lechea tenuifolia* Michx. (narrowleaf pinweed) – P; F; AP103, GC1278, KC61

Cornaceae
*Cornus drummondii* C.A. Mey. (roughleaf dogwood) – P; T; AP58, CC64, RC56

Cucurbitaceae
*Melothria pendula* L. (Guadeloupe cucumber) – P; F; KC109

Ebenaceae
*Diospyros virginiana* L. (common persimmon) – P; T; KC50

Euphorbiaceae
*Acalypha gracilens* A. Gray (slender threeseed mercury) – A; F; KC46, SD58
*Acalypha ostryifolia* Riddell (pineland threeseed mercury) – A; F; KC117
*Croton glandulosus* L. (vente conmigo) – A; F; KC48, KC75
*Croton lindheimerianus* Scheele (threeseed croton) – A; F; AP110
*Croton monanthogynus* Michx. (prairie tea) – A; F; SD78
*Euphorbia corollata* L. (flowering spurge) – P; F; CC62
*Euphorbia dentata* Michx. (toothed spurge) – A; F; KC47
*Euphorbia maculata* L. (spotted sandmat) – A; F; SD64, KC49
*Euphorbia nutans* Lag. (eyebane) – A; F; KC97

Fabaceae
*Acacia angustissima* (Mill.) Kuntze (prairie acacia) – P; F; CC45
*Acmispon americanus* (Nutt.) Rydb. (American bird's-foot trefoil) – A; F; RC73
**Albizia julibrissin* Durazz. (silktree) – P; T; KC51, KC105
*Cercis canadensis* L. (eastern redbud) – P; T; AP66, SD57, KC137
*Chamaecrista fasciculata* (Michx.) Greene (partridge pea) – A; F; AP102, CC43
*Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald (Illinois bundleflower) – P; F; AP97
*Desmodium paniculatum* (L.) DC. (panicledleaf ticktrefoil) – P; F; KC153
*Desmodium sessilifolium* (Torr.) Torr. & A. Gray (sessileleaf ticktrefoil) – P; F; CC59
*Desmodium viridiflorum* (L.) DC. (velvetleaf ticktrefoil) – P; F; KC141
*Galactia regularis* (L.) Britton, Sterns & Poggenb. (eastern milkpea) – P; F; KC66, AP131
*Gleditsia tricanthos* L. (honeylocust) – P; T; GC 1321
*Gymnocladus dioicus* (L.) K. Koch (Kentucky coffeetree) – P; T; GC1283
**Kummerowia stipulacea* (Maxim.) Makino (Korean clover) – A; F; KC152
*Lespedeza capitata* Michx. (roundhead lespedeza) – P; F; CC55
**Lespedeza cuneata* (Dum. Cours.) G. Don (sericea lespedeza) – P; F; SD74
*Lespedeza stuevei* Nutt. (tall lespedeza) – P; F; KC55
*Lespedeza virginica* (L.) Britton (slender lespedeza) – P; F; CC46
**Medicago lupulina* L. (black medick) – A; F; RC47
**Medicago minima* (L.) L. ex Bartal. (little bur-clover) – A; F; RC46
**Melilotus albus* Medik. (white sweet clover) – A; F
**Melilotus officinalis* (L.) Lam. (yellow sweet clover) – A; F; GC1280
*Psoralidium tenuiflorum* (Pursh) Rydb. (slimflower scurf pea) – P; F; AP100
*Robinia pseudoacacia* L. (black locust) – P; T; KC98

*Strophostyles helvola* (L.) Elliott (amberique-bean) – A; F; AK7
**Trifolium dubium* Sibth. (suckling clover) – A; F; AP56
**Trifolium repens* L. (white clover) – P; F; RC53, KC157
**Vicia sativa* L. (garden vetch) – A; F; GC1295

Fagaceae
*Quercus macrocarpa* Michx. (bur oak) – P; T; KC70
*Quercus marilandica* Munchh. (blackjack oak) – P; T; CC66
*Quercus muehlenbergii* Engelm. (chinquapin oak) – P; T; SD56
*Quercus shumardii* Buckley (Shumard's oak) – P; T; KC90
*Quercus stellata* Wangenh. (post oak) – P; T; CC68

Gentianaceae
*Sabatia campestris* Nutt. (Texas star) – A; F; AP128

Geraniaceae
**Erodium cicutarium* (L.) L'Hér ex Aiton (redstem stork's bill) – A; F; AP63
**Geranium pusillum* L. (small geranium) – A; F; RC40, GC1297
*Geranium texanum* (Trel.) A. Heller (Texas geranium) – A; F; GC1307

Juglandaceae
*Carya illinoinensis* (Wangenh.) K. Koch (pecan) – P; T; KC93
*Juglans nigra* L. (black walnut) – P; T; RC78

Lamiaceae
**Lamium amplexicaule* L. (henbit deadnettle) – A; F; KC126
*Monarda citriodora* Cerv. ex Lag. (lemon beebalm) – A; F; AP98
*Scutellaria parvula* Michx. (small skullcap) – P; F; GC1298
*Teucrium canadense* L. (Canada germander) – P; F; AP129

Malvaceae
*Callirhoe involucrata* (Torr. & A. Gray) A. Gray (purple poppymallow) – P; F; KC154
**Hibiscus trionum* L. (flower of an hour) – A; F

Menispermaceae
*Cocculus carolinus* (L.) DC. (Carolina coralbead) – P; F; AP119, KC82

Molluginaceae
*Mollugo verticillata* L. (green carpetweed) – A; F; KC110

Montiaceae
*Phemeranthus parviflorus* (Nutt.) Kiger (sunbright) – P; F; GC1279

Moraceae
**Morus alba* L. (white mulberry) – P; T; KC124
*Morus rubra* L. (red mulberry) – P; T; SD65

Nyctaginaceae
*Mirabilis albida* (Walter) Heimerl (white four o'clock) – P; F; AP130
**Mirabilis jalapa* L. (marvel of Peru) – P; F; KC114
*Mirabilis nyctaginea* (Michx.) MacMill. (heartleaf four o'clock) – P; F; GC1296

Oleaceae
*Fraxinus pennsylvanica* Marsh. (green ash) – P; T; KC65, KC106
**Ligustrum sinense* Lour. (Chinese privet) – P; S; AP91, SD59, GC1299

Onagraceae
*Ludwigia alternifolia* L. (seedbox) – P; F; AP126
*Oenothera biennis* L. (common evening primrose) – B; F; KC108
*Oenothera curtiflora* W.L. Wagner & Hoch (velvetweed) – A; F
*Oenothera laciniata* Hill (cutleaf evening primrose) – P; F; AP69

Oxalidaceae
*Oxalis dillenii* Jacq. (slender yellow woodsorrel) – P; F; AP54, RC36
*Oxalis violacea* L. (violet woodsorrel) – P; F

Passifloraceae
*Passiflora lutea* L. (yellow passionflower) – P; F; KC38

Phytolaccaceae
*Phytolacca americana* L. (American pokeweed) – P; F; AP123

Plantaginaceae
*Plantago aristata* Michx. (largebracted plantain) – A; F; AP76
*Plantago patagonica* Jacq. (woolly plantain) – A; F; RC64, KC161
*Plantago virginica* L. (Virginia plantain) – A; F; RC39, AP57, GC1290
**Veronica arvensis* L. (corn speedwell) – A; F; GC1293, KC155
**Veronica hederifolia* L. (ivyleaf speedwell) – A; F; KC138
**Veronica polita* Fr. (gray field speedwell) – A; F; KC132

Polygonaceae
*Fallopia scandens* (L.) Holub (climbing false buckwheat) – P; F; GC1313
*Persicaria bicornis* (Raf.) Nieuwl (Pennsylvania smartweed) – A; F; KC100
*Persicaria lapathifolia* (L.) Gray (curlytop knotweed) – A; F; KC118
*Persicaria virginiana* (L.) Gaertn. (jumpseed) – P; F; KC119
**Polygonum aviculare* L. (prostrate knotweed) – A; F; KC92
*Rumex hastatulus* Baldwin (heartwing sorrel) – P; F; AP62, RC63

Portulacaceae
*Portulaca pilosa* L. (kiss me quick) – A; F; GC1286

Ranunculaceae
**Clematis terniflora* DC. (sweet autumn virginsbower) – P; V; KC107
*Ranunculus abortivus* L. (littleleaf buttercup) – P; F

Rosaceae
*Geum canadense* Jacq. (white avens) – P; F; GC1282, KC142
*Prunus angustifolia* Marshall (Chickasaw plum) – P; S; KC140
*Prunus gracilis* Engelm. & A. Gray (Oklahoma plum) – P; S; RC75, AP121
*Prunus mexicana* S. Watson (Mexican plum) – P; T; KC134
*Prunus virginiana* L. (chokecherry) – P; T; YS30
**Pyrus calleryana* Decne. (Callery pear) – P; T; KC72
**Rosa multiflora* Thunb. (multiflora rose) – P; V; KC71
*Rubus aboriginum* Rydb. (garden dewberry) – P; S; HU32, YS32

Rubiaceae
**Cruciata pedemontana* (Bellardi) Ehrend. (piedmont bedstraw) – A; F; RC43, RC44
*Diodella teres* (Walter) Small (poorjoe) – A; F; CC54
*Galium aparine* L. (stickywilly) – A; F; GC1288
*Galium circaezans* Michx. (licorice bedstraw) – P; F; AP95, RC80
*Galium pilosum* Aiton (hairy bedstraw) – P; F; AP68
*Houstonia pusilla* Schoepf (tiny bluet) – A; F; KC131, GC1289
**Sherardia arvensis* L. (blue fieldmadder) – A; F; AP73

Rutaceae
*Zanthoxylum americanum* Mill. (common pricklyash) – P; T; AP125, KC56, KC135

Salicaceae
*Populus deltoides* W. Bartram ex Marshall (eastern cottonwood) – P; T; KC52, KC96
*Salix nigra* Marshall (black willow) – P; T; RC58

Santalaceae
*Phoradendron serotinum* (Raf.) M.C. Johnst. (oak mistletoe) – P; S; KC125

Sapindaceae
*Acer negundo* L. (boxelder) – P; T
*Acer saccharinum* L. (silver maple) – P; T; KC122
**Koelreuteria paniculata* Laxm. (goldenrain tree) – P; T; RC81
*Sapindus saponaria* L. (western soapberry) – P; T; KC44, KC62, KC79

Sapotaceae
*Sideroxylon lanuginosum* Michx. (gum bully) – P; T; SD53

Solanaceae
*Solanum dimidiatum* Raf. (western horsenettle) – P; F; TW46
*Solanum elaeagnifolium* Cav. (silverleaf nightshade) – P; F; KC103
*Solanum ptycanthum* Dunal (West Indian nightshade) – A; F; KC113, KC120

Ulmaceae
*Ulmus americana* L. (American elm) – P; T; RC35, SD54, SD55, KC128
**Ulmus parvifolia* Jacq. (Chinese elm) – P; T; GC1314
*Ulmus rubra* Muhl. (slippery elm) – P; T; CC63

Urticaceae
*Parietaria pensylvanica* Muhl. ex Willd. (Pennsylvania pellitory) – A; F; RC55

Violaceae
*Viola bicolor* Pursh (field pansy) – A; F; KC130
*Viola sororia* Willd. (common blue violet) – P; F; KC136

Vitaceae
*Parthenocissus quinquefolia* (L.) Planch. (Virginia creeper) – P; V; AP112
*Vitis vulpina* L. (frost grape) – P; V; RC68, RC79

MONOCOTS
Amaryllidaceae
**Allium vineale* L. (wild garlic) – P; F; KC158
*Nothoscordum bivalve* (L.) Britton (crowpoison) – P; F; KC133

Asparagaceae
**Muscari botryoides* (L.) Mill. (common grape hyacinth) – P; F; KC129

Commelinaceae
**Commelina communis* L. (Asiatic dayflower) – A; F; KC81
*Commelina erecta* L. (whitemouth dayflower) – P; F; AK2, AP101, RC72
*Tradescantia ohiensis* Raf. (bluejacket) – P; F; RC70, AP111

Cyperaceae
*Carex muehlenbergii* Schkuhr ex Willd. (Muhlenberg's sedge) – P; G; AP87, RC60
*Carex retroflexa* Muhl. ex Willd. (reflexed sedge) – P; G; GC1305
*Cyperus echinatus* (L.) Alph. Wood (globe flatsedge) – P; G; KC144
*Cyperus lupulinus* (Spreng.) Marcks (Great Plains flatsedge) – P; G; AP78, RC51
*Cyperus reflexus* Vahl (bentawn flat sedge) – P; G; AP59, AP117
*Cyperus squarrosus* L. (bearded flat sedge) – A; G; AP61
*Lipocarpha drummondii* (Nees) G.C. Tucker (Drummond's halfchaff sedge) – A; G; AP118
*Scleria ciliata* Michx. (fringed nutrush) – P; G; GC1277

Iridaceae
*Sisyrinchium angustifolium* Mill. (narrowleaf blue-eyed grass) – P; F; KC159

Juncaceae
*Juncus coriaceus* Mack. (leathery rush) – P; G; AP79
*Juncus interior* Wiegand (inland rush) – P; G; GC1303
*Juncus marginatus* Rostk. (grassleaf rush) – P; G; AK6, RC61, AP60

Poaceae
*Andropogon gerardii* Vitman (big bluestem) – P; G; CC60
*Andropogon ternarius* Michx. (splitbeard bluestem) – P; G; GC1287, GC1318
*Aristida oligantha* Michx. (prairie threeawn) – A; G; CC57
*Bothriochloa laguroides* (DC.) Herter (silver beardgrass) – P; G; KC143, GC1276

*Bouteloua curtipendula* (Michx.) Torr. (sideoats gramma) – P; G; KC64
*Bouteloua dactyloides* (Nutt.) Columbus (buffalograss) – P; G; AP83
*Bouteloua hirsuta* Lag. (hairy grama) – P; G; KC63
**Bromus catharticus* Vahl (rescuegrass) – A; G; GC1310, RC50
**Bromus commutatus* Schrad. (meadow brome) – A; G; RC62
**Bromus japonicus* Thunb. ex Murray (Japanese brome) – A; G; AP77
*Bromus pubescens* Muhl. ex Willd. (hairy woodland brome) – P; G; RC54
**Bromus tectorum* L. (cheatgrass) – A; G; GC1309
*Cenchrus incertus* M.A. Curtis (field sandbur) – P; G; KC121, AP116
*Chasmanthium latifolium* (Michx.) H.O. Yates (Indian woodoats) – P; G; AP114
*Chloris verticillata* Nutt. (tumble windmill grass) – P; G; SD68
*Coelorachis cylindrica* (Michx.) Nash (cylinder jointtail grass) – P; G; AP81
*Coleataenia anceps* (Michx.) Soreng (beaked panicgrass) – P; G; KC36
**Cynodon dactylon* (L.) Pers. (Bermudagrass) – P; G; RC49, KC160
**Dactylis glomerata* L. (orchardgrass) – P; G; AP82
*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark (tapered rosette grass) – P; G; KC74, AP115, AP52
*Dichanthelium oligosanthes* (Schult.) Gould (Heller's rosette grass) – P; G; GC1311, KC60
*Dichanthelium scoparium* (Lam.) Gould (velvet panicum) – P; G; SD70
*Digitaria ciliaris* (Retz.) Koeler (southern crabgrass) – A; G; KC111
*Echinochloa muricata* (P. Beauv.) Fernald (rough barnyardgrass) – A; G; KC104
**Eleusine indica* (L.) Gaertn. (Indian goosegrass) – A; G; KC146
*Elymus virginicus* L. (Virginia wildrye) – P; G; AK4, AP72
*Eragrostis capillaris* (L.) Nees (lace grass) – A; G; KC73
*Eragrostis secundiflora* J. Presl (red lovegrass) – P; G; KC53
*Eragrostis spectabilis* (Pursh) Steud. (purple lovegrass) – P; G; CC56
*Hordeum pusillum* Nutt. (little barley) – A; G; AP70, RC52
*Panicum virgatum* L. (switchgrass) – P; G; CC61, KC145
*Paspalum setaceum* Michx. (thin paspalum) – P; G; AP80, KC45
**Phragmites australis* (Cav.) Trin. ex Steud. (common reed) – P; G; KC151
**Poa annua* L. (annual bluegrass) – A; G; AP55, RC37
**Schedonorus arundinaceus* (Shreb.) Dumort. (tall fescue) – P; G; KC156, RC65
*Schizachyrium scoparium* (Michx.) Nash (little bluestem) – P; G; CC47
**Setaria faberi* R.A.W. Herrm. (Japanese bristlegrass) – A; G; AK5, SD61
*Sorghastrum nutans* (L.) Nash (Indiangrass) – P; G; CC58
**Sorghum halepense* (L.) Pers. (Johnsongrass) – P; G; RC71, KC54, AP86
*Tridens flavus* (L.) Hitchc. (purpletop tridens) – P; G; SD76
**Vulpia myuros* (L.) C.C. Gmel. (annual fescue) – A; G; AP85
*Vulpia octoflora* (Walter) Rydb. (sixweeks fescue) – A; G; GC1312

Smilacaceae
*Smilax bona-nox* L. (saw greenbrier) – P; V; AP106
*Smilax tamnoides* L. (bristly greenbrier) – P; V; RC69

# FIRST RECORD OF *CHORIOACTIS GEASTER* FROM OKLAHOMA

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## ABSTRACT

*Chorioactis geaster* (Peck) Kupfer, the devil's cigar fungus, is reported from Oklahoma for the first time. A collection was made in Choctaw County in southeast Oklahoma in January 2017. *Chorioactis geaster* is a fleshy fungus that belongs to the Ascomycota and is an example of what are commonly referred to as cup fungi. The young ascomata are closed, swollen-elongate, brown and finely hairy. During expansion, the ascomata split into 3–6 rays that are reminiscent of earth star fungi. The hymenophore color is pale yellow to tan. The ascospores are large, measuring 60–70 x 12–13 µm, and are curved-fusoid in shape. All previous records from the United States have been reported from Texas, and the fungus is also known from Japan. The holotype was collected in Austin, Texas in 1891 and described by Charles H. Peck in the genus *Urnula*.

## INTRODUCTION

The second author made a collection of *Chorioactis geaster* (Peck) Kupfer ex Eckblad (devil's cigar mushroom) in January 2017 in southeast Oklahoma. The fungus belongs to the Ascomycota, Pezizomycetes, Pezizales, Chorioactidaceae. The Pezizales includes the larger ascomycete fungi commonly referred to as cup fungi. This is the first record of the fungus for Oklahoma. In this paper we present a description of the fungus and discuss the current state of knowledge regarding the species' distribution.

## MATERIALS AND METHODS

The collection was made on January 16, 2017, by the second author in Choctaw County, Oklahoma. The material was photographed *in situ,* dried and sent to the first author who confirmed its identity. The collection is housed in the University of Central Oklahoma Herbarium (CSU). The macroscopic description was compiled from the Oklahoma collections and from previously published descriptions. The microscopic details of the fungus were made by reviving dried sections of the ascomata in 3% KOH.

## DESCRIPTION

Young ascomata closed, fusoid, club- or cigar-shaped, upper portion hollow, surface densely hairy and brown, dehiscing at stipe apex into 4–7 rays with the resultant apothecia forming a star-shaped pattern reminiscent of earthstars, up to 12 cm across (Figures 1 and 2). Hymenial surface pale yellow to tan. Stipe cylindrical, up to 7 cm long, solid, usually buried. Ascospores large, 56–70 x 12–14 µm, curved-fusoid, hyaline. Asci 650–750 x 15–20 µm,


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8-spored, thick-walled. Paraphyses moniliform, apex narrow and to 3 µm wide, hyaline. Surface hairs to 5–10 µm wide, brown, finely spiny or warty.

Oklahoma collection: Choctaw County: Fort Towson, ½ mi S of U.S. Hwy 70, ½ mi E of St Hwy 109, 16 Jan 2017, collected by Sheila Brandon. Scattered, in grassy/weedy area, with leaf litter and woody debris.

Figure 1 Ascomata *in situ*

Figure 2 Dried ascoma showing stipe

## DISCUSSION

*Choriactis geaster* was first described by Charles Horton Peck (1893) in the genus *Urnula* from material collected in Austin, Texas. Later, the genus *Chorioactis* was established to accommodate the species (Kupfer 1902; Ekblad 1968). Interestingly, the species was reported from Japan (Miyazaki Prefecture) from a collection made in 1937 (Imazeki 1938) and was rediscovered in Japan at the same location nearly four decades later (Imazeki and Otani 1975). Peterson et al. (2004) undertook a molecular study of the species, analyzing collections from Japan and Texas, and found that collections from the two geographic locations represent two lineages but could not be distinguished morphologically.

In the United States, the fungus has been known only from central and north-central Texas with fruiting times being documented from September to March (Rudy 2001; Peterson et al. 2004; Ubelaker and Starks 2005; Watson 2010). Here we report the fungus from Oklahoma for the first time. The Oklahoma fungus was collected in a grassy-weedy-rocky area with decomposed leaf litter. Previously, the area had been covered with honey locust (*Gleditsia triacanthos* L.), eastern redcedar (*Juniperus virginiana* L.) and bois d' arc (*Maclura pomifera* (Raf.) C.K. Schneid.). The species has previously been recorded as being associated with cedar elm (*Ulmus crassifolia* Nutt.) and often near and attached to stumps or to buried wood (Rudy & Keller 1996; Rudy 2001). Other reports indicated that the fungus occurred in an open pasture with no stumps or shrubs nearby (Ubelaker and Starks 2005), but it is unclear whether the fungus may have been attached to buried wood. The fungus appears to be a saprotroph, and future collecting will require careful digging to confirm if the ascomata are attached to wood.

*Chorioactis geaster* was thought to be rare and restricted to Texas, but because of its occurrence in north-central Texas, it is not all that unusual for it to be found in Oklahoma. Future records will likely reveal it to be more broadly distributed at least in the south-central part of the United States.

## ACKNOWLEDGMENT

We thank Ben Liles for providing the collection that was used to make the photograph of the dried ascoma.

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*Critic's Choice Essay*

# ALLELOPATHY

**Reprinted from *Gaillardia*, Summer 2004**

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An ONPS member sent an interesting article from the *New York Post* dealing with allelopathy. (I've received several copies since.) This Botany Bay is dedicated to that person, still active Charter Member Marcy Robinowitz. Marcy, thank you for thinking of me.

The *Post* article dealt with spotted knapweed (*Centaurea maculosa*), an invasive exotic introduced from Caucasia. The author reports, "..it is thought to have been introduced in North America as a contaminant in crop seed or in dirt used as ship's ballast and then dumped." The species is a recognized problem over much of the contiguous United States. Many western Colorado highways are virtually lined with pure stands.

In 1920, but one county in western Montana reported the presence of this species. In 1940, five western counties and by 1982, it was reported in all counties, having spread across the entire state. I recall the concerted effort my son and I made to eradicate the plant from a small abandoned horse pasture in the western part of the state. The following year, scattered patches appeared on the site, but a few years later, spotted knapweed was once again abundant.

Although spotted knapweed has not been reported in Oklahoma, it is a widely scattered pest of the Great Plains. We must be alert for it in the state; it seems to have the ecological potential to invade our western grasslands.

However, there is another noxious, caucasian weed of that genus which should concern us. Russian knapweed (*Centaurea repens*) is reported over much of Oklahoma. This species was introduced to North America in 1898 and has become established as a pernicious weed throughout the country.

Close your eyes for a moment and consider the following question: 'Why do so many exotic species successfully overwhelm native species?' Many readers probably suggested success is due to leaving predators and pathogens behind by moving. It is possible an earlier aggressive herbivore kept the population under control or a pathogen or perhaps in the new habitat the species is able to out-compete others for light, water, minerals or soil nutrients. Recent research reported in the *New York Post* article suggests another factor. Researchers now attribute success in numerous cases to allelopathy.

For many the term allelopathy is new. An excellent definition is the one given by the University of Oklahoma's late Dr. Elroy Rice in his book *Allelopathy*. He defined it as "...any direct or indirect harmful effect by one plant (including microorganisms) on another through the production of chemical compounds that escape into the environment."


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Consider that definition for a moment. It opens a whole new can of worms in our world of botany. Notice it does not involve the over utilization of an essential environmental factor such as water, sunlight, or nutrients. That would be competition. Dr. Rice suggests the term interference might be used to encompass both allelopathy and competition.

To many, the foregoing may appear complex, but then most are already familiar with a classic case of allelopathy, one reported in botanical literature in the 19th Century. No doubt, vegetable gardeners were aware of it much earlier. The example is that garden crops will not survive under or near a black walnut (*Juglans nigra*) tree. Early workers suggested the trees were able to exhaust the soil of vital nutrients. It was subsequently discovered the trees were producing a chemical compound which, when released into the soil, is toxic to other green plants, even black walnut seedlings. Biochemists have since identified that compound and named it juglone, a takeoff on the black walnut genus *Juglans*. If you are a skeptic, plant some seedlings under a black walnut and observe them. The survival value of the allelopathic phenomenon is evident. Eliminate competition! Even parent walnut trees do not compete with nearby offspring. It has been known for years that walnut trees will injure and sometimes kill adjacent apple trees.

The *Post* article reports spotted knapweed's ability to overwhelm native species and establish itself in pure stands as allelopathic. Workers found the knapweed in question synthesizes a poison which, when released through the roots, will eliminate competing neighbors. Researchers at Colorado State University report the toxin acts so quickly it will initiate a sequence of chemical reactions resulting in the death of root cells within ten seconds of contact. They also reported, "In one hour the roots die" and "The whole plant dies in a matter of days." Currently there are no known native species resistant to the toxins secreted by spotted knapweed.

On the other hand, allelopathic toxins need not be lethal. Rice reported that in some cases they serve to inhibit populations of nitrogen fixing microorganisms in the soil, resulting in the lowering of available nitrogen below that required by native species. An invasive species may hold competing species at bay by simply maintaining a less favorable environment.

Rice also reported that in the early 1900s apple trees were observed to be injured by surrounding grass. Initially it was thought the harm was due to competition for minerals or utilization of soil oxygen by grass, thus suffocating tree roots. Laboratory tests were carried out in which apple trees were provided abundant oxygen but subjected to chemicals secreted by the grass. The results supported the hypothesis that allelopathy is responsible.

Experiments have also shown a number of crop plants, including cultivated wheat, exude an inhibitory substance that functions on seedlings of the same species. That presents another aspect to the question of mineral exhaustion and crop rotation. Perhaps it is not mineral depletion but an accumulation of toxic compounds secreted by the plants.

The *Post* report brings to mind a short article that appeared in the *Readers Digest* many years ago. If I recall correctly, the title was simply "War in the Garden," and it introduced the concept of allelopathy to the lay person. Keep your eyes open for allelopathy in your yard; I suspect it is there. It is a vicious world in nature.

ONPS

Paul Buck

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*Oklahoma Native Plant Record* is published annually by Oklahoma Native Plant Society. Submission for publication in the journal is open to all. Manuscripts will be accepted on topics related to Oklahoma's regional botany, including historical research reports, current research articles, site record species lists, and descriptions of new or important species sightings in Oklahoma. Oklahoma's environmental gradients of human impact, climate, and elevation make the *Record* a prime resource for research on habitat edges, species ranges, and edge species. Articles of other themes may be included as well. Local research overlooked by journals of broader geographic regions will be considered for publication in the *Record*.

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Common names should be referenced to a scientific name using nomenclature that has been revised according to the Integrated Taxonomic Information Service (ITIS) database (http://www.itis.gov). Abbreviations of authorities for scientific names should follow *Authors of Plant Names* (Brummitt, R.K. and C.E. Powell. 1992. Richmond, Surrey, England: Royal Botanic Gardens Kew). Titles of periodicals should be abbreviated following Botanico-Peridoicum-Huntianum and its supplement, except in historic publications when original format may be used.

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