The Conservation Status of *Echinacea* Species

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Introduction to the Conservation Status of *Echinacea* species

Kelly Kindscher

Species in the plant genus *Echinacea* are highly valued as medicinal plants for the herbal products industry. This industry has grown dramatically, and echinacea sales have been in the millions of dollars, with wild-harvested material being a substantial part of the market (American Herbal Products Association 2003). As a result, extensive and potentially unsustainable harvesting of wild populations of echinacea has occurred. In addition, two species, *E. tennesseensis* and *E. laevigata*, are very rare and are federally listed as endangered. Thus we have developed the national conservation assessment presented in this report, using the extensive research on Echinacea conducted at the University of Kansas, where one of the most extensive Echinacea herbarium collections is located and was used to develop the most widely known systematic classification of *Echinacea* species (McGregor 1968) and where more recent research has looked at its ethnobotany, wild harvest, and plant population dynamics (Kindscher 1989, 1992; Hurlburt 1999). In addition, the Kansas Biological Survey at the University of Kansas is a partner in the U.S. Natural Heritage Program and Canadian Conservation Data Centre (CDC) networks, which rank conservation status of Echinacea and other species and conservation elements throughout their ranges. We hope that this conservation assessment will contribute to a framework for successful conservation of Echinacea species by promoting good stewardship among managers and informed awareness among users of the National Forests, National Grasslands, and other federal lands, as well as among private landowners. Maintaining the viability of wild populations of the species of this wild-harvested and potentially vulnerable North American plant genus is an important goal.

The U.S. Forest Service is responsible for maintaining populations of plants and animals on the 191 million acres of National Forests and National Grasslands in 43 states and for developing and disseminating up-to-date information on threatened, endangered, and sensitive species. This information on species status, distribution, stewardship, and biology provides an essential link in the Forest Service management of these great natural resources. Utilizing the vast and up-to-date national and international imperiled species data maintained by cooperators like Heritage programs is imperative for implementing adequate management of National Forests and Grasslands. The Forest Service strives to protect and restore populations and habitats for more than 280 species of plants and animals officially designated as being threatened or endangered with extinction, and provides special management for more than 2,500 plant and animal species on its regional sensitive-species lists. Management of these vulnerable links in the biodiversity chain is crucial for implementing the Forest Service vision of ecosystem management. Because of its responsibility to natural resource management, the U.S. Forest Service has undertaken an evaluation of echinacea species status and conservation.

Our assessment is a collaborative effort by a team of researchers directed by Kelly Kindscher, Ph.D. at the Kansas Biological Survey at the University of Kansas, and is based on field studies, data collection, and observation. This work has been peer reviewed, but it is still open for interpretation and, we hope, continued dialogue and discussion.

The perspective for this study is purposefully broad, and we accomplished the following objectives:

1. We compiled range-wide status information on all nine currently recognized species in the plant genus *Echinacea* based on herbarium records throughout their

ranges. We have developed Geographic Information System (GIS) maps showing the documented distributions of all species.

2. We thoroughly reviewed the literature related to the conservation status of echinacea species and assessed current species threats, especially the magnitude of any impacts on the medicinal herb industry from overharvesting of these species.
3. We summarized the biology, life histories, and autecology of all species, with a special emphasis on the species most actively harvested for the medicinal herb industry (*E. angustifolia*, *E. purpurea*, and *E. pallida*) and their habitat requirements.
4. We reviewed the ethnobotanical uses of echinacea species, especially *E. angustifolia*, which is the most well documented.
5. We maintained cooperating relationships with pertinent members of the Natural Heritage Program network and sought assistance as needed from other organizations, agencies, and researchers to obtain a broad understanding of the biological and conservation status of the genus *Echinacea* and its component species.
6. We collected field data from two locations with a history of echinacea harvest (the Little Missouri National Grasslands in North Dakota and private ranches in Kansas) for use in developing population and monitoring plans. Those data are included in this report. In addition, we visited additional ranches in Texas, Oklahoma, Kansas, Nebraska, and Montana where *E. angustifolia* was growing, and we visited field sites in Missouri, Oklahoma, and Kansas of *E. atrorubens*, *E.*

pallida, E. paradoxa, and *E. purpurea*. We also visited specific locations where overharvesting is known to have occurred in north-central Kansas and Custer National Forest and the Ft. Peck Indian Reservation in Montana.

7. We detailed the commercial history of echinacea harvest during the last 100-plus years in the north-central Kansas rangelands.
8. We reviewed modern medicinal uses of echinacea, which could have a great bearing on the conservation status of wild populations.
9. We provided information on what is known about echinacea market cycles and demand.
10. We reviewed the legal protection status of echincea under both state and federal law.
11. We assessed the extent of cultivation activities pertinent to medicinal uses, domestically and internationally, especially as those activities relate to possible amelioration of impacts from wild harvesting.
12. We reviewed the systematics of the genus *Echinacea*, including current suggested revisions and unresolved taxonomic questions pertinent to echinacea conservation.
13. We developed conservation recommendations for all species, including the seven species that are not federally listed.
14. We assessed the appropriateness of proposing listing of any *Echinacea* taxa under CITES and/or under the U.S. Endangered Species Act.
15. We created an echinacea-monitoring plan that can be used by staff of the National Forests, National Grasslands, other federal agencies, state agencies, the Nature

Conservancy, and other nonprofits to monitor existing stands of echinacea species that occur on lands under their jurisdiction.

16. Lastly, the study of these objectives has resulted in the compilation of the following reports, resulting in a range-wide conservation assessment for the genus *Echinacea*.

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The Naming and Classification of *Echinacea* Species

Kelly Kindscher and Rebecca Wittenberg

Taxonomy is the science of naming natural organisms so that the names of organisms can be organized to show relationships that reflect their evolutionary history. It provides the nomenclatural basis of all the natural sciences. Taxonomy enables us to identify a species no matter what language we speak or common name we use by assigning a Latin binomial name (*genus* and *species*) to an organism. Each binomial name is unique. Common names, although useful in the field, are sometimes confusing and of limited use beyond where they are commonly used. For example, all nine species of *Echinacea* (and of several other genera as well) have been called "Snakeroot."

Identifying species by Latin binomials is important when working with a medicinal species. Many names used in the natural products industry refer to older texts, and older names often are quoted in the literature. Thus it is important to be aware of all the possible names used for a particular plant. With recently proposed revisions to the names of species in the genus *Echinacea*, there can be confusion between the newly named *E. pallida* var. *angustifolia* and its former name, *E. angustifolia.* Fortunately, the *Flora of North America* editors (Urbatsch *et al.* 2005) have decided to maintain the common taxonomy of the *Echinacea* genus.

Because of high morphological variability within the genus, its taxonomy has often changed since the 1700s. As a result of this taxonomic confusion, some German research that was actually conducted on the species *Echinacea purpurea* was originally reported to be on the species *E. angustifolia* (Foster 1991; McKeown 1999; Binns *et al.* 2004). Individual plants do not always fit the descriptions provided below, and hybridization in the wild occurs where species ranges overlap.

Taxonomic History of the genus *Echinacea*

The genus *Echinacea* is in the daisy family, Asteraceae, which is also called Compositae. Although we now know it to be the genus called *Echinacea,* species belonging in it have also been placed in the genera *Rudbeckia* and *Brauneria.* These names are important to know because older botanical, horticultural, and medical texts may use these names in discussing what we now call *Echinacea.*

In 1753, Linnaeus described a species we know to be in the genus *Echinacea,* naming it *Rudbeckia purpurea.* (The genus name came from the name of the Swiss botanist Olaf Rudbec, and the specific epithet means "purple."). In his *Species Plantarum,* Linnaeus based the identification of this species on the earlier-named *Chrysanthemum americanum* of Leonard Plukenet (1720) and *Dracunculus virginianus* of Robert Morison (1699). Linnaeus's description effectively named the genus *Rudbeckia.* In 1790, Noel Joseph de Necker renamed the genus *Brauneria* (after the botanist Jakob Brauner), but that name was later invalidated by the organization responsible for regulating botanical names, the International Botanical Congress. In 1794 Conrad Moench renamed the species that Linnaeus had described as *Echinacea purpurea*, naming the genus after the Greek word "echinos," meaning hedgehog, because of the spiny projections on its cone in the seed stage (Hobbs 1995).

When it was realized that Linnaeus's *Rudbeckia purpurea* did not belong in the genus *Rudbeckia*, the rules of the International Botanical Congress, called the International Code of Botanical Nomenclature, dictated that the genus name should have been the oldest valid published name. But no name published before 1753, when Linnaeus used the name *Rudbeckia,* had priority, and *Brauneria* was no longer appropriate. The congress therefore decided that *Echinacea* was the first validly published name and should be used in preference to *Rudbeckia* or

Brauneria. (Hobbs 1995; *Rudbeckia* is, of course, a valid genus name for several species, but it does not include the species we refer to as *Echinacea*.)

More Recent Taxonomies

McGregor (1968) conducted a 15-year morphological analysis of the *Echinacea* genus, utilizing field studies; transplant, greenhouse, and garden studies; and all possible crosses and backcrosses of species and their varieties. Binns *et al.*'s (2002) systematic survey of *Echinacea* is more recent, using phytochemical analysis as well as morphological features for classification purposes. Systematic DNA research is being conducted that may help further clarify the species relationships (Urbatsch *et al.* 2000; Kim *et al.* 2004; Mechanda 2004).

Research by Binns and her colleagues does not support McGregor's taxa at the species level. This is not a new occurrence. For example, in 1955 Cronquist reduced *E. angustifolia* to a variety of *E. pallida*. These taxa are very similar, so whether they are separate species or varieties of the same species would not seem all that important. But these two particular taxa are both medicinally important, so differences in classification have had a confusing effect, especially in the medicinal plant trade. For instance, in 1825, Constantine Rafinesque wrote about the medicinal properties of plants he placed in the genus *Helichroa* (Hobbs 1995). No one realized that he was referring to the genus now called *Echinacea*, and much of his work went unnoticed. Because of this past and present confusion, Binns *et al.* suggested conserving the name *Echinacea purpurea*—meaning that the name stays the same even if future taxonomic work indicates that the name should change according to botanical naming rules. The International Botanical Congress decided to conserve the name (Binns *et al.* 2004).

For ease of use and to avoid confusion, McGregor's (1968) taxonomy, now essentially adapted by the *Flora of North America* (Urbatsch *et al.* 2005), is used throughout this chapter. Table 1 compares McGregor's and Binns *et al.*'s treatments.

Although *Echinacea* has been cultivated, it has undergone less selection than might be expected for a plant with a horticultural history dating back to 1860 and only *E. purpurea* has been developed as a cultivar (Starman *et al.* 1995). Several cultivars exist, such as "Magnus," a six-inch lavender coneflower, and "White Swan," an all-white option (both offered by commercial seed companies), but until recently, most varieties were seen in wild populations (McGregor 1968), with the exception of a newly introduced doubled horticultural strain and a newly developed orange-petalled variety (Hawks 2004). In addition, extensive germplasm collections by McKeown (1999) and others have now been archived in the USDA National Germplasm System at Iowa State University and will be available for both medicinal plant and horticultural breeding programs.

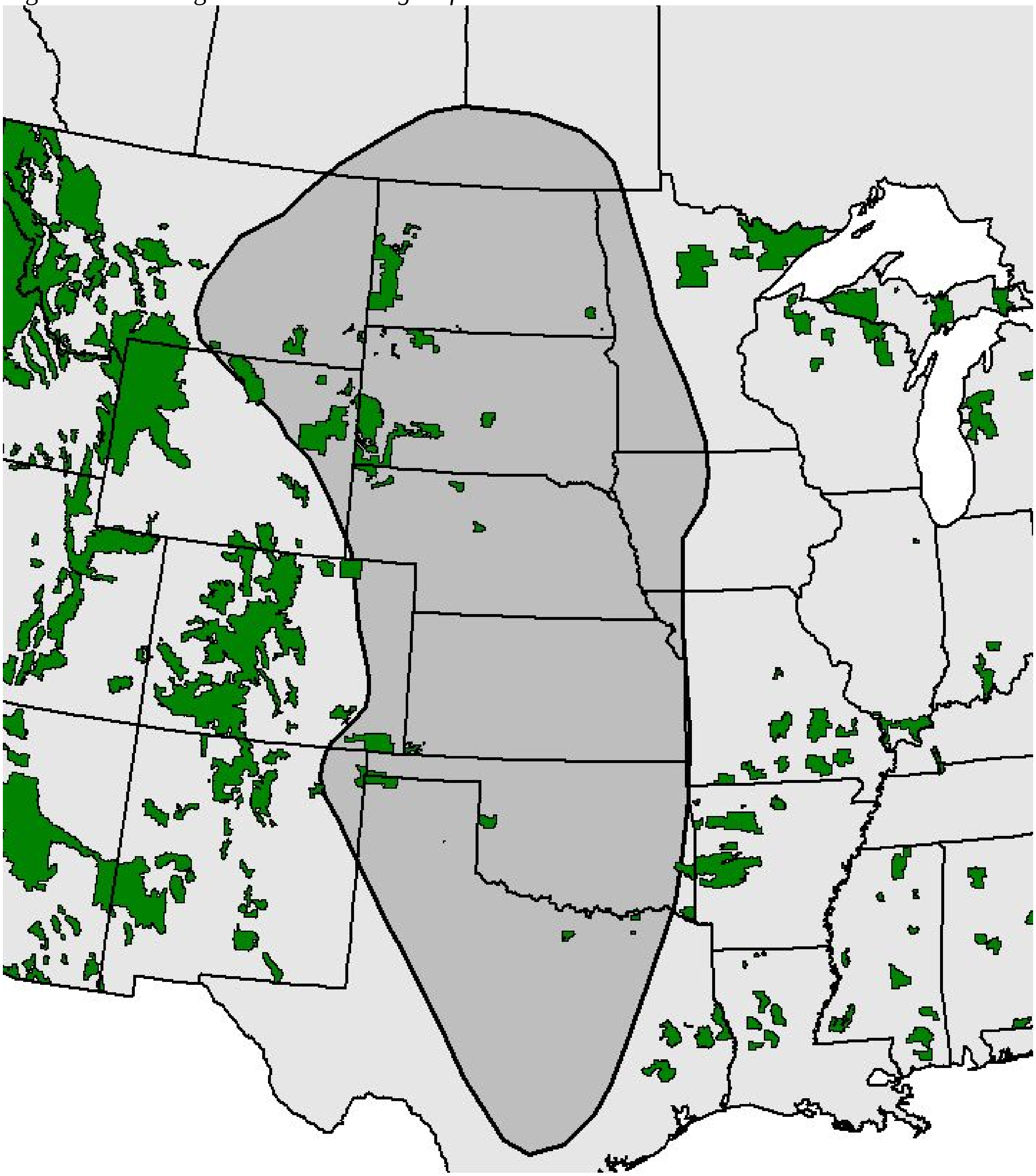
Distinguishing Characteristics of *Echinacea* Species

Within the family Asteraceae (Compositae), *Echinacea* is one of the coneflower genera, which includes *Rudbeckia*, *Ratibida*, and *Dracopsis*. *Echinacea* species are herbaceous perennials with erect stems. The lower leaves are often with stalks; the upper leaves are usually attached directly to stems. Leaves are oval to lance shaped, sometimes toothed, sometimes hairy, with three to five veins running from base to tip. The center of the flower is a spiky cone head surrounded by ray flowers. Each flower head is subtended by a group of three to four whorls of bracts. Ray flowers are usually rose-colored to purple, white, pink, or yellow (McGregor 1968). County-specific range maps for each species are in the Biology and Ecology chapter (in this volume) while generalized ranges related to U.S. Forest Service are below.

Echinacea angustifolia

Stems are 10–50 cm tall, simple, sometimes branched, sparsely to densely covered with rough thick hairs, and occasionally swollen at their bases. The leaves are oblong, lanceolate, and entire, with entire (never serrated) leaf margins; dark green, with veins slightly more rounded than parallel. The head is conical and the pales (receptacle spines) are rigid at the tip. The ray flowers are very short (2–4 cm long), shorter than the width of the head and spreading (perpendicular to the stems) with very little drooping. The petals are about as long as the diameter of the central cone. It is found on barren, dry prairies, thin soils, and limestone and sandstone rock outcrops in the Great Plains. McGregor (1968) recognized two varieties (var. *strigosa* and var. *angustifolia*), but these are not supported by the work of Binns *et al.* (2002) and others and are the only significant change from the taxonomy that will be used in the *Flora of North America* (Urbatsch *et al.* 2005).

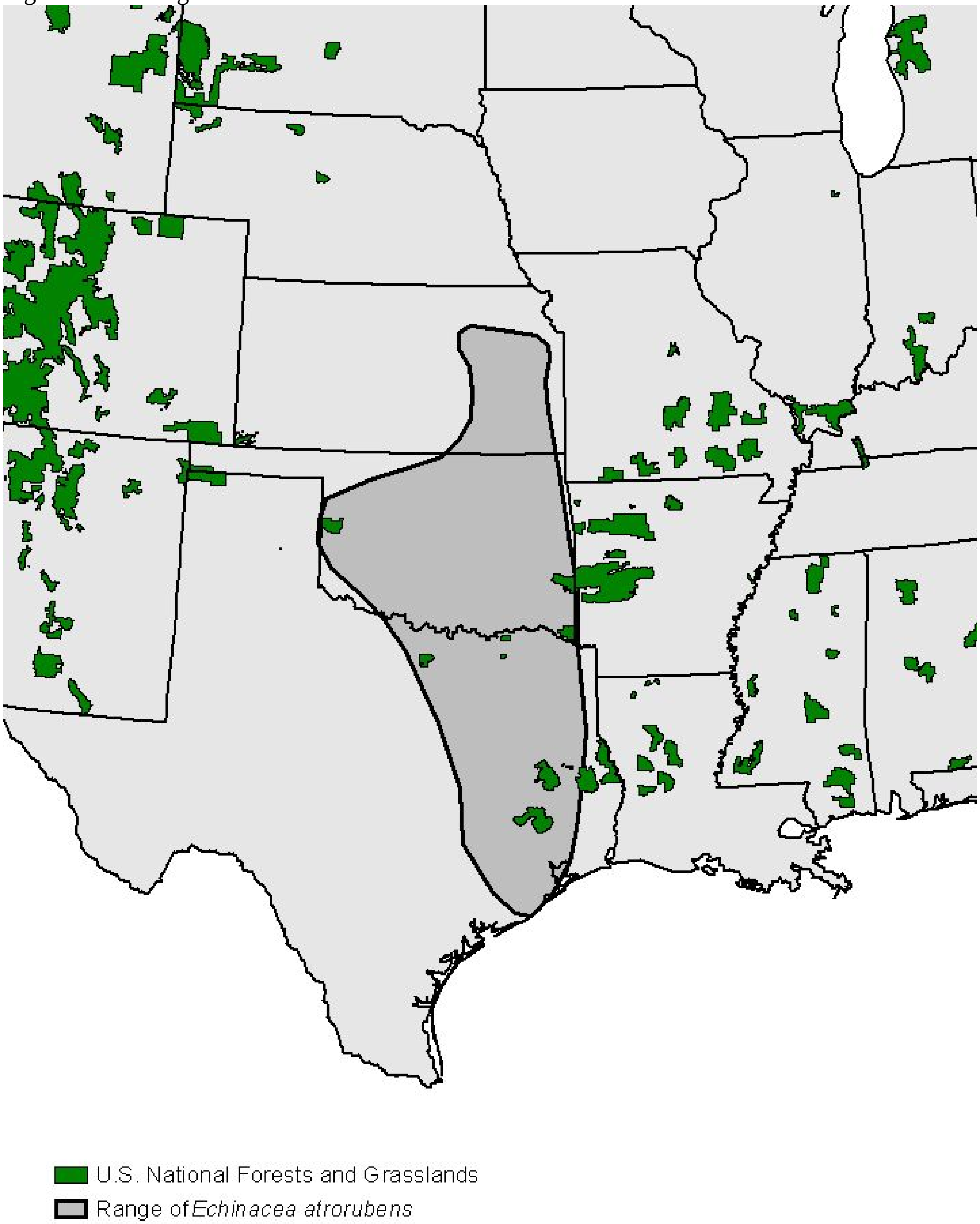
Figure 1. The range of *Echinacea angustifolia* related to U.S. Forest Service lands.



Echinacea atrorubens

Stems are 30–90 cm tall, light green, hairy and simple or rarely branched. Leaves are lanceolate and entire, often smooth. Pales tips are rigid. Short ray flowers (2-4 cm long) curve down to touch the stalk. The petals are dark purple, occasionally pink, or white. It grows on prairies.

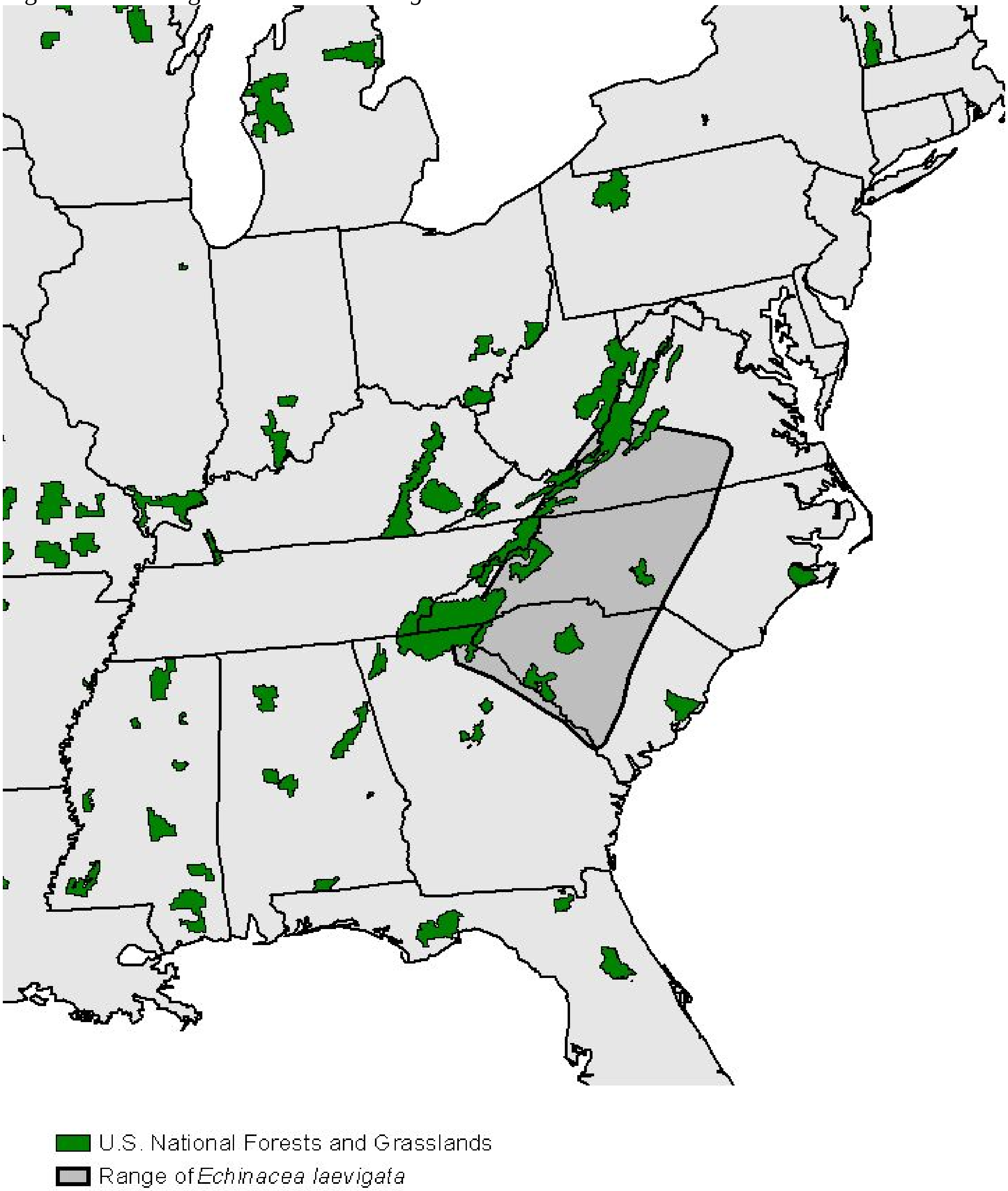
Figure 2. The range of *Echinacea atrorubens* related to U.S. Forest Service lands.



Echinacea laevigata

Stems are 50–100 cm tall and rarely branched. It often has a forked taproot, and the leaves are ovate and sometimes serrated. The bristles of the central cone are only a quarter as long as the main part of the cone and have flexible curved tips. The ray flowers are three to ten times longer than wide. It grows in open woods and grassy glades. The U.S. Fish and Wildlife Service has listed this species as endangered.

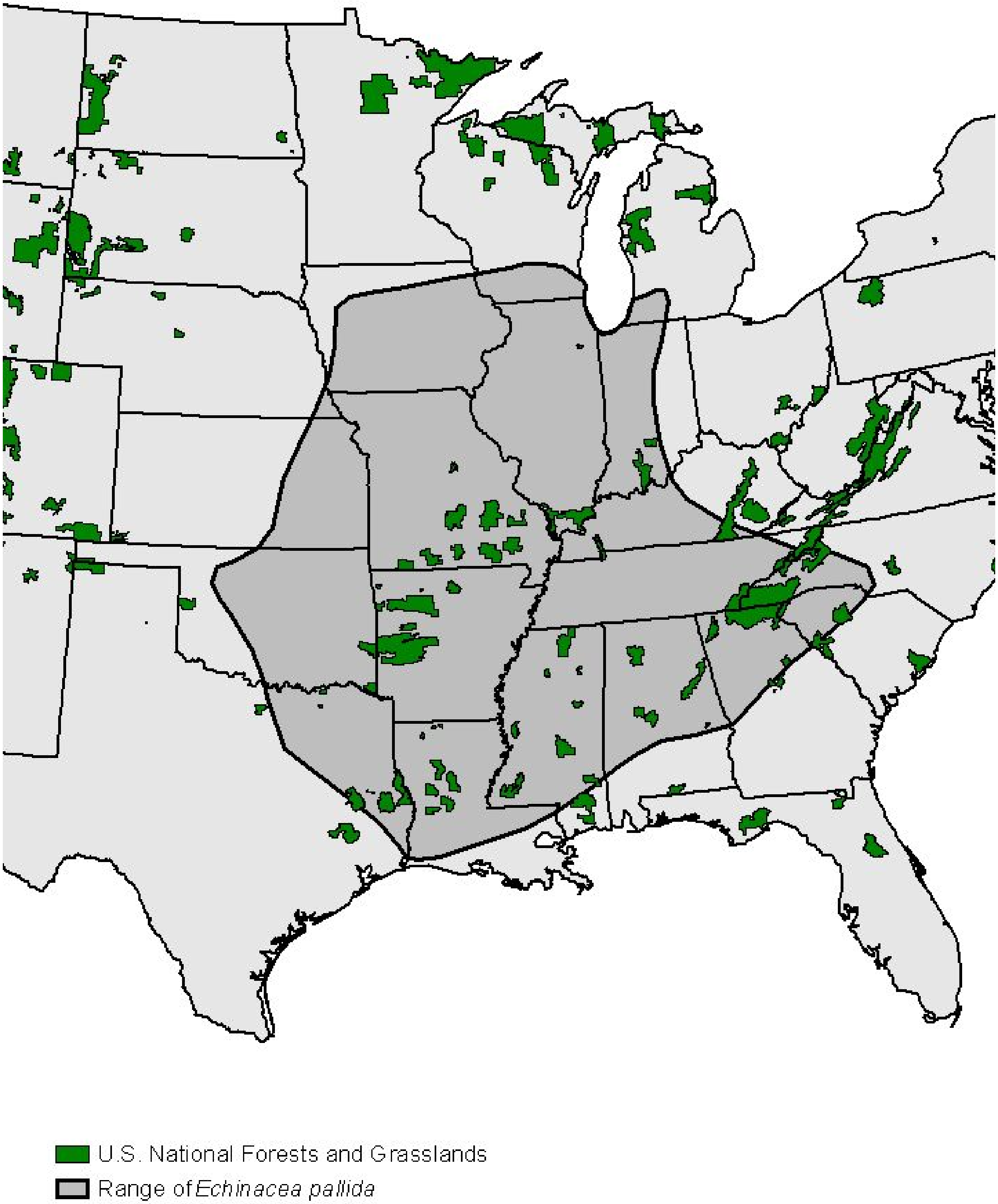
Figure 3. The range of *Echinacea laevigata* related to U.S. Forest Service lands.



Echinacea pallida

Stems are 40–90 cm tall. The leaves are lanceolate with entire margins. The head is conical, and the pales are rigid at the tips. This is the only *Echinacea* with white pollen. The ray flowers or petals are narrow and droop and curve toward the stem and are 4–9 cm. The ray flowers are usually white to pink but can very occasionally be deep purple. This plant occurs in woods, glades, and rocky prairies.

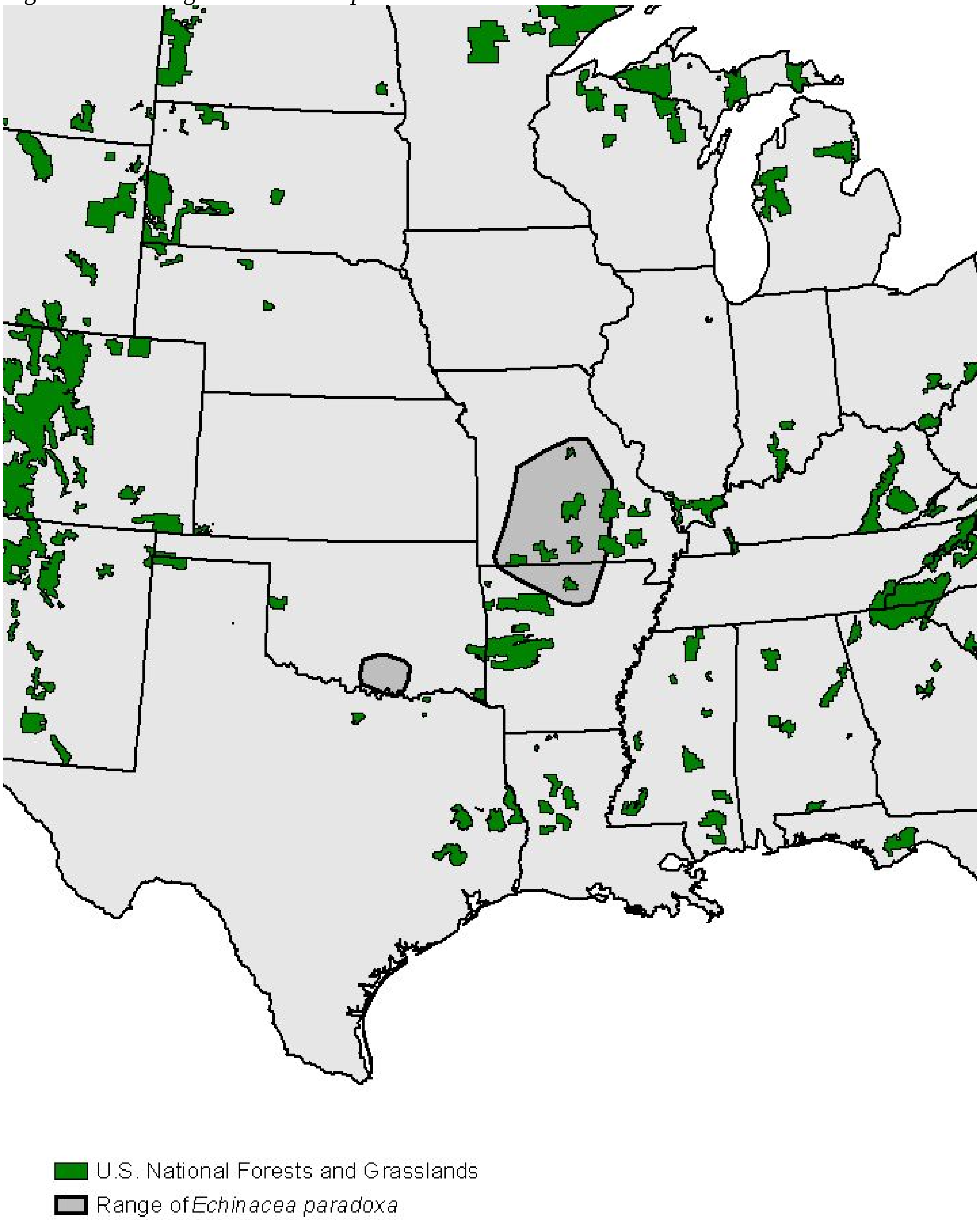
Figure 4. The range of *Echinacea pallida* related to U.S. Forest Service lands.



Echinacea paradoxa

Stems are 30–80 cm tall, light green, and otherwise smooth. Leaves are lanceolate (never serrated). The central disk is dark brown and conical. Pales have rigid tips. Ray flowers are longer than the width of the head and vary from generally yellow (var. *paradoxa,* found in the Ozarks) to light purple (var. *neglecta*, found only in the Arbuckle Mountain area of Oklahoma). It grows in glades, on bald knobs, in open woods, and in rocky prairies.

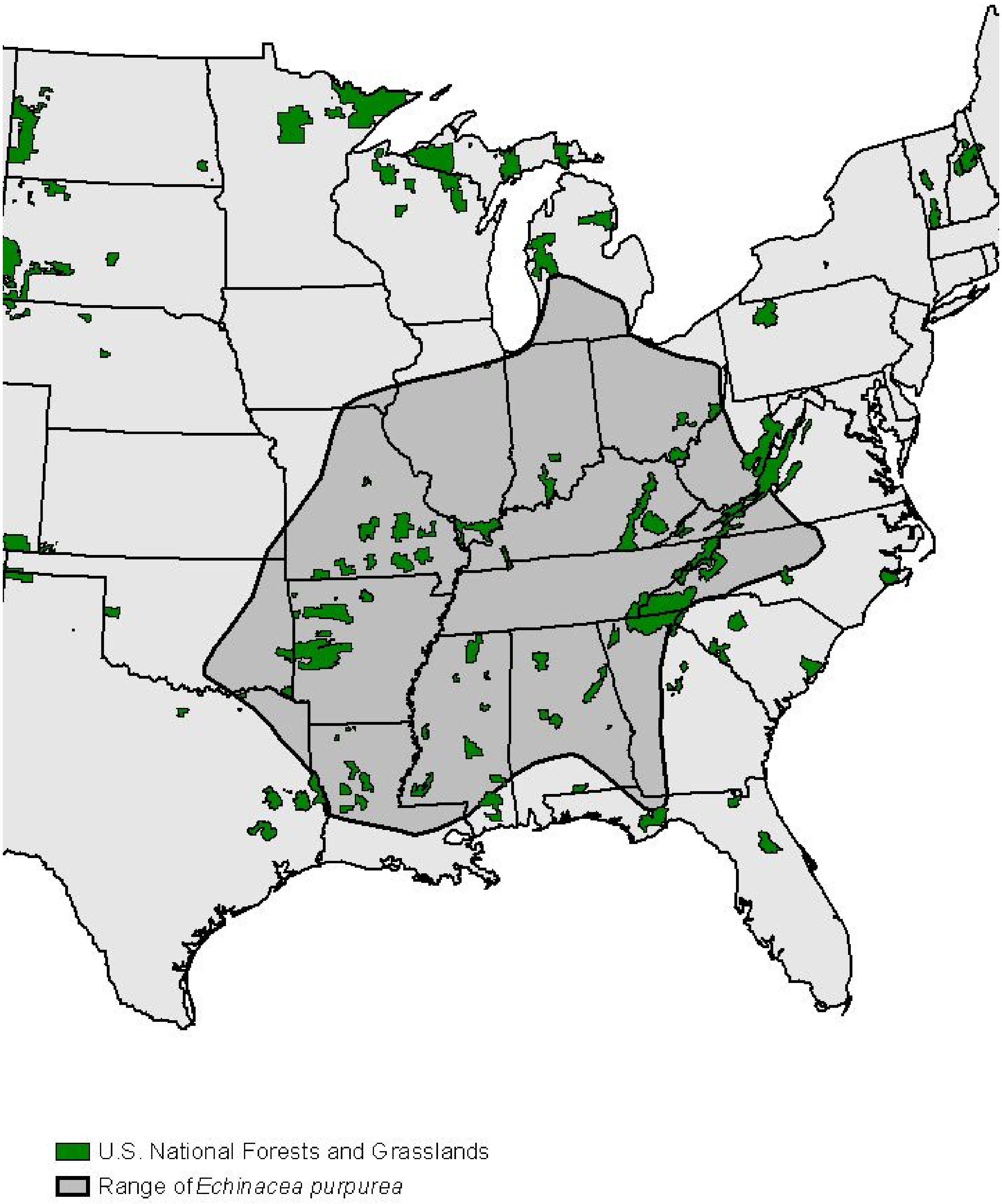
Figure 5. The range of *Echinacea paradoxa* related to U.S. Forest Service lands.



Echinacea purpurea

Stems are 60–180 cm tall, often branching near the top with soft short hairs. The lowermost leaves are oval to broadly lanceolate and coarsely toothed with irregular teeth (the best characteristic for distinguishing this species). The tips of the center cone are often tipped bright orange (probably the second-best distinguishing characteristic). Pales have flexible straight tips. Bristles of the central cone are half as long as the cone's body. The ray flowers vary from rose to deep purple, rarely white. It grows in open woods, prairies, and thickets.

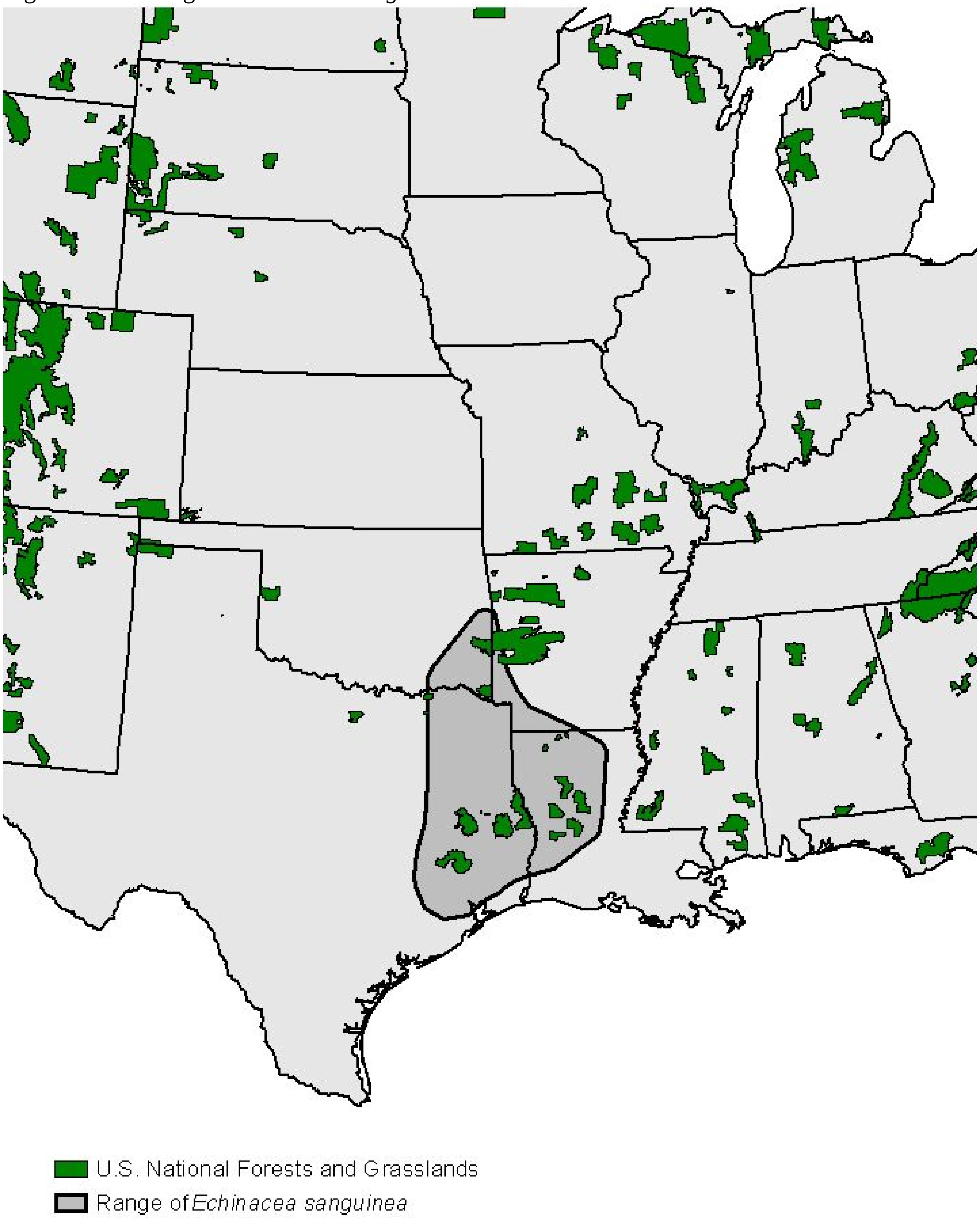
Figure 6. The range of *Echinacea purpurea* related to U.S. Forest Service lands.



Echinacea sanguinia

Stems are 40–90 cm tall. Leaves are lanceolate and entire. The basal leaves are elliptical. Flower head is a half sphere; it has thin stems and dark red, rarely white, flowers. Pales have rigid tips. It grows on sandy pine barrens and prairies.

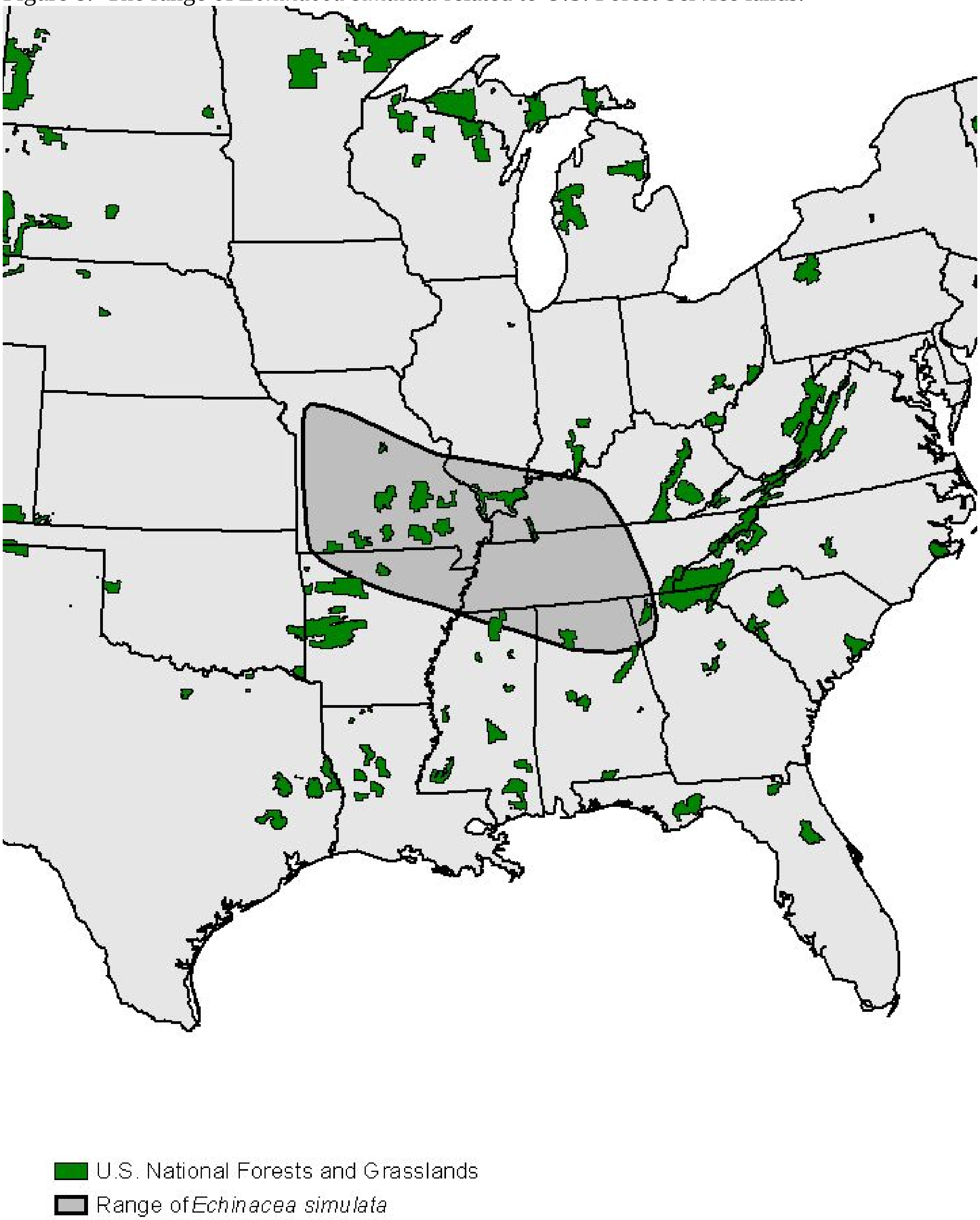
Figure 7. The range of *Echinacea sanguinia* related to U.S. Forest Service lands.



Echinacea simulata

Stems are 40–90 cm tall. Leaves are lanceolate and entire. The head is conical, and the tips of the pales are rigid. The ray flowers are 4–9 cm and drooping, usually pale white but can vary to deep purple. The pollen is yellow, which helps distinguish it from *E. pallida*. It grows on rocky, open wooded hillsides and prairies.

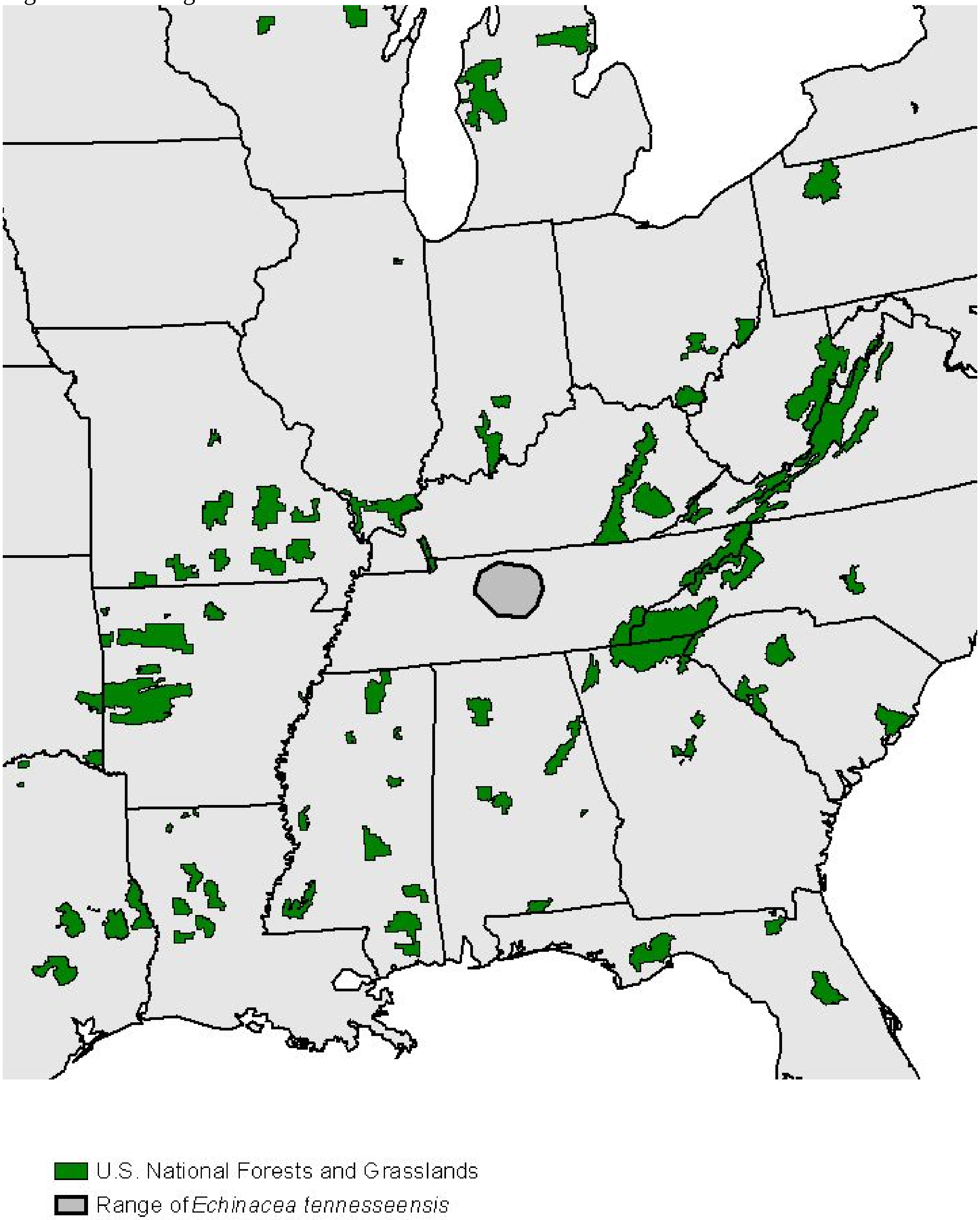
Figure 8. The range of *Echinacea simulata* related to U.S. Forest Service lands.



Echinacea tennesseensis

Stems are 10–40 cm tall and are leafy with soft hairs. The leaves are lanceolate and entire. The head is conical. The pollen is yellow and small. The tips of the pales are rigid. Ligules are 2–4 cm long and spreading. The flower petals turn up as though to touch the sun. This species has been listed by the U.S. Fish and Wildlife Service as endangered. Only five populations are known, all in gravelly cedar barrens and limestone outcrops in central Tennessee.

Figure 9. The range of *Echinacea tennesseensis* related to U.S. Forest Service lands.



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The Biology and Ecology of *Echinacea* species

Kelly Kindscher

The species in the genus *Echinacea* form a fairly similar group of nine herbaceous, perennial species of the Asteraceae family. These species have similar biological and ecological requirements. *Echinacea angustifolia* has the largest geographical range and is the primary species discussed here, with notes given when other species differ significantly.

Echinacea utilizes the C3 photosynthetic pathway. Although it has a cool-season plant physiology, it is well adapted to summer heat and to dry periods. Seedlings germinate in the early spring and have fleshy cotyledons that are followed by one true leaf. In the wild, this may be the entire growth for the first year. For older and more mature plants, growth begins early, when most danger of frost is past. For most of its range, that growth begins in April.

Echinacea purpurea and *E. laevigata* have spreading, fibrous roots that are not as deep or as large in diameter as other *Echinacea* species. These two species benefit from additional soil moisture and are easier to transplant, which may explain why *E. purpurea* is a favorite for gardens and cultivation.

Echinacea angustifolia is anchored in the soil by a deep and large taproot (up to 1 inch in diameter) that is almost woody and can grow 5.5–8 feet deep (Weaver and Fitzpatrick 1934**).** Taproot species can resprout from roots. This is not a form of reproduction but, rather, a method of sustaining the plant. In Kansas where diggers harvested the top 6 inches of *E. angustifolia* roots with a pickaxe, 25% of roots resprouted the first year after harvest, and up to 35% had resprouted by the second (Hurlburt 1999).

Echinacea reproduces only by seeds in the wild, and only a small percentage of the seeds that mature in the fall germinate. In the wild, seedlings grow slowly, sometimes requiring 3 years for the small rosette of basal leaves to put forth a flower stalk (Weaver and Fitzpatrick 1934).

By May, plants begin to bloom in Texas and by the middle of June, plants throughout Kansas and the genus midrange are flowering. In the northern reaches of its range (i.e., Montana and Saskatchewan), echinacea will flower into August. In any given year, the majority of mature plants do not bloom, but it appears that the healthiest plants will bloom during most good years.

Flowering lasts about a month. Echinacea pollinators include a diverse mix of flying insects, including native bees, wasps and butterflies. Some rare butterflies such as Dakota skippers pollinate *Echinacea* species in the northern Plains while regal fritillaries pollinate them in the upper Midwest and central Plains. "Echinacea is an out-crosser, sharing pollen with other individuals for miles around, the spread of pollen limited only by large land features and the practical range of the pollinators" (Cech 2002). Where species ranges overlap, pollinators carry pollen from one species to another, and this may encourage the species crosses observed by McGregor (1968).

The sterile strap-shaped ray flowers have attractive colors ranging from pink to purple. An exception is *E. paradoxa* var. *paradoxa,* which is a yellow-flowered purple coneflower. The brownish-purple to maroon disk flowers are fertile, and the corolla expands into a fleshy bulb-like base, while the tube is cylindrical and has a 5-lobed erect limb (Hobbs 1989). Flowers bloom from the center of the cone outward, and the seeds mature later in the same order. Echinacea makes considerable quantities of relatively large but lightweight seeds. It may take 145,000 seeds to make one pound (Foster 1990). Individual cones can produce 100 or more seeds, and large healthy plants occasionally have more than one cone (flowering head) in the wild. An exception to this is *E. purpurea*, which makes several flowers each season.

Once fertilization is complete, ray flowers begin to fade, and the cone itself swells and becomes nearly round as the seed matures. The pointed receptacle spines protect the green seed, but when the seed ripens, it loosens in the cone head and begins to work its way out between the receptacle spines. By autumn, some of the seeds will ripen and scatter in the wind. The cones continue to open up over a period of months, allowing for dispersal when air is dry throughout the winter and even into the early spring. Although Echinacea seeds are considered to be gravity-dispersed, high winds across sparsely vegetated habitats can blow seeds considerable distances across rocky or crusty frozen surfaces. The rains and snows of winter leach germination-inhibiting compounds from the seed, and the oscillating temperatures of winter and early spring help break the dormancy (Cech 2002).

Echinacea's underground plant parts store food during the long period of winter dormancy and account for the rapid growth of the plants following their early awakening in the spring. Plants rapidly begin storing nutrients in their roots after flowering and seed development are complete and continue this process until they go dormant late in the fall. This is an important stage for the health of the plant.

Echinacea angustifolia is very drought tolerant. Across its range, wind movement is fairly constant and often high, which promotes water loss. The long strappy leaves and coarse hairs of the *E. angustifolia* plant protect it from excessive evapotranspiration. The deep taproot evolved to find water stored deep in the ground, often among large rocks. When conditions are too extreme, the plant will go dormant or the seeds will remain dormant, waiting for more conducive weather to germinate. *Echinacea angustifolia* seeds can remain dormant for a couple years, then germinate and grow (Cech 2002). Germination rates, as with many wild species, are low in the wild, well under 50% (Foster 1990).While many of the plants competing with *E. angustifolia* will be set back by fire (especially woody species), *E. angustifolia*'s deep roots are protected in the ground and are likely to reemerge, even after a hot fire, and continue to grow. Seedlings can also emerge after a fire, and seeds, too, will often survive a fire passing through the landscape.

Cech (2002) points out that "Echinacea is designed for life among grasses. This is evidenced by the root form (taproot) that utilizes a different soil horizon than do the grasses. The rosette springs from a cohesive crown, and the leaves push back the grasses and lay on top of them to photosynthesize, making room for the tall echinacea stalks. These stalks are in turn adapted to hold the flower and the seed out of direct competition with the grasses." (Cech 2002)

Echinacea species, with few exceptions, are remarkably free from disease. It is thought that the medicinal properties of echinacea may be due to secondary chemical compounds that defend the plant against insects. Despite these defenses, we have occasionally observed plants being denuded by tent caterpillars (in both Kansas and Montana), and we have occasionally seen root damage caused by root borer predation (in both Kansas and Montana as well; root borer predation is likely to occur throughout echinacea's range). The disease, aster yellows, is found in the wild, but rarely, occurring mostly in cultivated *E. purpurea.*

Basing her findings on 3 years of field data gathered from detailed plant population work in our study area in north-central Kansas, Dana Price Hurlburt (1999) calculated that wild *E. angustifolia* can live between 18 and 44 years. The longevity of these plants, their ability to produce significant numbers of seed in good years, and their ability to at least occasionally resprout if the root is damaged or dug, all allow for the continuation of wild populations.

Habitat

Echinacea species typically prefer full sun and well-drained soils. They are often found in thick patches on rocky sloping limestone or sandstone outcroppings in native habitats, although they also can occur in glades, barrens, and openings in forests (McGregor 1968). Under these conditions, they are usually found within a grass-dominated plant community. When growing among native grasses, echinacea roots utilize a deeper soil horizon than the grasses do, reaching several feet into the ground and thereby avoiding competition with the grasses.

In the Little Missouri National Grasslands of North Dakota, we surveyed grasses growing alongside *E. angustifolia* and found the dominant species to be needle-and-thread grass (*Stipa comata*), little bluestem (*Andropogon scoparius*), bluegrass (*Poa pratensis*, a non-native species), and side-oats grama (*Bouteloua curtipendula;* see the tables in the Baseline Monitoring chapter, in this volume). *Echinacea angustifolia* was the most common non-grass species, ranking fifth of all species in plant cover, indicating that it is the most dominant forb species in these habitats. Other dominant forbs and woody species measured in the dense *E. angustifolia* stands of North Dakota included creeping juniper (*Juniperus horizontalis*), prickly rose (*Rosa acicularis*), and golden aster (*Chrysopsis villosa*).

In Kansas, *E. angustifolia* stands were dominated by the following grasses: little bluestem (*Andropogon scoparius*,), big bluestem (*A. gerardii*), and side-oats grama (*Bouteloua curtipendula*). Although grasses dominate these plant communities, niche spaces exist for deep-rooted forbs such as echinacea. Important forbs in the Kansas sites were, in the following order of amount of cover, *E. angustifolia*, resinous skullcap (*Scutellaria resinosa*), and white aster (*Leucelene ericoides*).

Echinacea is a slow-growing plant in the wild, and seedlings can easily be crowded out by invasive, fast-growing taxa. Throughout the centuries, prairie fires have served *E. angustifolia* very well by removing trees and shrubby growth that would likely overcome native forbs if left unchecked.

Echinacea species with taproots (all species except *E. purpurea* and *E. laevigata*, which have fibrous roots) require well-drained soils. Because taproots can reach water and nutrients deep in the ground, these species are extremely drought hardy. Wild stands of echinacea have survived severe drought cycles through the centuries, but such conditions will seriously affect the production of seed size and viability. Species with fibrous roots are better adapted to poorly drained soils, making good use of surface moisture and nutrients (Cech 2002). Although echinacea can be found in a variety of soil types, rocky clay, sandy loam, and lime substrates are where large healthy populations will likely be found. *Echinacea* species generally prefer a pH between 6 and 7 (Cech 2002), but *E. angustifolia* and *E. pallida* tolerate more alkaline soil, while *E. paradoxa* and *E. tennesseensis* tolerate a more acid soil.

Distribution

The genus *Echinacea* has a wide distribution, extending from the Rocky Mountains to the Atlantic and from Texas and Florida up into southern Saskatchewan, Manitoba, and Ontario. The densest populations exist throughout the short- and mixed-grass prairies, extending to the edge of the tall-grass prairie (see Figures 1–7: range maps at http://www.kbs.ku.edu/people/staff_www/kindscher/echinacea/maps2.htm.

Echinacea’s wide, but patchy, distribution covers a range of moisture and temperature regimes, from central Texas, Georgia, and Alabama to frigid winters in North Dakota, Minnesota, and Canada. Most wild populations of echinacea occur on private property, based on herbarium records and observations. Throughout the northern Plains, many of these populations occur on cattle ranches. Some private hay meadows that are used only for hay production and are not grazed provide known habitat for *E. angustifolia*, *E. pallida,* and *E. atrorubens* in the eastern Great Plains and Midwest. The Nature Conservancy has protected numerous tracts with known populations of echinacea. Additionally, many tribal lands contain extensive stands of echinacea, including native prairie areas on the Osage, Potawatomi, Santee, Rosebud, Pine Ridge, Standing Rock, Ft. Berthold, Crow, Cheyenne, Fort Peck, and other Indian Reservations.

Public lands also provide important habitat for native populations of echinacea. National grasslands are known to contain *E. angustifolia* in a wide band stretching through the Great Plains states from Oklahoma to North Dakota, including the Thunder Basin, Little Missouri, Buffalo Gap, Oglala, Pawnee, Cimmaron, Commanche, Lyndon Baines Johnson, Rita Blanca, Black Kettle, and Kiowa National Grasslands. U.S. Forest Service lands contain several *Echinacea* species, notably *E. angustifoli*a, in the Custer National Forest, Black Hills National Forest, and the Nebraska National Forests, and other species are found in the Mark Twain, Ozark-St. Francis, and other National Forests.

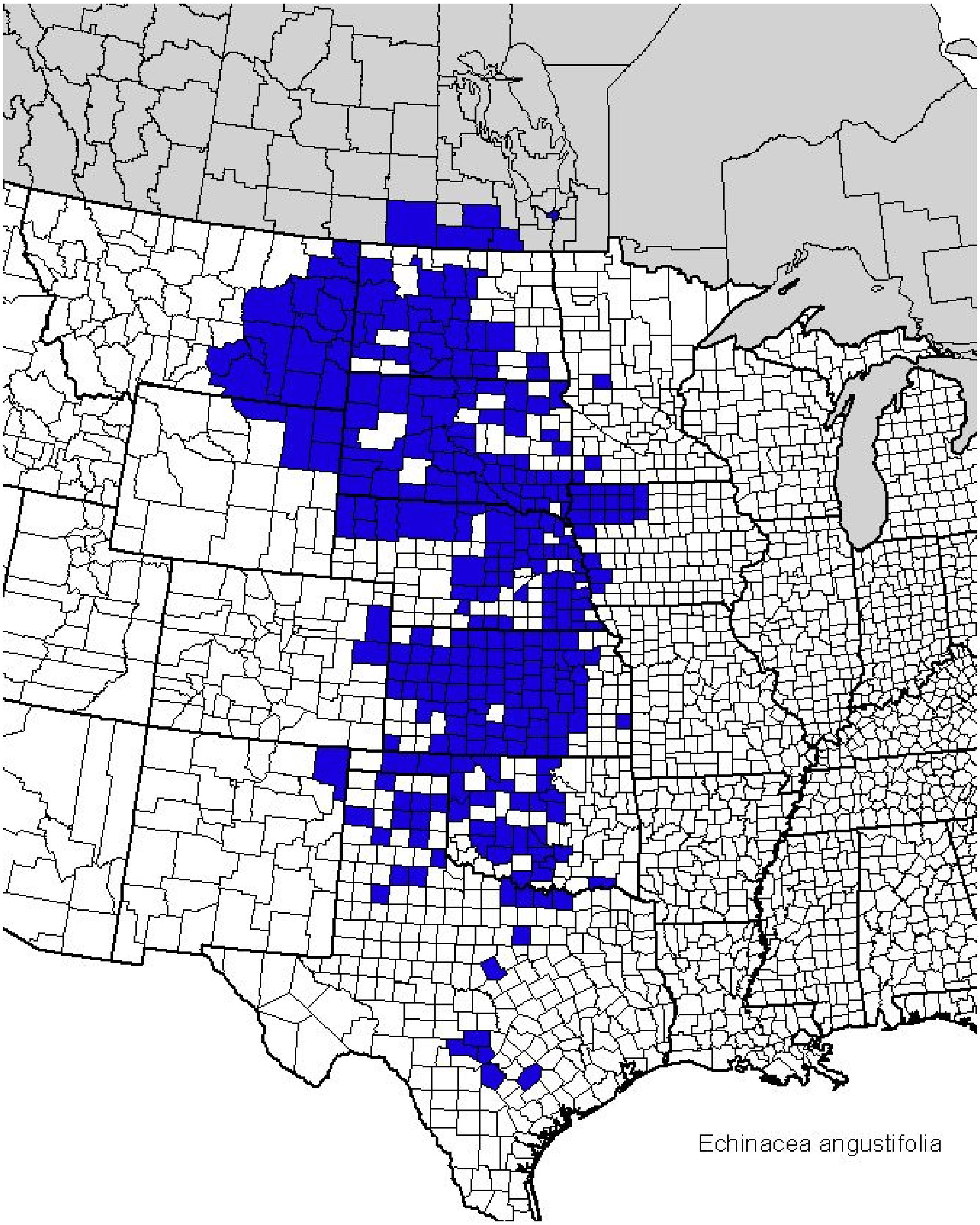
Specific Habitat and Range of *Echinacea* Species

The following is a short discussion of the specific habitat of each *Echinacea* species followed by a map of the known locations based on county records at herbaria. These maps reflect only locations from herbarium species where it could be verified, directly or indirectly, that the herbarium record was, in fact, the correct species. We primarily looked at herbarium specimens ourselves or obtained the expert opinion of other botanists. The three species used in commerce—*E. angustifolia*, *E. pallida*, and *E purpurea*—are discussed first, followed by the rest in alphabetical order.

Echinacea angustifolia

Echinacea angustifolia has the most northerly range of the Echinacea species, stretching from central Texas to southern Saskatchewan and Manitoba. It inhabits rocky and dry prairies, open woodlands, and glades and is often associated with a limestone substrate. This species will most often be found on sunny, well-drained, rocky outcroppings, hilltops, and southwest-facing hillsides. It is found in openings among ponderosa pine trees in the Black Hills of South Dakota, Custer National Forest in Montana, and other ponderosa pine stands throughout the northern plains. *Echinacea angustifolia* has a deep taproot, adapting well to dry conditions.

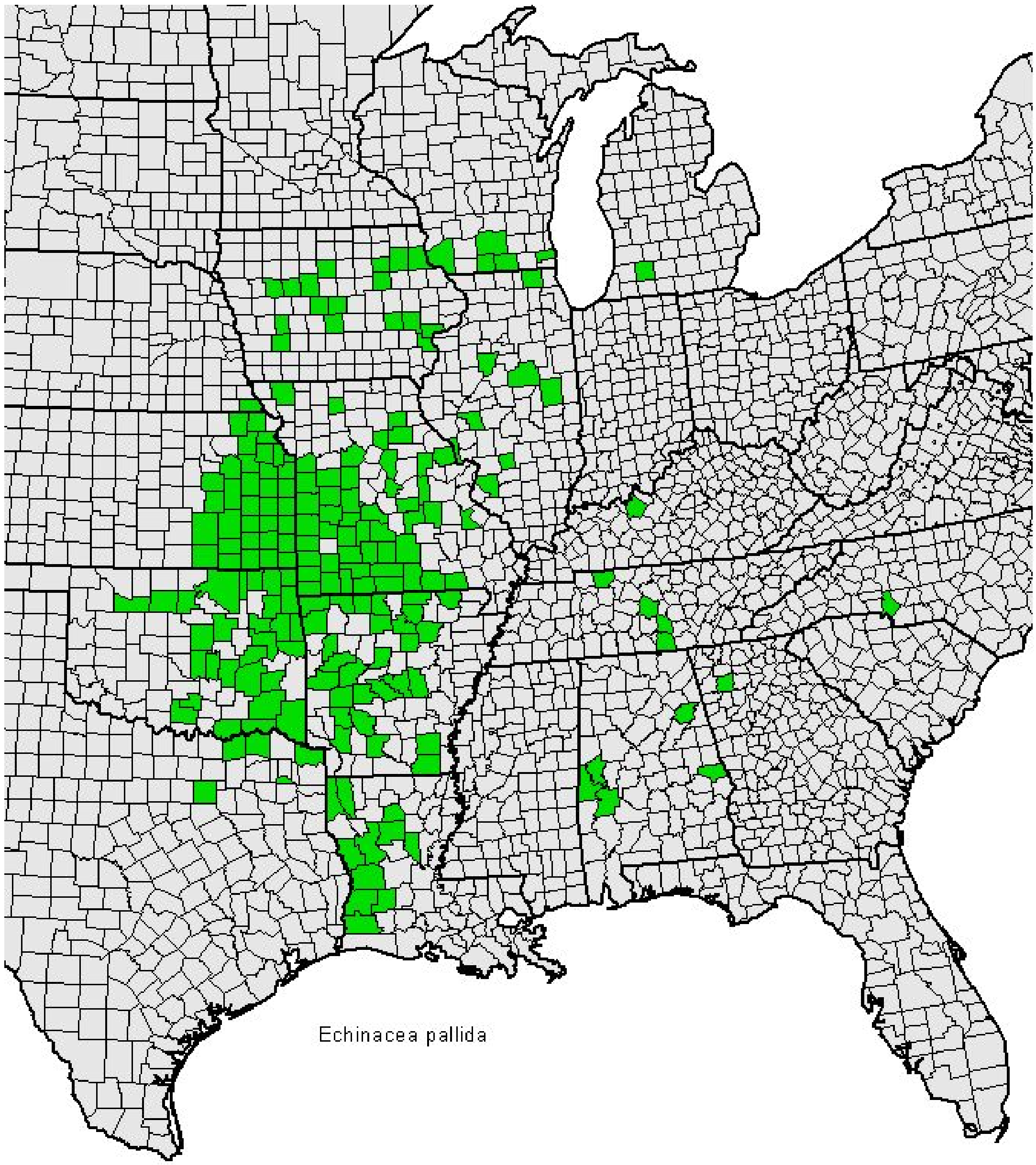
Figure 1. Range of *Echinacea angustifolia*



Echinacea pallida

Echinacea pallida occurs just east of the range of *E. angustifolia* in rocky or deep-soil prairies, woodlands, and glades. It becomes less common in the eastern parts of its range owing to less open habitat and the occurrence of other *Echinacea* species. It is most abundant in sunny, well-drained prairies.

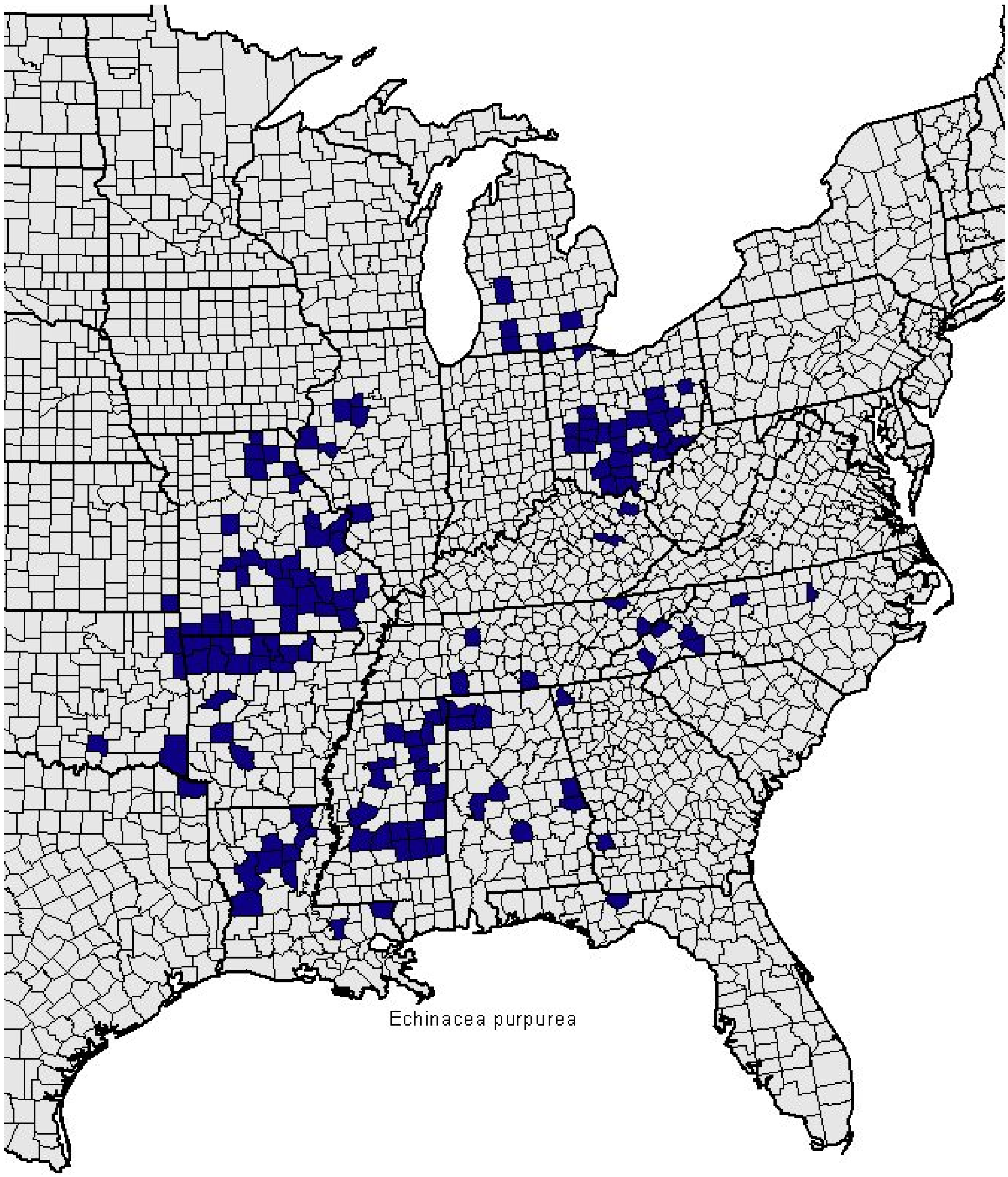
Figure 2. Range of *Echinacea pallida*



Echinacea purpurea

Echinacea purpurea inhabits open woods and prairies and is sometimes found in lowland riparian areas, which are also often partially shaded. This species has a fibrous root and can tolerate wetter soils. It also has larger leaves, making it more adapted for habitats with less light. For these reasons, home owners and gardeners do well growing it.

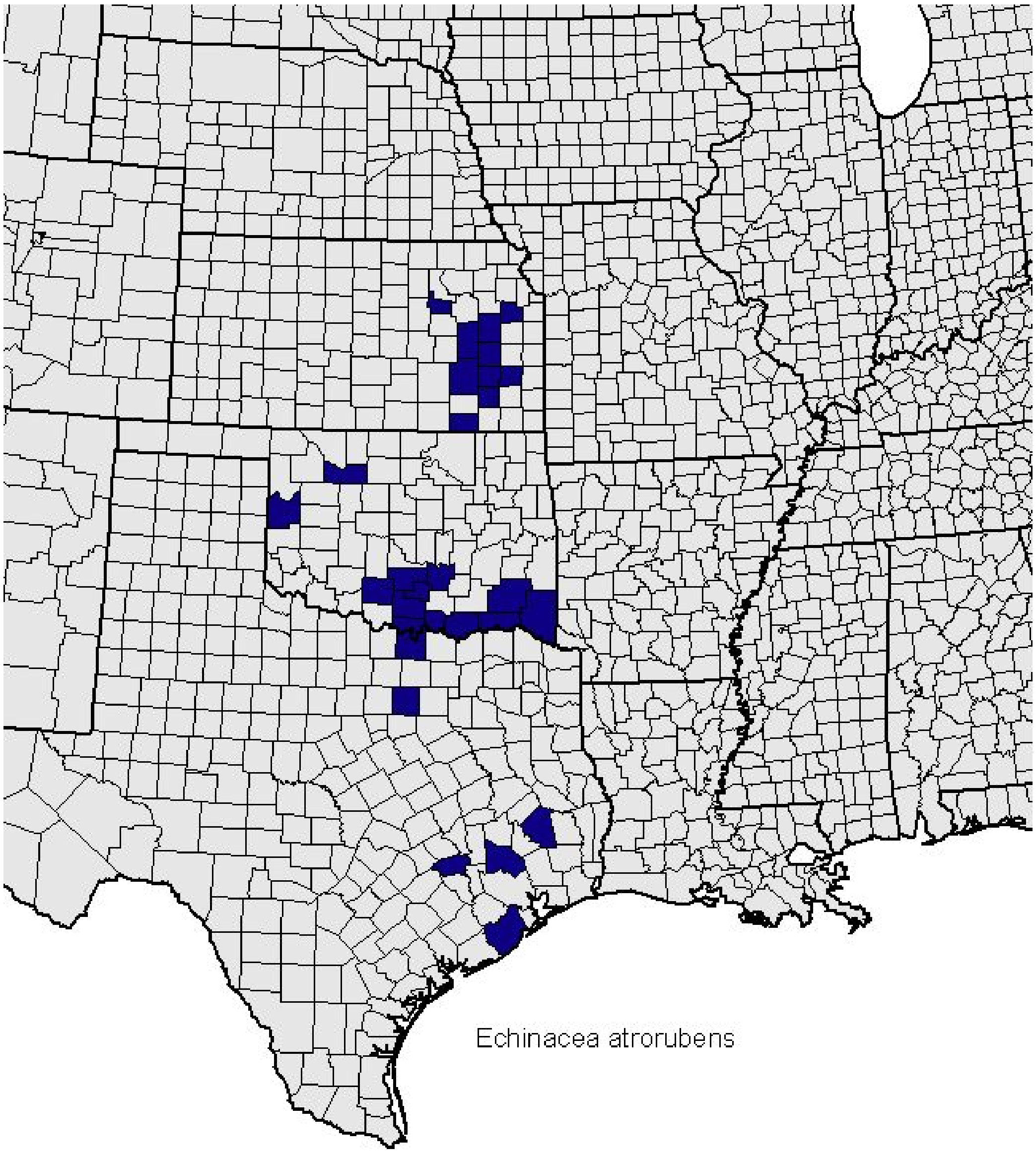
Figure 3. Range of *Echinacea purpurea*



Echinacea atrorubens

Echinacea atrorubens occurs in prairies and open woodlands in both deep soils and rocky habitats in a very narrow range from Texas to Kansas.

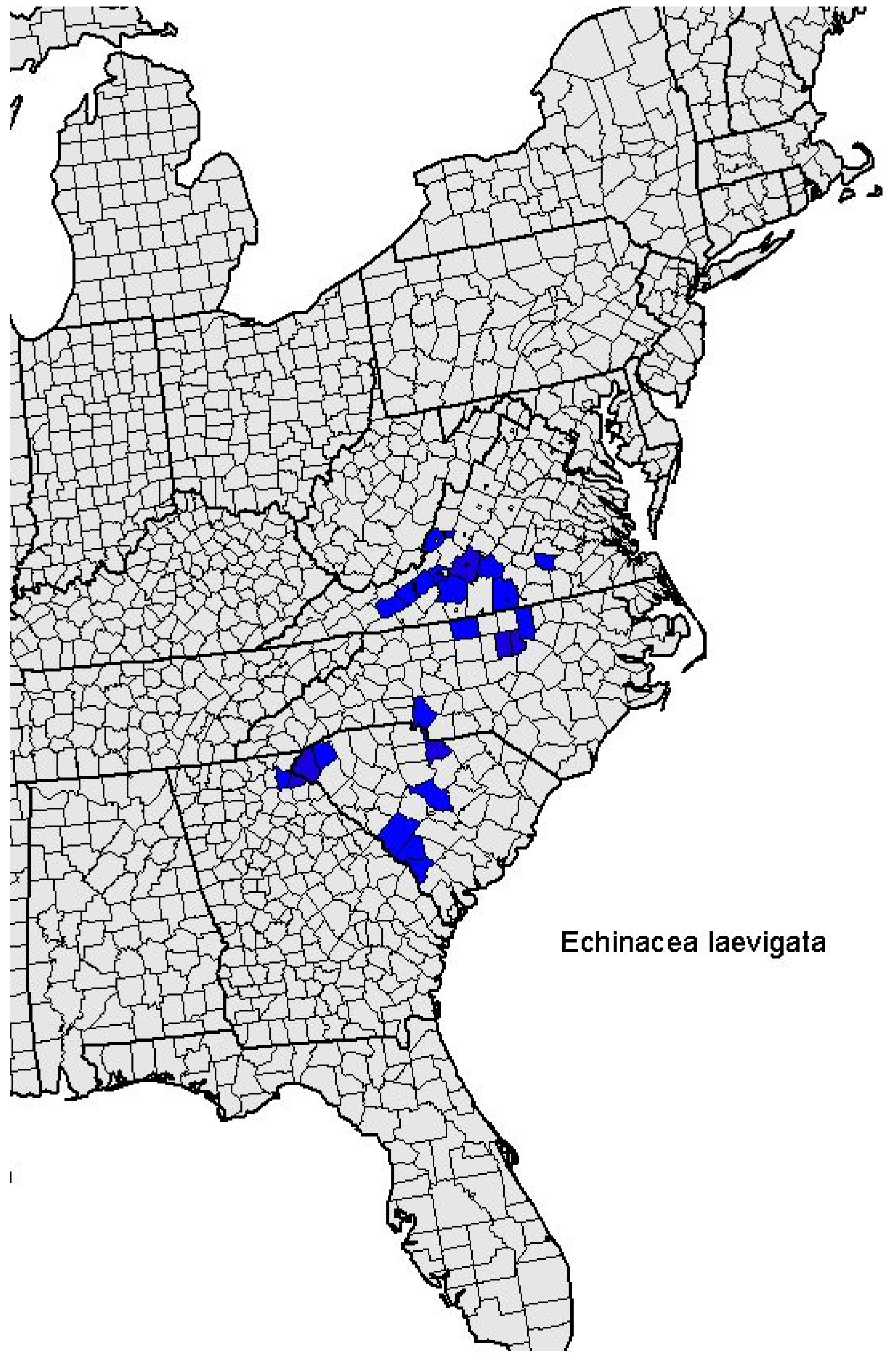
Figure 4. Range of *Echinacea atrorubens*



Echinacea laevigata

Echinacea laevigata is known from only 20 recorded occurrences from Virginia to Georgia at the eastern edge of the range for the species complex. It is found in open woods, cedar barrens, grassy glades, and bluffs. Open habitats in these states have been lost due to suppression of fire and habitat alteration. Because of its imperiled status, *E. laevigata* was listed as endangered under the Endangered Species Act in 1992 (U.S. Fish and Wildlife Service 1995).

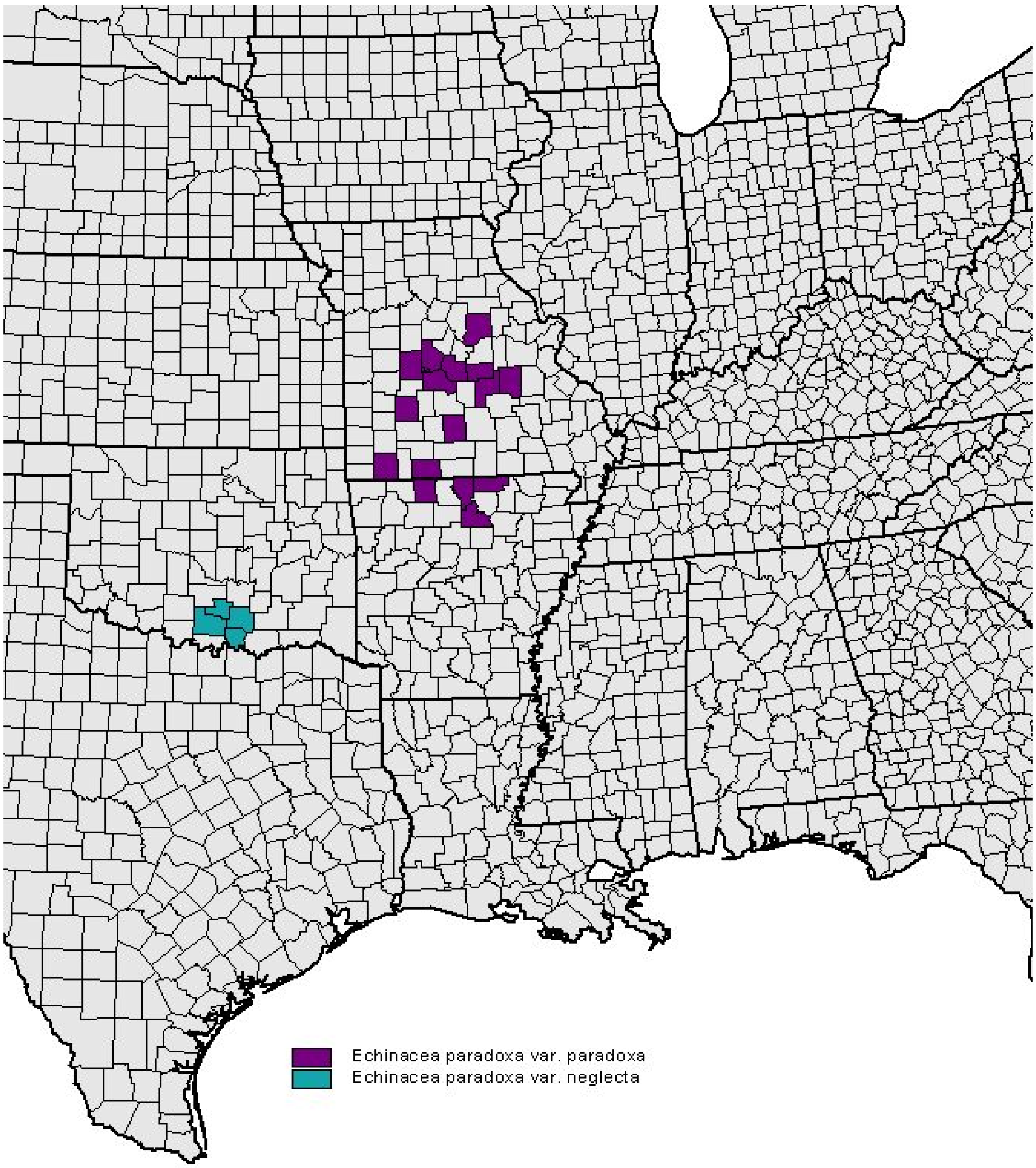
Figure 5. Range of *Echinacea laevigata*



Echinacea paradoxa

This species has two distinct varieties. *Echinacea paradoxa* var. *paradoxa* is found in glades, on bald knobs, in open woods, and in rocky prairies in the Ozarks of Arkansas and Missouri. *Echinacea paradoxa* var. *neglecta* is found only in the Arbuckle Mountains of southern Oklahoma, where it is found in prairies, on granitic outcrops, and in woodland openings.

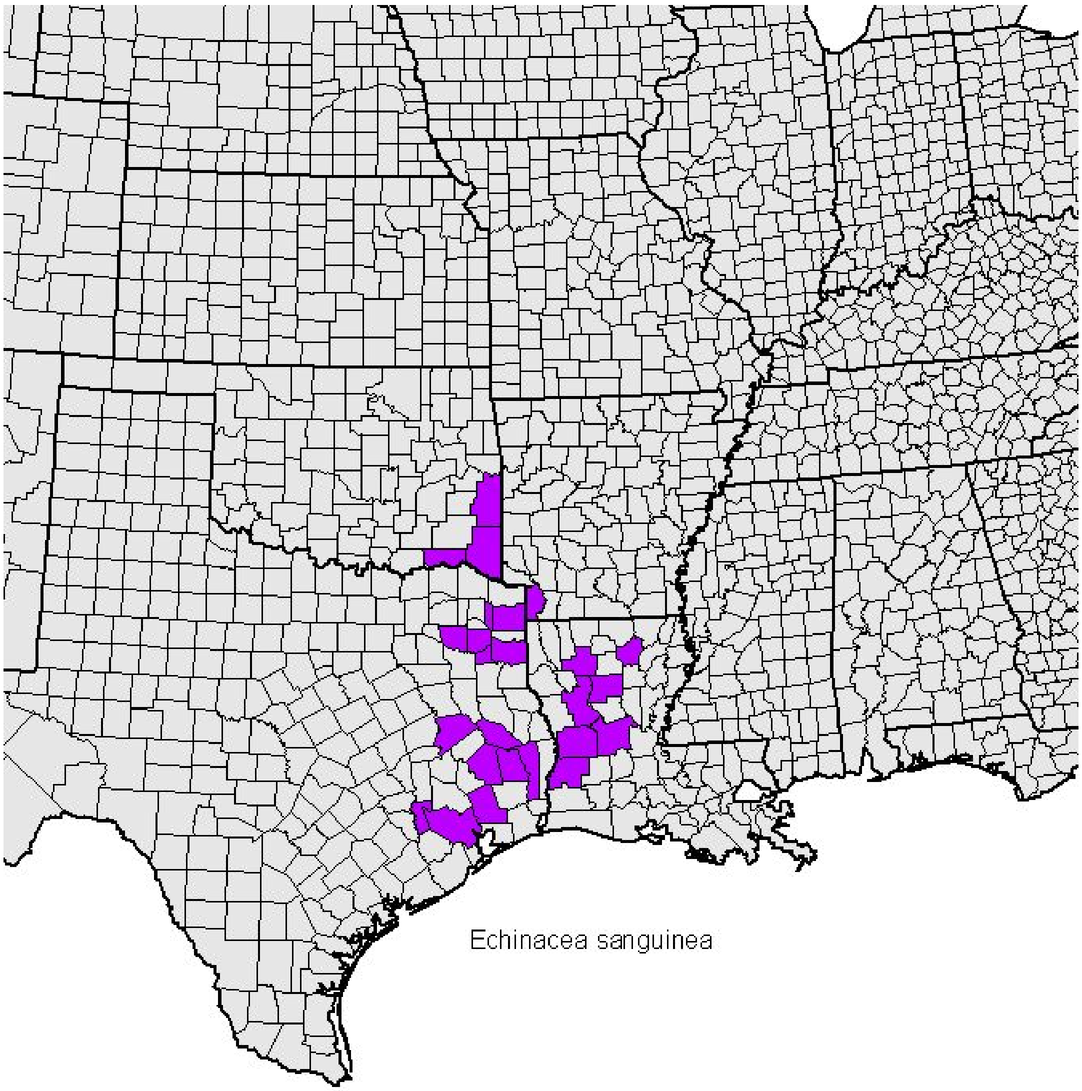
Figure 6. Range of *Echinacea paradoxa*



Echinacea sanguinea

Echinacea sanguinea has the most southern range of all *Echinacea* species and is found in open sandy fields and pine woods.

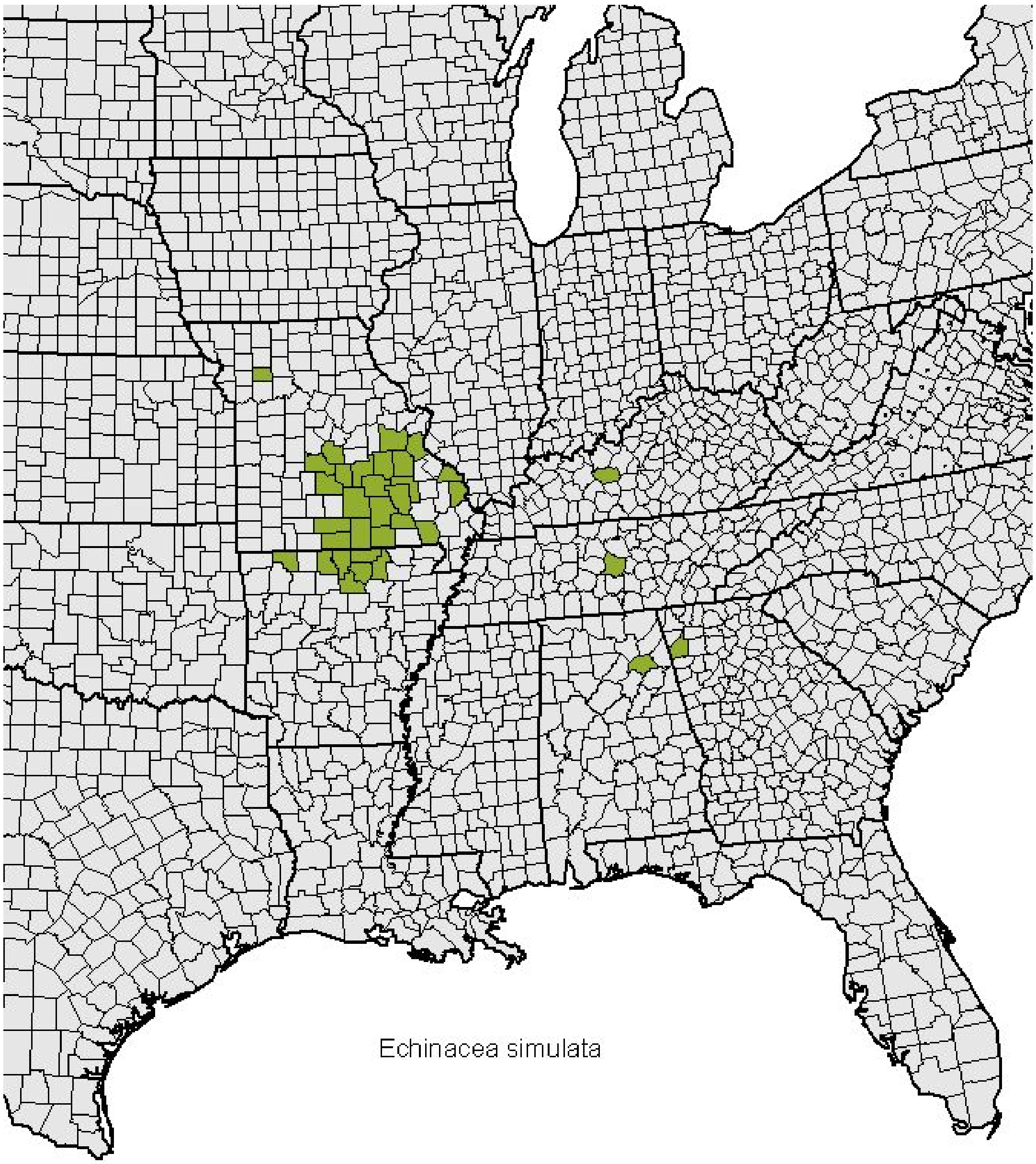
Figure 7. Range of *Echinacea sanguinea*



Echinacea simulata

Echinacea simulata occurs in prairies and rocky open woods.

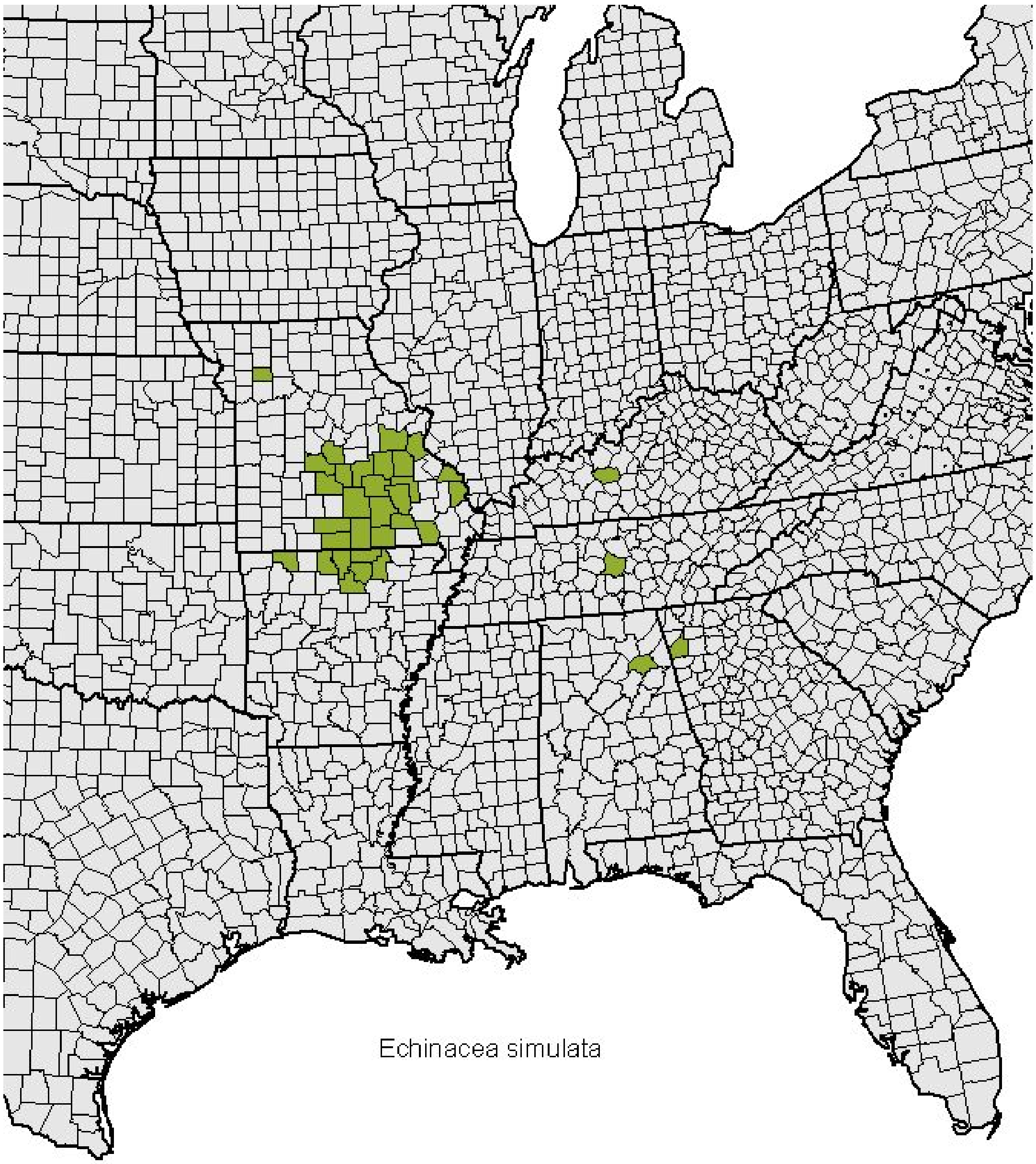
Figure 8. Range of *Echinacea simulata*



Echinacea tennesseensis

Echinacea tennesseensis is known from only five locations in the Central Basin of Tennessee. It is found in open limestone cedar glades and in deep-soil, calcareous barrens. U.S. Fish and Wildlife Service (1989) listed *E. tennesseensis* as endangered under the Endangered Species Act in 1979 (1989).

Figure 9. Range of *Echinacea simulata*



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The Uses of *Echinacea angustifolia* and Other *Echinacea* Species by Native Americans in the Great Plains

By Kelly Kindscher

The purple coneflower, *Echinacea angustifolia*, has been the most widely used medicinal plant of the Plains Indians in North America (Kindscher 1989, 1992). It has a large number of common names and Indian names (See Table 1). It has been used for a variety of ailments, including toothache, coughs, colds, sore throats, snakebite, and as a painkiller. In the Native American healing system, the uses of any plant, such as echinacea, are grounded in a religious or spiritual context. Spiritual forces, coming through the plant, are the healing agent, rather than the chemicals of modern Western science. Although the vast majority of medicinal plants that Native Americans have used within the region have pharmacologically active substances (Kindscher 1992), these plants have not been used by Native Americans for the sole purpose of benefiting from active ingredients. Rather, these plants, and others, are primarily used for their spiritual healing properties.

The use of *Echinacea angustifolia* by Native Americans is not just a historical practice. It is still being harvested and used traditionally today on many reservations. The author has observed its use on the Rosebud Sioux Indian Reservation in South Dakota. On the Fort Peck Indian Reservation in Montana where *Echinacea angustifolia* is still being used traditionally, there is great concern that it is being over-harvested for the herbal product trade (Kolster, 1998).

The history of North American settlement by Europeans is a history dominated by the lack of interest in or antagonism toward traditional practices. The traditional medicinal plant use of Native Americans was contained within a spiritual worldview that was very foreign to Europeans. Soon after contact, conflicts emerged between those of European heritage and Native

Americans. These conflicts ultimately resulted in much of Native American culture being stripped away and most tribes being forced to give up their lands and settle on reservations. Often these reservations were not part of their homelands, where their familiar medicinal plants grew. Travelers, traders, and early doctors seldom took the opportunity to learn about medicinal plant resources from Native Americans. This occurred for a variety of reasons including warfare, attitudes of cultural and scientific superiority, inability to communicate because of language problems, and different spiritual and cultural practices. Ethnobotany (the study of cultural use of plant materials) is a relatively new science, so unfortunately there has been little funding in the past (or currently) for this endeavor. Most especially in the Great Plains, many tribes that used echinacea were never encouraged to share what they know. Because of this situation, there is relatively little ethnobotanical information on how echinacea species were used for medicine among Native Americans. Specifically, we know little about the lesser-known echinacea species uses (Kindscher, 1989; Foster, 1991). In addition, we know very little about traditional harvest methods, management, preparation, and dosage.

The ethnobotanist Melvin Gilmore reported in 1917 that the macerated root of the purple coneflower (method of preparation and dosage not given) was "used as an antidote for snake bite and other venomous bites and stings and poisonous conditions" by all the Indians of the Upper Missouri River region (Gilmore, 1977). In addition, these Indians used the purple coneflower "for more ailments than any other plant" (Gilmore, 1913a). The Dakota (Sioux) used the freshly scraped root as a remedy for hydrophobia (rabies), snakebite, and situations where a wound had putrefied (Smith, 1928). They applied the root (probably ground up) for its "feeling of coolness" to areas of inflammation to relieve the sensation of burning (Gilmore, 1913b). The Lakotas (Sioux) used the root and green fruit for relieving thirst or perspiration and also as a painkilling remedy for toothaches, tonsillitis, bellyache, and pain in the bowels (Rogers, 1980; Munson, 1981). The Lakota on the Standing Rock Reservation use the powdered root for toothache and as a poultice for wounds and sores (Left Hand August, as cited in Kraft, 1986). During visits to the Rosebud Reservation in South Dakota over the last 12 years, the author learned that the purple coneflower is still widely harvested by the Lakotas for a variety of medicinal uses.

The Omahas recognized two kinds of purple coneflower: *nuga* ("male"--being larger and having other masculine characteristics) and *miga* ("female"--being smaller and a more efficient medicine; Gilmore, 1913a). The Omahas used some parts of the plant (identified as *Echinacea pallida*, but probably *E. angustifolia*, see discussion by Baskin *et al.*, 1993, 1994) for sore eyes, and medicine men applied the macerated root as a local anesthetic so that they could remove pieces of meat from a boiling pot without flinching. This practice indicated to others their ability to perform supernatural feats. A Winnebago medicine man also used it to make his mouth insensitive to heat so that he could take a live coal into his mouth to demonstrate his power (Gilmore, 1977). Both of these feats helped to create confidence in the human ability to heal.

The Kiowas have used the purple coneflower root as a cough medicine since prehistoric times. In the 1930s, they still used the dried seed head as a comb and brush (Vestal and Schultes, 1939). The Kiowas and the Cheyenne treated colds and sore throats by chewing a piece of the purple coneflower root and letting the saliva run down the throat (Vestal and Schultes, 1939; Grinnell, 1962). The Kiowa-Apache used a little piece of the root and stuffed it into the cavity of an aching tooth or pounded it to use against a sore gum or tooth like a poultice (Jordan, 1965). They dug the roots at any time of the year, but the plants were most easily located in the summer when they were in bloom or shortly thereafter. A year's supply of roots would then be dug and dried. Dried roots were supposedly more potent than fresh ones, though either could be used (Jordan, 1965).

The Cheyennes used the purple coneflower as a remedy for sore mouth and gums. They made a tea from the leaves and roots; sometimes it was powdered first (Grinnell, 1962). This liquid was also rubbed on a sore neck to relieve pain. Toothache was relieved by letting this liquid contact the cavity. The root was chewed to stimulate the flow of saliva, which was especially useful for Sun Dance participants as a thirst preventative (Hart, 1981).   The Cheyenne also drank a purple coneflower tea for rheumatism, arthritis, mumps, and measles. A purple coneflower salve was made for external use in treating these ailments. When the roots were mixed with blazing star (*Mentzelia laevicaulis*) and boiled, the resulting tea was drunk to relieve smallpox. When purple coneflower roots were mixed with puffball (*Lycoperdon* species) spores and skunk oil, they were used to treat boils.

Edwin Denig lived at Fort Union along the Missouri River in Montana for 21 years during the mid-1800s and came to know the Assiniboine people well. In discussing their medicine, he reported that the purple coneflower was their most important medicinal plant:
"The principal of these is the black root, called by them the comb root, from the pod on the top being composed of a stiff surface that can be used as a comb. It is called by the French *racine noir*, and grows everywhere in the prairie throughout the Indian country. It is chewed and applied in a raw state with a bandage to the part affected. We can bear witness to the efficacy of this root in the cure of the bite of the rattlesnake or in alleviating the pain and reducing the tension and inflammation of frozen parts, gunshot wounds, etc. It has a slightly pungent taste resembling black pepper, and produces a great deal of saliva while chewing it. Its virtues are

known to all the tribes with which we are acquainted, and it is often used with success." (Denig, 1930)

As this passage indicates, French trappers and traders were probably aware of the medicinal qualities of the purple coneflower.

Other tribes that lived in the Great Plains and the Tallgrass Prairie region to the east used the native purple coneflower. Among these tribes were the Crows, Hidatsas, Comanches, and Pawnees. The Crows chewed the root for colds and drank a tea prepared from the root for colic (Hart, 1976), and on the present-day Crow Reservation in Montana, traditionalists describe *E. angustifolia* as having the "greatest medicinal value of all plants (Snell, as cited in Kolster, 1998). Hidatsa warriors chewed small pieces of the root as a stimulant when traveling all night (Nickel, 1974). The Comanches used the root for treating sore throat and toothache (Carlson and Jones, 1939). The Pawnees also used the root for medicinal purposes (Gilmore, 1977). Roots excavated from one of their earthen lodge villages (the Hill site, located near Guide Rock, Nebraska, and occupied around 1800) were identified as purple coneflower by Melvin Gilmore at the University of Michigan Ethnobotanical Laboratory (Wedel, 1936). H.C.F. Meyer, who introduced echinacea to the Lloyd Brothers Pharmacy, supposedly learned of its medicinal use from the Pawnee (Meyer, 1887; Foster, 1991).

Echinacea species were also used outside of the Great Plains. An Indian from Mexico, who served as a translator for Melvin Gilmore when he was interviewing the Lakotas on the Pine Ridge Reservation in South Dakota in 1912, indicated that the purple coneflower was used by his people for snake bites (Gilmore, 1913b). The native distribution of the purple coneflower does not extend into Mexico. Its use in Mexico may indicate a history of trade for this root between tribes of the southern portion of the Prairie Bioregion and Mexico or that species used similarly were also found in Mexico.

The Meskwaki or Fox used the plant (probably *E. pallida*, rather than *E. angustifolia*), along with the roots of wild ginger (*Asarum canadense*), flowering spurge (*Euphorbia corollata*), and beebalm (*Monarda punctata*) as part of a medicinal cure for stomach cramps (Smith, 1928). Their name for the plant translates as “smells like a muskrat scent” or “widow’s comb” (to comb the hair; Smith, 1928).

The use of *E. purpurea* is recorded for the Delaware in Oklahoma in 1942 (Tantaquidgeon, 1942, as cited in Shemluck, 1982) and for the Choctaw (Campbell, 1951). The Choctaw use was recorded by a self-taught physician and trading-post operator, Gideon Lincecum, who lived in Mississippi and Georgia between 1800 and 1835 and made herbarium specimens. He reported:

> “The tincture of the roots of this plant has been used with success in bad cough, and dyspepsia attended with a bad cough. . . The Choctaws use it for the above purposes, by chewing and swallowing the saliva. They keep a small piece of the root in the mouth nearly all the time, continuing its use for a long time” (Campbell, 1951).

As mentioned previously, echinacea use is not just a historical phenomena. Many tribes in the Great Plains are still actively using it for medicine. There has been little recent effort to learn about those practices, although the work of Kolster (1998) is one recent exception. For this to be remedied, funding for research and sufficient time for traditional learning opportunities are needed. Most Native American people still have great qualms about sharing their knowledge and often feel that it is inappropriate to share it for published resources because it could be taken out of context. As mentioned previously, the Native American health and healing system does not separate spirit from substance. Medicinal plants need to be gathered and prepared properly (usually with prayers and ceremony) to be effective. Nonetheless, ethnobotanists have much to learn, and the entire context of echinacea’s uses can be appropriately shared and understood if the sharing can be done within a context of respect. This provides an opportunity for Native Americans and ethnobotanists (of any heritage) to develop ways to collaborate. Considering the great importance of the use of echinacea and the wealth of information still unknown by ethnobotanists of its traditional use, Native American knowledge about echinacea is still an untapped resource.

Table 1: Names for *Echinacea* species (Kindscher 1992)

Common Names:

Purple coneflower, echinacea, snakeroot, Kansas snakeroot, black sampson, narrow-leaved purple coneflower, scurvy root

Indian head, comb flower, black susans, hedge hog (in reference to round, black, spiny seed head)

Indian Names:

mika-hi, “comb plant” (Omaha and Ponca)

inshtogahte-hi (Omaha and Ponca): inshta means “eye, reference to use as an eye-wash

ksapitahako, “hand, to whirl” (Pawnee): reference to child play

saparidu hahts, “mushroom medicine” (Pawnee): reference to shape of seed head (similar to mushroom)

ica’hpehu, “something used to knock something down” (Lakota)

on’glakcapi, “something to comb the hair with” (Lakota)

shika’wi (Meskwaki)

wetop, “to comb the hair” (Meskwaki)

ashosikwimia’kuk, “smells like muskrat scent” (Potawatomi)

o.hicise’ ize, “tooth-gum medicine” (Kiowa-Apache)

ize. iso. he., “medicine makes you numb” (Kiowa-Apache)

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One Hundred Years of *Echinacea angustifolia* Harvest in the Smoky Hills of Kansas, USA

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The popular medicinal herb echinacea led a dramatic expansion of the U.S. herbal products market from 1994 to 1998. During this time medicinal plants, sold as herbal products in the United States, expanded out of their specialty niche in health food stores to reach the mass market. In the process, sales of herbal products grew from U.S. $360 million per year in 1981(Tyler 1986) to $1.6 billion in 1994 (Brevoort 1996) and $3.87 billion in 1998 (Brevoort 1998). Despite a downturn from 1999 to 2000, herbal products had sales of about $4.13 billion in 2000 (Blumenthal 2001b). Echinacea accounted for about 9% of this market and was the top-selling medicinal herb in the United States, with retail sales totaling approximately $320 million in 1997 (Brevoort 1998).

Echinacea (family Asteraceae) is a genus of herbaceous perennials endemic to tall- and midgrass prairie and glade habitats and open woodlands of North America (McGregor 1968; Binns *et al.* 2002; Urbatsch *et al.* 2005). Three of the nine species in the genus are important in commerce: *Echinacea purpurea* (L.) Moench, *E. pallida* (Nutt.) Nutt., and *E. angustifolia* DC. Because it is easy to grow, *Echinacea purpurea* use has been predominantly from cultivated sources (McGuffin 2001). *E. pallida*, *E. angustifolia*, and other uncommon species in the genus have been harvested primarily from the wild, with the majority of wild harvest being *E. angustifolia* (Foster 1991; Fuller 1991; McGuffin 2001). For these and other wild-harvested medicinal species in commerce, concerns are increasing regarding the sustainability of supply.

Trade in wild-harvested ("wildcrafted") medicinal herbs is culturally and economically important, yet its effects on wild populations are not well understood. The long-term economic or ecological sustainability of commercial harvest of even well-known wild-harvested plant products has received little study (Godoy and Bawa 1993; Hall and Bawa 1993; Balick and Cox 1996). Commerce in wild plants, with the exception of those listed under the Convention on International Trade in Endangered Species (CITES), is seldom tracked by U.S. federal or state agencies. Only five of the 175 native North American plant taxa in commerce are listed under CITES (Robbins 1998). The tonnage of plants harvested and the value of this trade have been quantified for few species. Examples of important medicinal plant harvests from the United States include goldenseal (*Hydrastis canadensis;* Bannerman 1997), with 1998 wild harvest of 117,300 kg (McGuffin 1999); saw palmetto (*Serenoa repens*), harvested for export in quantities possibly exceeding 6,800,000 kg annually (Bennett and Hicklin 1998); and American ginseng (*Panax quinquefolius*), with annual exports of 60 metric tons of wild material (Dreyfuss 1999) despite its large cultivated supply. Wild *Echinacea angustifolia* root harvest in 1998 was over 90,000 kg (McGuffin 2001).

The vast majority of sustainable-use studies have concerned forest products, especially in the tropics. Wild-harvested plants of North American grassland habitats have received little study, with the notable exception of Anderson's (1993, 1996, 1997) and Anderson and Downey's (1999) work with food and fiber plants used by indigenous peoples of California. *Echinacea angustifolia*, native to the tall- and midgrass prairies of North America, has been commercially harvested for its medicinal properties for over 100 years. The threat of overharvesting has been a concern throughout its 100-year commercial history. Nonetheless, like other wild-harvested medicinal herbs, the impact of harvest on plant populations has never been quantified or associated with actual practices used by the harvesters, or "diggers."

Echinacea's 100-year history of harvest

Although echinacea was one of the most important medicinal plants used by indigenous people in the Prairie Bioregion (Gilmore 1977), the details of its traditional method of harvest are not well known (Kindscher 1989). *E. purpurea* was the earliest echinacea species to be mentioned in Euro-American medical botany (Foster 1991; Flannery 1999). *E. angustifolia* was introduced to medical use in 1885 by the folk doctor H. C. F. Meyer of Pawnee City, Nebraska. Meyer sent a sample of his "Meyer's Blood Purifier" to prominent Eclectic physician John King (King 1887). The corresponding botanical sample, sent to the Lloyd Brothers Pharmacists in Cincinnati, Ohio, was determined to be *E. angustifolia* (J. U. Lloyd 1917; Foster 1991). King conducted therapeutic trials and became convinced of the plant's value; shortly thereafter, the Lloyd Brothers began manufacture of *E. angustifolia* preparations (J. U. Lloyd 1904, 1917). By 1897, the plant was well established among the Eclectics, a group of physicians who emphasized the use of medicinal plants in their practice (J. U. Lloyd 1897). Also widely used by "regular" doctors, *E. angustifolia* was the most-prescribed medicine made from an American plant through the 1920s (Foster 1991). Its use subsequently declined with the introduction of sulfa drugs and antibiotics (Foster 1991; Flannery 1999). However, since the 1980s, the resurgence of herbalism in the United States and Europe has brought a renewed interest in echinacea. The passage of the Dietary Supplement Health and Education Act of 1994 initiated the expansion of herbal products including echinacea into the mass market. It was the best-selling medicinal herb in health foods stores in the United States from 1995 to 1999 (Richman and Witkowski 1996, 1999; Johnston 1997, 1998a) and was also in the top 3–5 selling herbs in the mass market during this time (Johnston 1998b; Blumenthal 2000).

Conservation concerns and harvest practices: gaps in understanding

With echinacea's increased popularity have come warnings from the botanical and conservation community that its commercial exploitation is unsustainable. Only a few years after its introduction to the medical profession, concern was expressed that the quantity harvested exceeded the plant's ability to regenerate (Sayre 1903). Decades later, McGregor (1968) noted declines in *E. pallida* populations in Eastern Kansas. Foster (1991) documented large harvests of uncommon echinacea species, *E. paradoxa* and *E. simulata,* in the Ozarks. Poaching in protected stands and overcollecting have been reported in Missouri (Missouri Department of Conservation 1998; Trager 1998) and Oklahoma (Boyd 1997; Lantz 1997). A "gold rush" of unethical harvesting has affected North Dakota (Crawford 1998, 1999) and Montana (Kolster 1998; Kolster and Youpee 1998; Klein 1999).

While these observations are compelling, they are insufficient to determine how harvesting affects populations over time. To understand the impact of harvesting more fully, it is important to observe and quantify the actual harvest and management practices used (Anderson 1993, 1997; Joyal 1996). It is essential to learn from harvesters both how they work and what they understand about the plant's growth and ecology. This ethnobotanical approach leads to understanding why diggers operate as they do and what economic realities they face. These insights will enable the conservation community to place harvesting within the context of other threats to the species' persistence.

Echinacea angustifolia is unique among major native North American medicinal plants in that it is native to the prairie rather than the forest and occurs in extensive populations on a landscape scale. In contrast to the medicinal plants that are forest herbs, such as ginseng and goldenseal, *E. angustifolia* still may be common over much of its historic range despite a long commercial harvest (the NatureServe global Heritage status rank is still G4, “apparently secure”, although it is reported as declining to an unknown extent; NatureServe 2005). In this study, our objectives were to (1) learn from harvesters about their methods of harvest and views regarding its sustainability; (2) compile historical information about the trade in echinacea roots; and (3) identify factors that may contribute to sustainability and to apply this information to conservation of wild populations.

METHODS

Study area

The study was conducted from 1996 to1998 with a follow-up visit in 2002. Our study area was in north-central Kansas, in Rooks County and adjoining counties (39º05’–39º34’N, 99º00'–99º30'W). This area was chosen for its 100-year history of *E. angustifolia* harvest because it was an area of continued commercial activity during the study and because it is likely the area of greatest wild echinacea harvest during the past century. The study area is in the Smoky Hills physiographic province and contains large areas of mixed-grass prairie rangeland that provides habitat for *E. angustifolia*. Detailed information on the study sites is given in Hurlburt (1999).

Historical research

While the history of *Echinacea angustifolia’s* medicinal use is well documented, less is known about its commercial history. We reviewed published literature and unpublished correspondence from ca. 1890 to 1920, the period of *E. angustifolia’s* introduction to the medical profession and popularization. The historical literature has been previously summarized (Kindscher 1989; Foster 1991; Hobbs 1995; Flannery 1999). Unpublished correspondence was obtained from the Kansas Historical Society and from the Lloyd Library, Cincinnati, Ohio (Hurlburt 1999).

To obtain local history, we interviewed four older residents of Rooks County who had been involved in the "root" trade since their youth (Mr. Kenton Lawson, Mrs. Sandy Lawson, Mr. Ivan Thrasher, and Mr. Thornton Sanders), and three others who were second- or third-generation harvesters (Mr. Pat Thrasher, Mr. Pat Thayer, and Mr. T. Houser). Pat Thrasher was the major buyer of *E. angustifolia* roots in Stockton, Kansas, during the time of the study. Initial interviews were conducted in March 1996, and follow-up interviews took place in 1997–1998 and 2002.

Market information

To obtain quantitative information on the market in *E. angustifolia* roots, we first searched the historical literature and unpublished correspondence mentioned above. Interviews with older harvesters provided further information on root prices. Additionally, we obtained wholesale price quotes from the *Oil, Paint, and Drug Reporter,* which listed prices of echinacea from 1910 into the 1940s.

Contemporary information on the price and quantity of echinacea roots on the market came from various literature sources (McGregor 1968; Bare 1979; Brevoort 1998). Finally, during the course of our collaboration with buyer Pat Thrasher of Stockton, Kansas, we observed and discussed with him the variable market cycles experienced in the business. He summarized the prices and quantities of root sold from 1986 to 2002.

Harvest methods

We learned about harvest methods through semi-structured interviews with twenty harvesters, including those mentioned above. During interviews we inquired about harvesters' method of digging, motivation, and views on the abundance, life history, and resilience of *E. angustifolia.* To efficiently obtain qualitative information, we began by interviewing knowledgeable individuals who were easily identifiable following the techniques of Patton (1990). In our case we were interested in the specialized topic of root digging and specifically, dealers who advertised that they were buying roots. The harvesters with whom we consulted constitute a snowball sample, as outlined by Robson (1993), and generated a pool of respondents through referrals from the root buyer, other harvesters, landowners, and fortuitous meetings. It was difficult to survey harvesters systematically because many of them, responding to the fluctuating market for *E. angustifolia* roots, moved or changed occupations during the period of study.

We participated in echinacea root harvest on four occasions; two of these were commercial harvests. We used these occasions and others when we came upon diggers working, to confirm methods described by diggers.

RESULTS

History of the echinacea market in Rooks County, Kansas

Literature from the period of *Echinacea angustifolia's* introduction and popularization shows that north-central Kansas quickly became an important area of supply. The earliest published reference to *Echinacea* digging in the area is from the diary of Elam Bartholomew, a settler, botanist, and mycologist. In 1894 he records digging 45 kg (100 lbs) of "Echinacea roots for shipment to Lloyd Bros. wholesale druggists, Cincinnati, Ohio,, for which he received $25.00 (Bartholomew 1998). University of Kansas Professor L. E. Sayre (1897) called *E. angustifolia* "the most noteworthy plant growing abundantly in the state and of medicinal quality" and noted that echinacea "is only gathered in commercial quantities from the northwestern part of the state" (Sayre 1903).

Interviews with older-generation and second- or third-generation harvesters and buyers confirm that *E. angustifolia* harvest was established in Rooks County by 1900. One early buyer of medicinal roots, furs, wool and horses, Fred Lawson, set up shop in Stockton in 1895 or 1896 (K. Lawson, interview); his son's "Snakeroot Wanted" poster (ca. 1968) appears in Figure 1. The family's history in the trade was confirmed by other diggers. Among them is Thornton Sanders, who began digging *E. angustifolia* root with his father in about 1927 at age 10.

Writings from the period suggest that quality, abundance, and economic considerations were important in the establishment of commercial *Echinacea angustifolia* harvest in the Smoky Hills. Felter (1898) stated in the *Eclectic Medical Journal* that "the best quality of root comes from the prairie lands of Kansas and Nebraska." Sayre (1903), referring to the Smoky Hills extension area of soft limestone, stated that echinacea was harvested in commercial quantities from this part of the state because "the root thrives better in the rocky soil of that district." Finally, responses to the Lloyd Brothers' 1903 inquiries seeking suppliers emphasize that profitability and the cost of labor determined who would harvest roots. Several correspondents stated that the price offered was insufficient for a person to make a living by collecting echinacea in the rocky areas or thin stands of the Kansas Flint Hills, southeast Kansas, southwest Kansas and Oklahoma (DeMarr 1903; Lewis 1903; Cormack 1903; Moore 1903; Sharp 1903). For example: "The plant in this locality grows only on rocky land and stone ledges and the process of digging is very laborious, and the time required is out of all proportion to what you can pay" (Roberts [1903], writing from Manhattan, northeast Kansas). Affirmative responses to the Lloyd Brothers' inquiries came from Elk City, southeastern Kansas (Blank 1903), Webster and Burr Oak, Kansas, in the Smoky Hills (Oliver 1902; Kirk 1903), and Whitewater, Kansas, in the southern Kansas Flint Hills (Luddington 1903). Interestingly, these three areas have continued to experience echinacea harvest up to the present (*E. angustifolia* in the Smoky Hills and southern Flint Hills, and *E. pallida* in southeast Kansas).

History of market quantities and price

E. angustifolia has experienced periods of both intense and weak demand. A chronology of market and price information from all available sources is listed in Table 1 and is illustrated in Figure 2. Unfortunately, short-term changes in market demand are captured during only a few years for which data are available on a monthly basis. The price paid to diggers is a substitute index for scarcity of supply, in absence of data on quantities demanded by the market (Fuller 1991). However, supply depends on availability of wild plant stock, availability of diggers' labor, and amount previously stockpiled.

Changing market conditions

The correspondence between Elam Bartholomew and the Lloyd Brothers Pharmacists reveals changing market conditions even during the beginning of trade. The earliest price of $0.55/kg ($0.25/lb) of dry root in 1894 was reduced to $0.275/kg ($0.125/lb) by 1901 as more suppliers entered the trade and the Lloyd Brothers obtained large contracts (C. G. Lloyd 1897, 1901). Nevertheless, in years of peak demand, prices returned to, or surpassed, their earlier levels. For example, in June 1897 when the Lloyd Brothers ran out of echinacea, prices rose to $0.55/kg but began falling in November of that year (C. G. Lloyd 1897; Sayre 1897).

In 1903, the market for echinacea appears to have experienced a very large demand. The Lloyd Brothers not only contacted Bartholomew but also sought new suppliers throughout the Great Plains and Midwest states (Hurlburt 1999). In this year, the price rose to $0.55/kg ($0.25/lb). Sayre (1903) reported that echinacea "in one year has brought to the state over

$100,000, as over 200,000 pounds have been collected, and it has brought at times as much as fifty cents per pound."

In 1910, echinacea was well established as a drug commodity and was reported as "scarce" in the New York wholesale market, "with quotations at 65–70 cents" ($1.43–$1.54/kg). Subsequent reports listed the price in slow decline, so that by 1914 it was bringing only $0.48–0.53/kg ($0.22–0.24/lb). Another period of price increases culminated in January 1921 with a peak at $1.65–1.76/kg ($0.75– 0.80/lb). Wholesale prices then declined, reaching a low of $0.33–0.35/kg ($0.15–0.16/lb) in 1933 (*Oil, Paint and Drug Reporter* 1910–1941). Nevertheless, the prices paid to diggers during the Depression era, 3–4 cents per pound of "wet," fresh root (equivalent to $0.20–0.26 per kg dry root or $0.09–0.12/lb), meant that "snakeroot digging paid better than a Government job" (T. Sanders, interview).

From this low point, the price of echinacea root appears to have steadily increased (Fig. 2). Nevertheless, the underlying market may have been more complex. For example, the species preferred for harvest (*E. angustifolia* or *E. pallida*) changed historically, as did the part of the plant used (root, aerial parts, or whole plant) and method of shipment (fresh or dry; K. Lawson, interview). Further, cycles in the market that occurred during 1996–98 probably occurred in other years as well.

In recent years, the price of echinacea root paid to Kansas diggers has tended to cycle (P. Thrasher, interview). During this study, the market as experienced by diggers had two peaks and three "crashes" when the local buyer was not purchasing roots. In winter–spring 1995–1996, the price of dried root reached $46–48/kg ($21–$22/lb). In summer 1996, with excess root on the market, the price plummeted, and no root was bought for several months. In spring 1997, activity resumed at $26/kg ($12/lb). The winter of 1997–1998 again saw the price increase up to $44–

46/kg ($20–21/lb), but in May 1998 it began falling again. By September the price had declined to $26/kg ($12/lb) or lower, and there was no root-buying activity for over 2 weeks. The market for echinacea root was weak throughout 1999–2001 (Blumenthal 2000, 2001a; *Nutrition Business Journal* 2001), but digging resumed in 2002 at a price of $26/kg ($12/lb); Pat Thrasher, interview). During periods of little demand, diggers find other work; most do not return to digging until the price is favorable again.

Social aspects of "snakeroot digging"

Since the 1890s, echinacea, or "snakeroot," digging has been one of a few natural commodities that could provide cash income to rural residents of the Great Plains. Digging was a family enterprise; father-son digging teams and multigenerational family outings to dig root were common (Bartholomew 1999; Hurlburt 1999). Similar family enterprises characteristic to the digging business have been recorded in Montana (Kolster 1998) and West Virginia (ginseng root digging, as discussed by Bailey [1999]).

A variety of people still dig snakeroot, including those with full-time jobs (Kolster 1998) and college degrees; however, diggers are often self-employed or not fully employed and may be economically marginalized (Fuller 1991; Bailey 1999). Harvesters reported that youth, underemployed people, agricultural workers in the off-season, and people who want to set their own working conditions are attracted to digging.

Landowners' views of echinacea root diggers appear to be more negative now than in the past. The harvesters we interviewed complained about being viewed as people who did not have "steady" jobs and said that efforts to restrict digging amounted to "trying to take away our buffalo." Those who participate in digging as a result of family tradition said that they seek out known digging areas and always obtain the owner's permission to work there. However, newcomers to the trade who were trespassing to dig were said to be “ruining it for people who’ve been doing it for years and years” (P. Thrasher, quoted in the *Lyons Daily News* [1996]). An older harvester commented that “people’s attitude has changed”; while it used to be that “people would help each other out and I never had any problems with anyone I asked going on their land,” now people “don’t want diggers around” (T. Sanders, interview).

Kansas landowners have reacted negatively to increased digging pressure during times of peak demand. Their complaints include trespass digging, gates being left open, trash left in the pastures, holes left uncovered, and the threat of fire when vehicles are driven over the dry grass in search of echinacea plants. Similar concerns have been expressed in harvested areas in Montana and North Dakota (Crawford 1998; Kolster 1998). As a result of these problems, many landowners in Kansas no longer allow harvest on their properties and prosecute trespassing diggers. Of seven landowners we contacted during the study, three had allowed a relative to dig on their property, one allowed a nonrelative to dig, and three did not allow harvest. Landowners who permit digging generally restrict this to one person or group of people, who then keep others out (Hurlburt 1999). While we did not estimate the frequency of trespass digging, another study recorded that three of four large ranch managers who had encountered diggers reported trespass digging (Loring *et al.* 1999a).

Harvest methods and economics of digging

Harvesters uniformly expressed concern about getting a good return for their efforts when digging “snakeroot.” The importance of harvesters’ economic motivation to obtain a good return or hourly wage from their efforts has several implications. First, speed of work is important and is expressed in terms of quantity of root dug per hour or per day. The usual harvesting rate was said to be 0.9–1.35 kg per hour, or up to 2.25 kg per hour in a good stand (2–

3 lbs up to 5 lbs/hr). Four factors determine the hourly yield: time spent searching, distance traveled, time spent extracting the root, and weight of the root (influenced by its diameter and length). The depth to which a root can be dug is limited by rocky soil and the depth of a swing of the pick. Most harvesters prefer to dig large roots, and some seek out very large roots, which they call "carrots." However, this may come at a cost in the form of increased search time.

A second implication of the harvesters' economic motivation is that the desired pace of work influences the qualities of stands in which a harvester will consider digging. Individuals' preferences and styles of work are varied in their choice of where to dig. For example, many diggers prefer to work in rocky areas with little vegetation where *E. angustifolia* is easier to find and dig. However, some prefer the "sod root," which is said to be larger and heavier than "rock root" as a result of better soil in grassy areas. Size of the stand is also a consideration. One harvester was said to be good at finding and digging little patches, while others prefer to obtain permission on a large ranch where they can work for many weeks or months.

Harvesters have repeatedly stated that "you can't get all the root." This statement has two meanings: first, the entire root of any one plant is not harvested, and second, it is not possible to harvest all the plants in a population. It is not profitable to search out every plant or to spend time digging the entire root of any single plant. As the density of remaining plants decreases in a stand being harvested, search time increases and economic returns diminish. At one site, we estimated that *E. angustifolia* harvest density represented between 6.4% and 36% of the mature plants in a population (Hurlburt 1999).

All the harvesters we encountered during this study used a pick mattock as a digging tool. The pick has been the tool of choice historically, as recorded by Sayre (1903). The harvesters interviewed believe that it is a quicker method of digging and has less impact on the grassland than either a shovel or the specialized digging tool in use in the Northern Plains, a metal bar with a thin, sharpened blade (Kolster 1998).

Resilience of *Echinacea angustifolia* plants

Harvesters' opinions on the abundance and resilience of *E. angustifolia* are varied. Most currently active diggers were optimistic about the resilience of *E. angustifolia* and illustrated their point by referring to traditional, longtime digging areas. We visited several of these areas, including a pasture that had been known as a digging area since the 1930s. In 1999 we observed thousands of plants at a ranch that was heavily harvested in 1996. The uplands surrounding the Saline River were mentioned as an area that was traditionally harvested and "still has lots of root," but it has been closed to digging (Hurlburt 1999; P. Thrasher, interview).

The need to allow populations to recover after harvest was noted by several diggers. A 2- or 3-year rotation was commonly mentioned as a practical harvest interval. Harvesters all claimed that plants whose roots have been harvested will resprout and can be harvested again in 2–3 years.

Older harvesters expressed a different opinion, recalling their fathers' friendly competitions, with daily harvests exceeding 45 kg (100 lbs; K. Lawson, interview; T. Sanders, interview). This is double the amount that could currently be harvested (at 2.25 kg/hr) in a 10-hour day in a good stand. In traditional digging areas as well as in stands close to Stockton, plants were said to be fewer and smaller than in the past (Hurlburt 1999). Though these men thought that over-harvesting had caused the declines, they recognized other causes of echinacea population declines, such as spraying the pastures with herbicides.

Participation in harvest

Participation in commercial harvest confirmed the methods described by diggers and many of their observations. In contrast to the team approach used by Montana harvesters (Kolster 1998), the diggers in this study worked individually. They swing their pick once or twice to cut or loosen the root below ground, pull it up by its top, clip or pull off the aerial portions, and toss the root into a bag tied at the hip (Fig. 3). This method enables the digger to move quickly from plant to plant.

The diggers did not appear to either select or avoid flowering plants; instead, they looked for plants with multiple shoots or large rosettes of green and dead leaves. Smaller rosettes were skipped over, as were plants that would have been difficult to dig, such as those growing in dense sod or next to the sharply pointed leaves of *Yucca glauca* plants.

Many harvested roots appeared to have re-grown following earlier harvest. These roots had smaller diameter upper portions attached abruptly to a larger diameter lower portion. Shoots emerging from last year's pick holes were further evidence of regrowth. These observations of regrowth were confirmed separately at another site by tagging holes where plants had been dug (Hurlburt 1999). At that site, 5 of 14 roots had re-sprouted within 2 years of digging. Our observations thus support the harvesters' assertions that harvest is incomplete and that some plants grow back after harvest.

DISCUSSION

Economics of digging, harvest intensity, and recovery

E. angustifolia harvesting in Kansas meets three of Godoy and Bawa's (1993) four criteria that encourage "judicious use" of wild-harvested resources: secure property rights, low population density, and simple harvesting technology. A fourth criterion, traditional rule of use, is not met. Lacking traditional rules that would govern *Echinacea* harvest practices, economic criteria influence the severity of harvest. For *E. angustifolia*, these economic factors are the price per kg (or lb) of echinacea root relative to available wages, the effort required to dig the roots, and accessibility of land where the plants grow.

The economics of digging may explain why *Echinacea angustifolia* harvesting became established in the Smoky Hills but not in some other parts of the species' range. The cost of labor in Kansas in 1903 was $1.50 to $3.00 per day (Kirk 1903). At $0.33 per dry kg ($ 0.15/lb) and assuming that roots dry down to one-third of their fresh weight, a person would have to dig about 13.5–27 kg (30–60 lbs) per day to earn the going wage. While this was probably possible in a dense, unexploited echinacea population in the Smoky Hills, it would not have been possible in sparse populations or in areas where digging was difficult. The daily harvests of 45 kg (100 lbs) claimed by the older generation likely represent a maximum, not an average. It would have been difficult for an inexperienced harvester to dig this much. In today's market, a person who digs 1.5 kg fresh root per hour (equivalent to about 0.5 kg dry) can earn more by digging root only when the price per kg of dry root is more than twice the going hourly wage. This assumes that jobs are available and travel costs do not exceed those of going to a wage-earning job. In contrast, Kolster (1998) reported that high unemployment on the Ft. Peck Indian Reservation in northeast Montana led to harvesting even when root prices were lower.

The method of digging wild *Echinacea angustifolia* roots in Kansas normally leads to a low intensity of harvest. Plants are selectively harvested based on apparent size and accessibility, leaving many plants and parts of populations untouched in the variable terrain of the Smoky Hills. Harvesters digging echinacea roots tend to use an optimal foraging strategy, maximizing acquisition of the resource while minimizing their time costs. This strategy is similar to that noted by Runk (1998) for collection of vegetable ivory, tagua (*Phytelephas aequatorialis*) seeds. As a result, diggers seek out areas that have not been harvested recently and that have an abundance of large and easily accessible echinacea plants.

Access to *Echinacea angustifolia*, like other wild-harvested resources, affects the intensity and sustainability of its harvest. Resources characterized by open access to all harvesters tend to be exploited to maximize immediate returns, while resources where access is controlled by a single owner are harvested to maximize long-term yields, a more sustainable strategy (Milner-Guland and Mace 1998). *E. angustifolia* may fall toward either end of the spectrum. Populations along roadsides and in public areas are easily accessible and have proven problematic to protect from harvest in Missouri, Oklahoma, and Montana (Lantz 1997; Kolster 1998; Traeger 1998). However, in Kansas, most *E. angustifolia* grows on private land, and trespass laws are enforced. Conservation is carried out in effect by landowners who restrict harvest to one individual or do not allow it at all. For example, when high demand led to increased harvesting in early 1996, some Kansas landowners closed their properties to digging and prosecuted trespassers. These actions create refuges for *E. angustifolia* and may prove to be an effective conservation measure for the species. In contrast, local populations that are left open to harvest (such as those on Indian Reservations or federal lands in Montana) may be extirpated under persistent high demand (Kolster 1998).

This interplay of market price and cycles, harvesters' effort, and access to the resource determines the severity of harvest on *Echinacea angustifolia* populations. The large fluctuations in demand that we observed during this study have occurred since the beginning of the species' commercial history (Table 1). These marketing cycles have been reported for other medicinal plants (Fuller 1991). The periods of reduced harvesting pressure corresponding to market downturns provide recovery time for harvested populations. However, high prices could lead to overexploitation and local extirpation of populations if high demand is sustained for months or years. Moreover, harvest constitutes just one source of environmental variability affecting *E. angustifolia* populations. The co-occurrence of all these factors makes it difficult to assess the long-term effects of harvest on *E. angustifolia* over its range. Harvesting a population to very low density may leave it vulnerable; for example, harvest followed by a "bad" year could lead to further declines. In this case, wild populations are unlikely to have sufficient recovery time without other conservation measures. The plant's longevity, drought tolerance, and ability to resprout after harvest provide some buffer against this stochasticity.

Resilience and resprouting

The resilience of *Echinacea* has been noted by other observers (Little 1998). Despite being recorded as a species that decreases under grazing pressure by Weaver and Hansen (1941) and intolerant of grazing in the Kansas Flint Hills (Eddy 1990; Loring *et al.* 1999b), *E. angustifolia* plants persist in the less intensively grazed pastures of the Smoky Hills area of this study. Rangewide, *E. angustifolia* occurs not only in native prairies but also in slightly disturbed, rocky areas such as graded roadsides, embankments, pipeline trenching areas, and abandoned limestone quarry areas. However, it does not recolonize agricultural land or old fields. *Echinacea* species are noted for drought tolerance (Weaver, Stoddart and Noll 1935; Baskauf and Eickmeier 1994; Chapman and Auge 1994).

Regrowth of harvested *E. angustifolia* plants, as we observed during this study, was also documented by Kolster (1998) in Montana. This aspect of resilience suggests that occasional harvest (once every 3 or more years) will not eliminate populations.

Conservation measures for *Echinacea angustifolia*

E. angustifolia continues to be locally common in central Kansas but still faces threats to its abundance and persistence. Loss of mixed-grass prairie habitat is less than that of tallgrass prairie but has been estimated from 30% to 77% across the Great Plains states (Samson and Knopf 1994). Of the remaining native mixed-grass prairie, habitat alteration has occurred under a management system that focuses solely on production of grass and cattle. Fire is not normally used as a management tool in Smoky Hills pastures, and encroachment of woody vegetation or "brush" into the grassland is apparent (Loring *et al.* 1999a). Landowners in the area are increasing their use of herbicides to combat brush and the noxious weed, musk thistle (*Carduus nutans*). Harvesters have reported that *E. angustifolia* has disappeared from sprayed pastures. Finally, observers have noted that when pastures are grazed more heavily in the spring, flowering stalks of *E. angustifolia* are more often damaged and seed production is lower compared to *E. angustifolia* in pastures that were not grazed until mid- or late summer (Hurlburt 1999). These impacts, when combined with harvesting pressure, may threaten the species' long-term persistence.

Restoration and management: To maintain viable wild populations of echinacea, conservation measures are needed in addition to the harvesting methods employed by experienced diggers. Restoration and management of mixed-grass prairie is needed to counter the loss and alteration of *E. angustifolia* habitat. Returning disturbed land to prairie, and improving the quality of degraded prairie, can expand available habitat for wild *Echinacea* populations. Methods of brush and thistle control that do not involve widespread herbicide application, such as selective spraying and effective biocontrol for musk thistle, are needed. Programs to assist in re-vegetating degraded areas and Conservation Reserve Program lands with

E. angustifolia and other native forbs (in addition to grasses) would be beneficial. Landowners could be made aware that they can increase *E. angustifolia* on their lands by deferring grazing until midsummer in the pastures where it is present. In the Smoky Hills, where rangelands are almost entirely privately owned, this will happen only with the support of landowners. Some public lands in the area also have *E. angustifolia* populations that need stewardship. Degraded areas such as public road rights-of-way also could be reseeded to *Echinacea* and other native plants.

Cultivation: One commonly advocated solution for the threats to echinacea populations is to replace wild harvest with cultivation as a source of echinacea root supply (Foster 1991; Hobbs 1994; Crawford 1998). When a wild resource becomes scarce relative to its demand, cultivation becomes a logical step. The shift to primarily cultivated sources has already occurred for ginseng (Robbins 1998), which has been cultivated since the early 1900s, and goldenseal (McGuffin 1999). The demand for echinacea roots is increasingly being supplied from cultivated sources (McGuffin 1999 and pers. com.).

Cultivation of echinacea, however, like any new crop that has a limited market, is a risky endeavor (Oliver 1997; Redhage 1997; Byczynski 1998; Coltrain 1999). It takes at least 3 years to produce a crop with marketable sized roots (Foster 1991). The current downturn in the medicinal herb business means many growers have lost money and even plowed up medicinal crops or gone out of business (*Nutrition Business Journal* 2001). Nevertheless, *E. angustifolia* is being cultivated in Kansas and elsewhere both by small-scale and large-scale growers interested in producing a high-value crop.

The future of wild harvest: We do not expect cultivated *Echinacea angustifolia* to replace wild harvest entirely. Wild harvest appears to be driven by rapid increases in demand (associated with higher prices) that would be impossible to meet quickly enough with cultivation. There is a specific market demand for wild-harvested echinacea, particularly from small local companies and the European market (P. Thrasher, interview).

Finally, we believe that there are important reasons why wild harvest should continue. Family and cultural ties traditionally, and in the future, will encourage people in areas with large populations of echinacea to continue to harvest. This local harvest provides an economic benefit, cash income that can serve as an important personal resource for people who are not involved in full-time, year-round jobs. Most diggers who we have met enjoy work that allows them to be outdoors in the native prairie landscape, preserving the connection between people and land. Concern for the echinacea on their land is driving some landowners to be more careful stewards of biodiversity. In this study we met landowners who were controlling brush manually or with spot spraying of herbicides rather than aerial application. We have observed that long-term diggers have a strong conservation ethic and appreciation for the native prairie. This is one of two activities (hunting being the other) that encourages local people to be out on foot in the rural prairie landscape observing and valuing biodiversity.

Conclusion

Echinacea angustifolia harvest in north-central Kansas has a 100-year history that is well documented and represents one of the longest periods of sustained use recorded for a major wild harvested species in the United States. Interviews with harvesters and observations of commercial harvest and harvested populations suggest that experienced diggers use practices that contribute to sustainability of harvest: rotating harvest areas, selective harvesting of low-density plants, and returning to known areas to dig. Landowners also aid in the conservation of this species by restricting digging on their land. *E. angustifolia* is somewhat resilient to grazing and disturbance, and some plants resprout within 2 years after harvest. Nevertheless, in the highly variable environment of the Great Plains, a large and increasing commercial demand sustained over years is likely to exceed the ability of *E. angustifolia* populations to recover from harvest. This is especially true when drought years occur at the same time that commercial demand is high. Cultivation of *E. angustifolia* is under way and can potentially ease the pressure on wild stands. Other conservation measures such as habitat restoration and reintroduction of *Echinacea* into disturbed lands are also necessary to preserve the species in face of its diminishing and altered habitat. In addition, further education of landowners, reserve agency personnel, and diggers about *Echinacea* harvesting and conservation would be useful. If restoration, stewardship, and responsible harvest techniques are practiced, the valuable cultural tradition of wild harvesting echinacea can continue sustainably.

Table 1: *Echinacea angustifolia* market development and price history

Year	Market and Price Information and Reference
1885	Meyer sends "blood purifier" containing echinacea to Lloyd Brothers Pharmacists (King 1887; J. U. Lloyd 1904).
1887	First article on *E. angustifolia* as a medicinal plant is published (King 1887).
1892	Kansas University pharmacy students collect 68 kg (150 lbs) of dry root (likely *E. pallida;* Sayre 1903).
1894	Rooks County, Kansas, resident Elam Bartholomew collects 45 kg (100 lb) at $0.55/kg ($0.25/lb) for Lloyds' (Bartholomew 1998).
1896	Lloyd Bros. offers $0.44/kg ($.20/lb) for root "for next season" (C. G. Lloyd 1896).
1897	Roots are collected by Kansas University students for $0.55/kg ($0.25/lb; Sayre 1897).
1897	In June, Lloyd Bros. runs out of *Echinacea angustifolia* from Kansas and purchases root (likely *E. pallida*) from Iowa at $0.44/kg ($0.20/lb). In August, Lloyd Bros. begins purchasing "several hundred lbs of the root" from Bartholomew and offers him $0.44/kg ($0.20/lb) for "all you will gather this winter" (C. G. Lloyd 1897).
1901	Lloyd Bros. announces that it is "fully supplied with the root and will probably not be in the market this year," after contracting for the last several seasons at $0.27/kg ($0.12/lb; C. G. Lloyd 1901).
1903	Lloyd Bros. seeks contracts for echinacea roots at $0.33/kg ($0.15/lb). In

July Bartholomew is contracted to supply 1360.8 kg (3000 lbs) for $0.44/kg ($0.20/lb; N. A. Lloyd 1903).

1903 90,000 kg (200,000 lbs) of dry echinacea roots are shipped from Kansas. Prices are “as high as 50 cents per pound” ($1.10/kg; Sayre 1903).

1904 Bartholomew supplies Lloyd Bros. 1,485.5 kg (3,275 lbs) of echinacea roots at $0.67/kg ($0.30/lb) in February–March. In April, Lloyd Bros. receives “an offer of five thousand lbs [2,268 kg] of echinacea root at 18 cents per lb [$0.40/kg]” (N. A. Lloyd 1904).

1910 Echinacea is reported as “scarce” on the New York wholesale drug market, peaking at $1.45–$1.55/kg ($0.65–$0.70/lb; *Oil, Paint, and Drug Reporter* [*OPDR*] 1910).

1914 Wholesale prices are down to $0.49–$0.53/kg ($0.22–$0.24/lb; *OPDR* 1914).

1918 Wholesale prices are $0.67–$0.89/kg ($0.30–$0.40/lb; *OPDR* 1918).

1920 Echinacea market is “nominal” in November, with supplies scarce; price is $1.67/kg ($0.75/lb; *OPDR* 1920).

1922–1924 Wholesale prices are steady at $0.71–$0.78/kg ($0.32–$0.35/lb; *OPDR* 1922–24).

1925–1930 Wholesale prices decline slowly to $0.53–$0.58/kg ($0.24–$0.26/lb; *OPDR* 1925–30).

1931 Wholesale prices are $0.38–$0.40/kg ($0.17–$0.18/lb; *OPDR* 1931).

1930s At $0.06–$0.09/kg ($0.03–$0.04/lb) for green root paid to diggers, echinacea root digging provides a better wage than a "government job" (Sanders, interview).

1941	Wholesale prices are \$0.40–\$0.42/kg (\$0.18–\$0.19/lb; *OPDR* 1941).
1943–1944	Fresh echinacea root is priced at \$0.31–\$0.33/kg (\$0.14–\$0.15/lb; Lawson, interview).
1952	Dry echinacea root is priced at \$1.22/kg (\$0.55/lb; St. Louis Commission Co. 1952).
1965	11,340 kg (25,000 lbs) of *E. pallida* is harvested (McGregor 1968).
1968–1969	*E. angustifolia* root is sold at about \$2.20/kg (\$1.00/lb; Lawson, pers. com.)
1979	Echinacea root is at \$2.78/kg (\$1.25/lb; Bare 1979).
1982	Echinacea root price "has dropped by one-third," but tops are in demand, with harvest of 45,359 kg (100,000 lbs) dry. Several companies are buying and shipping to Germany (Richter 1982).
1986	Echinacea root price is up to about \$4.45/kg (\$2.00/lb) (Pat Thrasher, interview).
1988	Echinacea root price is at \$12.22–\$13.33/kg (\$5.50–\$6.00/lb; P. Thrasher, interview).
1992–1996	Echinacea booms to \$49.00/kg (\$22.00/lb); 4,500–18,600 kg (10,000–41,000 lbs) are sold annually in Rooks County. Thrasher has the second-largest payroll in Rooks Co. In June 1996 Thrasher stops buying; the market is "flooded" (P. Thrasher, interview).
1997	Market activity resumes at \$27.00/kg (\$12.00/lb) in early spring, but by

the winter echinacea root price is up to $44.00–$47.00/kg ($20.00-$21.00/lb). Thrasher buys 454 kg (1,000 lb) weekly while the price is high (P. Thrasher, interview).

1998 In May, price is $40.00/kg ($18.00/lb) but begins dropping; in September the echinacea market "crashes" for 22 weeks; sales finally resume at $27.00–$29.00/kg ($12.00–$13.00/lb; P. Thrasher, interview). In Montana fresh echinacea root is priced at $13.00–$18.00/kg ($6.00–$8.00/lb; Kolster 1998). Very little market exists for wild echinacea in Kansas: $5.56/kg ($2.50/lb; Coltrain 1999).

2002 Thrasher begins buying again in Kansas at $27.00/kg ($12.00/lb; P. Thrasher, interview).

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Uses of Echinacea Species in Western Medicine

Jeanne Drisko

I. Introduction

The popularity of medicinal plants has increased over the past decade, most likely as a result of sharp increases in prices of prescription drugs, restrictive access to physicians, media reports of adverse effects of prescription drugs, and as a result of the 1994 Dietary Supplement and Health Education Act (DSHEA; Brevoort, 1998; De Smet, 2002; Marcus and Grollman, 2002; Straus, 2002). DSHEA broadly defined medicinal plants and created confusion about standards and mechanisms under which claims about effectiveness and safety are evaluated and enforced. The Food and Drug Administration has been given the mandate to regulate dietary supplements for quality assurance and good manufacturing practices (US Code, 63 Fed. Reg. 23624). With the implementation of regulations to insure quality control of product manufacture of phytomedicinals (21 CSR 201.128, Food and Drug Cosmetic Act), species certification is likely to be required of all botanical raw materials. Even if not required by the FDA, such certification increases consumer confidence and provides competitive market advantage for producers of the certified product.

As one of the most popular medicinal plants, echinacea has been widely used and regarded as safe. Yet current efforts at investigation have left many health care providers perplexed about when or even if to recommend it. To effectively guide future investigators and to make use of the promising potential of echinacea as a therapeutic tool, it is imperative to understand the history of use and research to date. By understanding the history of echinacea investigation and current clinical trials, pitfalls can be identified and changes made in approaches. Echinacea may then serve as a model for study of other medicinal plants.

Evidence from Research for Safety and Efficacy

A. Background

Echinacea is indigenous to mid-North America, and it has a history of medicinal use in treating colds, infections, bee and insect stings, snakebite, headache and wounds that long predates European contact. Ethnobotanical uses of echinacea by Native Americans, early travelers, traders, settlers, and doctors reveal a history of use as a blood purifier, wound healer, and anti-infective (Moerman, 1986; Hobbs, 1989; Kindscher, 1989). Echinacea species have described immuno-modulatory effects and are known to be relatively safe for human use (Kindscher, 1989; 1992; 1999; Foster, 1991; Mengs et al., 1991; DerMarderosian, 1996; Bauer, 1998). Early usages of echinacea frequently incorporated more than one species, and apparently species under use were often misnamed. A review of this early literature led to the conclusion that chemical analyses were most likely completed on Echinacea angustifolia, while biological activity was tested with E. purpurea (Schumacher and Friedberg, 1991).

Currently, there is strong evidence for echinacea's action as a stimulant of innate immunity (Roesler *et al.,* 1991; DerMarderosian, 1996; Burger *et al.*, 1997; Bauer, 1998) as well as cellular immunity (Rehman *et al.,* 1999). In recent years, echinacea preparations have developed into one of the best-selling medicinal plants (Brevoort, 1998; Klepser, 1999; LaPuma, 2000).

Most of the recent research on the echinacea has been conducted in Germany where there is greater scientific interest in medicinal plants (Foster, 1991; Foster and Tyler, 1999). Subsequently, the Germans have published additional research, even on plants found only in North America. Currently, more that 800 products containing *E. purpurea* and to a lesser extent *E. angustifolia* are marketed in Germany alone (Bauer, 1998). Research has been conducted primarily on *E. purpurea*, but also on the similar and closely related *E. pallida* and *E. angustifolia*. The delivery forms used in trials include ointments and solutions for external use, extracts for oral use, and ampules for intravenous and intraperitoneal injection. It is regarded as effective in treating certain viral and bacterial infections as well as wounds and inflammation, while stimulating the immune system.

In 1989, the German Commission E published the official German monograph on the use of the fresh juice of the aboveground *E. purpurea* tops (Blumenthal, 1998). Its use is allowed for stimulating the regenerative processes, restoring damaged tissue, activating phagocytosis, and for the indirect anti-infective influence resulting from the effect of the herb on the hyaluronidase/ hyaluronic acid system (Foster, 1991; Blumenthal, 1998). Echinacea preparations have been found to be safe, but controversy exists for effectiveness in the treatment of upper respiratory tract infections ,and it is relatively ineffective when used on a preventative basis.

B. Medicinal Uses

1. Safety

Overall, the long history of safe use of echinacea by North American indigenous groups, its widespread use as a phytomedicine in Europe, its use as a food, tea, and dietary supplement additive, and recent scientific data indicate that echinacea is relatively non-toxic. Some individuals may experience rare immediate allergic reactions of varying degrees of severity, particularly with parenteral use of the substance, which is not uncommon for plant species in the Asteraceae.

The German Commission E monograph on *E. purpurea* aboveground parts state that no side effects are known when juice of the aboveground portion is administered orally or locally (Blumenthal, 1998). When administered parenterally, dose-dependent chills, self-limited febrile reactions, and nausea and vomiting may occur. In some medical editorial reports, an increase in temperature associated with parenteral administration is cited without reference to echinacea species, plant part used, product form used, route of administration, or primary source literature cited.

Multiple studies have been conducted in the murine model to assess acute toxicity, subacute toxicity, and genotoxicity of *E. purpurea* expressed juice administered as oral or intravenous doses. Long-term oral administration in doses many times above the human therapeutic dose in rats showed no evidence of toxic effects (Mengs *et al*., 1991). Negative results were achieved for mutagenicity with microorganisms and mammalian cells *in vitro* and in animals (Coeugniet and Elek, 1987; Lenk, 1989; Schimmer *et al*., 1989; Mengs *et al*., 1991). Additionally, malignant transformation of hamster embryo cells was not observed in an *in vitro* carcinogenicity test with *E. purpurea* expressed juice. It can be concluded that the acute and subacute toxicity studies carried out in rodents together with genotoxicity tests *in vitro* and *in vivo* do not reveal any evidence of toxic effects from *E. purpurea* even when administered at excessive dose levels or concentrations.

The risks and benefits of the expressed juice of *E. purpurea* for long-term immunostimulant therapy were assessed based on an exhaustive review of published toxicological, pharmacological, and clinical studies (Parnham, 1996, 1999). Reported dosing forms included intravenous and intraperitoneal ampules, oral lozenges, and topical application forms. Only those studies were reviewed in which the treatment protocol and number of patients were clearly defined and in which safety assessment could clearly be made in relation to the dose, route of administration, and indication. It was concluded that the low rate and minor nature of reported adverse events further supported the good tolerability of *E. purpurea* expressed juice on long-term administration. No conclusions could be drawn regarding efficacy.

Thirteen adverse events related to oral ingestion of expressed juice of *E. purpurea* were reported to German health authorities (Parnham, 1996). Analysis of the related reports revealed that only four cases were directly attributable to echinacea, all of which were allergic skin reactions. In 1996, a series of reports in the popular German press attributed several deaths due to anaphylaxis in patients taking echinacea (Foster, 1996). An investigation by German federal health authorities failed to establish direct cause between the deaths and echinacea and reported that a number of other treatments were being co-administered in each case.

In a review of three early studies of parenteral (intravenous) administration for the treatment of children with whooping cough, doses ranged from 1 to 2 ml of the aqueous extract injected twice daily for 3 to 21 days (Parnham, 1996). These three studies involved 257 children from infants to children 14 years of age. No adverse events were observed. In one nine-month-old infant, an increase of temperature from 40°C to 40.6°C of 12 hours duration was observed. Slight reddening at the injection site (of 1-2 days duration) was seen in a few cases.

In over 500 children with tuberculosis, parenteral administration of echinacea resulted in acute signs of immunostimulation such as shivering, headache, vomiting and fever within 2-4 hours of injection (Parnham, 1996). The symptoms disappeared after 1-2 hours, along with a 40-100% increase in blood leucocyte count. An additional report of nearly 300 children with whooping cough reported transient pain at the injection site and an increase in temperature of 1-2°C. The rise in temperature is attributed to stimulation of phagocytosis and associated production of cytokines and is a therapeutic goal of treatment. No other adverse events were observed.

A case of echinacea-associated anaphylaxis was reported (Mullins, 1998). Subsequently, an analysis of 15 randomly stored samples of serum from patients with atopy was undertaken, and 20% of the samples tested showed moderate to strong reactivity to echinacea challenge (Mullins, 1998). A commentary on the conclusions of the case report stated that in 1998 Australian consumers purchased an estimated 200 million doses (tablets and liquid) of echinacea preparations (Myers and Wohlmuth, 1998). The authors noted that if the rate of echinacea-induced anaphylaxis suggested was true, the widespread use of echinacea in Australia over the previous decade should have conservatively resulted in at least 2000 cases of anaphylaxis. Over the same period, over 20,000 cases might be expected throughout the world. This was not the case, and in fact relatively few reports of echinacea problems were identified. Relating the association of echinacea to anaphylaxis in the first case, the conclusion drawn was there might have been an acute reaction to the high concentration of isobutylamides in the original product.

Five additional cases of adverse reactions to echinacea were reported (Mullins and Heddle, 2002). Two patients suffered anaphylaxis and a third an acute asthma attack after a first-ever dose of echinacea (species and product form not specified). A fourth patient had recurrent episodes of mild asthma each time echinacea was ingested. A fifth patient developed a rash two days after ingestion of echinacea. The authors concluded that some atopic patients might have positive skin-prick tests to echinacea even without being exposed to it, suggesting a possible cross-reactivity between echinacea and other environmental induced allergens. They note that, given its widespread and largely unsupervised community use, rare adverse events are inevitable. In an extensive search, 26 possible cases of echinacea allergy were found. The denominator – those at risk – is likely in the 100s of 1000s. Therefore, the results are actually in favor of safety, as less than 1 consumer in 10,000 exposed was found to have a serious adverse reaction (Barrett et al., 2002).

Ondrizek et al. (1999) analyzed the effects of popular herbs including "*Echinacea purpura*" [*sic*], St. John's wort, saw palmetto, and *Ginkgo biloba* on sperm DNA and the fertilization process. The prospective comparative study found that high concentration of echinacea reduced oocyte penetration. This result is perhaps explained by anti-hyaluronidase action of *E. purpurea* since hyaluronidase is involved in the mechanism of sperm penetration in oocytes. *E. purpurea* did not affect sperm motility. High concentrations of *E. purpurea* caused a significant denaturing of human sperm DNA in an acridine orange study, reducing sperm viability after 7 days' incubation at 23°C. Of note, there is no mention of the source of the plant material, species tested, plant part tested, whether it was a lipophilic or hydrophylic extract, or whether any effort was made to authenticate the plant material used.

One unanswered question requiring further investigation is in the continuous daily administration of echinacea for periods longer than 2 weeks. Work in healthy individuals indicates that a period of initial stimulation (typically 1-7 days) is followed by a period (typically after about 11 days) when the immune system no longer responds (Hobbs, 1989; Bauer and Wagner, 1991). Accordingly, echinacea is often prescribed in 10 day treatment periods followed by two weeks of no administration.

A recent study evaluated the ability of *E. angustifolia* root preparations to inhibit the action of cytochrome P450 isozyme CYP3A4 *in vitro.* Suppression at high dilutions indicated the potential for significant drug-herb interactions, which may be a concern (Budzinski *et al.*, 2000). Further investigation should be directed to answering this question.

There is comparatively little information available from clinical trials or published reports about side effects and toxicity of specific echinacea preparations. Clinical studies rarely report side effects or intolerance following oral use in ordinary doses (Lersch *et al.*, 1992). However, it can be concluded from the above reports that echinacea is relatively safe at recommended administered doses.

2. Reported Immunomodulatory Effects

The majority of the more than 350 studies on the pharmacology of echinacea to date concern its immunostimulant activity (Hobbs, 1989). Pharmacological investigations over the past twenty-five years have shown immunostimulatory activities for cichoric acid, alkamides, and polysaccharides extracts of the roots and aboveground parts of *E. purpurea* (Bauer, 1998). Of these compounds, highly active polysaccharide molecules in *E. purpurea* were reported to possess immunostimulating properties (Wagner and Proksch, 1985; Wagner et al., 1985a; 1985b). And importantly, as isolated compounds, polysaccharides stimulate T-cell activity 20–to 30 percent more than a highly potent T-cell stimulator.

Immunological defense involves a complicated set of responses, but the overall objective is an increase in phagocytosis by macrophages and granulocytes that migrate freely from blood vessels into tissues during inflammation (Awang and Kindack, 1991).

An early study using an *E. purpurea* product containing the juice of the fresh aerial parts of *E. purpurea* was found to make mouse cells 50-80% more resistant to influenza, herpes, and vesicular stomatitis viruses when the mammalian cells were pretreated 4–6 hours before exposure (Wacker and Hilbig, 1978). The resistance lasted 24–48 hours. The antiviral active ingredient could not be isolated and was believed to be related to several of the chemical fractions that were separated.

A hydrophilic, highly purified polysaccharide from *E. purpurea* was found effective in activating macrophages to cytotoxicity against tumor cells and the microorganism *Leishmania enriettii* (Luettig, 1989). This polysaccharide induced macrophages to produce tumor necrosis factor, interleukin-1, and interferon-beta-2. Arabinogalactan did not activate B cells and did not induce T cells to produce interleukin-2, interferon-beta-2, or interferon-gamma, but it did induce a slight increase in T-cell proliferation. When injected intraperitoneally, macrophages were stimulated, a finding that may have therapeutic implications in the defense against tumors and infectious disease (Luettig, 1989).

Systematic fractionation and subsequent pharmacological testing of aerial and root parts of echinacea species demonstrate evidence for stimulation of non-specific immunity to include natural killer cells and monocytes (Sun *et al.*, 1999). Again, the aqueous polysaccharide components of all echinacea species stimulate phagocytosis, the production of oxygen radicals, increases in natural killer cells, and production of the inflammatory cytokines in varying degrees (Tubaro *et al.*, 1987; Roesler *et al.*, 1991; Egert and Beuscher, 1992; Steinmuller *et al.*, 1993; DerMarderosian, 1996; Elsasser-Beile *et al.*, 1996; Burger *et al.*, 1997; Bauer, 1998). Caffeic acid derivatives, which include a variety of compounds, have been shown to stimulate phagocytosis, inhibit hyaluronidase, and protect collagen from free radical degradation in varying degrees depending on the compound (cichoric acid) and the source (Facino *et al.*, 1995; DerMarderosian, 1996; Bauer, 1998).

Stimulation of the immune system appears to be strongly influenced by dose level in the case of isolated polysaccharides from *E. purpurea*. Pharmacological studies indicate that an oral 10 mg/kg daily dose of the polysaccharide given over a ten-day period is effective as an immunostimulant. Increases in the daily dosage beyond this value, however, resulted in “markedly decreased pharmacological activity,” indicating a need for pharmacokinetic studies (Wagner and Proksch, 1985; Wagner et al., 1985b).

Ethanolic extracts of the aerial parts of *E. angustifolia* and *E. purpurea* demonstrated immunomodulating activity on the phagocytic, metabolic, and bactericidal activities of peritoneal macrophages in mice (Bohlman and Grenz, 1966; Bauer *et al.*, 1988, 1989). The echinacoside component has low antibacterial and antiviral activity but does not have immunostimulatory activity (Beuscher *et al.*, 1989, 1992). Cichoric acid shows phagocytosis stimulation *in vitro* and *in vivo* but echinacoside, verbascoside, and 2-caffeoyltartaric acid do not (Bauer *et al.*, 1988). Cichoric acid also inhibits hyaluronidase (Soicke *et al.*, 1988) and protects collagen III from free radical induced damage (Sicha *et al.*, 1989). Purified alkamide fractions from *E. angustifolia* and *E. purpurea* roots enhanced phagocytosis in carbon-clearance tests. The main component, dodecatetraenoic acid isobutylamide only showed weak activity, however.

A cell tissue culture was reported in which cultured supernatants of stimulated whole blood cells derived from 23 tumor patients who were treated over a 4-week period orally with an extract from an herb preparation that included *E. angustifolia, Thuja orientalis,* and *Eupatorium perfoliatum***.** At baseline, a rather wide range of cytokines was found in the treatment and the control group. After therapy with the herbal mixture, there was no significant alteration in the production of the cytokines, and the leukocyte populations remained constant (Elsasser-Beile *et al.*, 1996). It could be argued that the active constituent may not have been present.

Currier and Miller (2000) showed that an *E. purpurea* root extract increased natural killer (NK) cell production in aging mice, paralleled by an increase in anti-tumor, lytic function capacity. They state that the extract appeared to be the only agent identified to date that significantly increases NK cell production and numbers in spleen and bone marrow of aging mice to levels present in young adulthood. A follow-up study demonstrated there was NK cell augmentation potential of an *E. purpurea* root extract *in vitro* and *in vivo* (Currier and Miller, 2001). After 9 days of treatment with male DBA/2 mice, a 2.5-fold increase in NK cells in spleens were observed. After three months they showed a "highly significant" survival advantage of *E. purpurea*-treated leukemic mice compared with controls. They concluded that the profoundly positive effects in disease abatement suggest the therapeutic potential of *E. purpurea,* at least with respect to leukemia, if not other tumors.

E. purpurea and melatonin (either alone or in combination) were investigated to determine effects on myeloid cells in mouse spleen and bone marrow (Currier *et al.,* 2001). Administered alone, *E. purpurea* did not affect the differentiation of granular leukocytes from their precursor myeloid cells, but in combination with melatonin, it hindered their differentiation into granular leucocytes from myeloid cells. This study highlights the importance of studying individual components as well as mixtures of combination products.

An *in vivo* study on male Sprague-Dawley rats examined the immunomodulatory effect of isolated cichoric acid, polysaccharides, and alkylamides from *E. purpurea* (Goel *et al*., 2002). At a dose of 12 micrograms/kg body weight/day, the alkylamide fraction significantly increased the phagocytic index and phagocytic activity of alveolar macrophages. Contrary to other studies on isolated compounds, they failed to show an immunomodulatory activity for polysaccharides or cichoric acid. They conclude that the alkylamides, used alone or in a complete echinacea extract, may be effective in upper respiratory tract infections. This is in conflict with the majority of other studies.

A double-blind, placebo-controlled crossover study evaluated the effects of echinacea on the immune system of healthy young males (Schwarz *et al*., 2002). The author stated that the study medication was the freshly expressed juice of echinacea, however the study medication was delivered as an alcoholic tincture, which most likely changed the active constituents. No effort was made by investigators to evaluate the study medication for content or to determine what constituents were present in the sample. The study conclusion was that echinacea failed to produce any effect on innate immunity *in vivo* in healthy subjects.

The general conclusion derived from the above studies is that no single echinacea constituent appears to responsible for the immunostimulant activity of expressed juice or of extracts, but evidence seems to favor the polysaccharide fraction. Both the lipophilic constituents and the aqueous soluble constituents have demonstrated activity in *in vitro* immunostimulant tests, although *in vivo* investigation should be considered the gold standard. In addition, there is no decisive information favoring the use of one particular plant or plant part. The most supportable conclusion is that certain echinacea products may promote innate immune activation in the form of transformation, production of interferon and secretion of certain lymphokines. This results in enhanced T-cell mitogenesis, macrophage phagocytosis, antibody binding, natural killer cell activity, and increased numbers of circulating polymorphonuclear cells. Evidence also exits for increased cellular immunity, but certainly much more work needs to be done.

3. Deficiency of Well-Designed Controlled Human Trials

Opinion is divided as to whether echinacea species are immunostimulant in humans and, if so, whether the active constituents are solvent soluble, water soluble, or a combination. It seems probable that the confused state of the reported human trials results from a combination of a lack of identification of plant material used and the chemical constituents present. Given this confusion, it is not possible at present to devise suitable analytical means of standardizing echinacea preparations so as to ensure consistent reported information from controlled clinical trials.

One obstacle to the performance of definitive studies on the issue of efficacy of echinacea is the fact that different medicinal preparations of echinacea have different compositions. Three different species of echinacea, each with a different phytochemical composition, are used for medicinal purposes. In addition to the selection of plant species, the composition of the final product may be altered by the parts of the plant used, the method of extraction, and even the season in which the plant is harvested. As a result, variability in phytochemical composition exists not only among different *Echinacea* preparations but also between lots of the same products. It has been suggested that different preparations of echinacea be standardized by measuring specific components. However, given the many variables that influence the composition of the preparations, it may be difficult to reproduce the material used in a particular study even when this information is provided (Turner, 2002).

Few well-designed controlled studies have been performed to demonstrate the therapeutic value of echinacea preparations. The studies that do exist point to the use of echinacea species in the modulation of length and severity of acute upper respiratory infections (Bauer, 1998; Brinkeborn *et al.,* 1999) and report a positive effect in patients with chronic fatigue or acquired immunodeficiency syndrome (See *et al.*, 1997). It has been reported that echinacea is not effective as a preventative for upper respiratory tract infections in the consumer but probably acts to shorten the duration of the infection once it is acquired (Melchart *et al.*, 1998).

The most consistently positive clinical results involving echinacea preparations are those using freshly expressed juices, which are more likely to contain the water soluble polysaccharide fraction (Bauer *et al.,* 1988; Bauer 1998). An adjuvant study of the use of expressed juice of *E.*

purpurea on recurrent vaginal *Candida* infections over six months showed a 5-16% recurrence rate with the expressed juice contrasted with treatment with econazol, which led to a 60% recurrence rate (Coeugniet and Kuehnast, 1986). A retrospective study with 1,280 children with acute bronchitis demonstrated that treatment with the expressed juice led to faster healing than in the cohort treated with an antibiotic (Baetgen, 1988). It is speculated that viral infections may have partly accounted for this difference.

In healthy volunteers, a commercial echinacea preparation was administered intramuscularly on 4 successive days to 12 healthy males. Phagocytosis by granulocytes against *C. albicans* and the activity of natural killer cells were measured and correlated with echinacea administration. A definite increase in cellular activity was seen, and this declined when administration stopped (Moese, 1983). A subsequent study with healthy volunteers dosed an alcoholic extract of *E. purpurea* roots whose constituents had been determined by high performance liquid chromatography. This was given orally to 24 healthy males daily for 5 days. Phagocytosis was stimulated, and this decreased when administration stopped. These preparations were well tolerated (Jurcic *et al.*, 1989). Interestingly, oral administration appeared to produce a greater rate of increase than did injection.

A German placebo-controlled clinical trial enrolled 109 volunteers who were determined to be at risk of upper respiratory infections (Schöenberger, 1992). Tolerability was comparable in both the placebo and treatment groups, and this assessment was scored subjectively at four and eight weeks by patients as very good, good, satisfactory, or poor. Efficacy of echinacea was deemed somewhat better than placebo.

In another German study, comparative doses of an *Echinacea purpurea* root tincture were evaluated (Braünig *et al.*, 1992). In a double-blind placebo-controlled trial with 180 volunteers, the effect of *E. purpurea root* ethanol extract (1:5 in 55% ethanol) was evaluated for efficacy in relieving symptoms and duration of upper respiratory tract infections. Volunteers receiving a dose of 180 drops per day exhibited statistically significant improvements compared with placebo. Volunteers who received half that dose showed improvement only comparable to the placebo. The study highlights the importance of dosage in evaluating effectiveness of echinacea preparations. The same investigators enrolled 160 patients using a hydroalcoholic extract of *E. pallida* roots showed a trend to quicker recovery from an upper respiratory tract infection when compared to placebo (Braunig and Knick, 1993). This study was less definitive.

Preliminary investigation in patients with far advanced colorectal cancer treated with an echinacea preparation found that there was improvement in the suppressed immune function and possibly some effect on tumor regression or stabilization and decreases in tumor markers (Lersch *et al.*, 1992).

Meta-analyses of randomized trials in healthy young volunteers were completed focusing specifically on the immunomodulatory effect of echinacea. One conclusion drawn from the earlier metaanalysis was the quality of the majority of studies was unsatisfactory. In the later review, two of the studies demonstrated that phagocytic activity was significantly enhanced over that of placebo, while in the remainder of the studies no significant effect could be demonstrated. Concerns were raised because the participants in five studies were conducted using healthy volunteers, and additional questions were raised concerning difficulties in phagocytic laboratory assessment in the three negative studies (Melchart *et al.*, 1994, 1995).

Hoheisel *et al*. (1997) conducted a double-blind placebo-controlled trial enrolling 120 volunteers that investigated the therapeutic benefits of the expressed juice of fresh-flowering *Echinacea purpurea* on the symptoms and duration of the common cold. The results of the study demonstrate that daily treatment with an echinacea preparation at the first signs of a cold inhibit the full expression of symptoms. In addition, if symptoms were fully developed, the echinacea preparation produced significantly more rapid recovery compared with placebo. No specific adverse events were reported. The treatment was deemed both well-tolerated and effective (Hoheisel *et al*. 1997).

A double-blind placebo-controlled randomized trial was conducted using echinacea root preparations in the prevention of upper respiratory tract infections (Melchart *et al*. 1998). At the end of the twelve-week period there was no statistically significant difference between the treatment group and the placebo group. No adverse events were reported. It was concluded that echinacea root preparations are not effective in preventing the incidences of cold infections. This seemed to confirm previous reports that echinacea preparations work best when taken at the onset of symptoms, rather than as a preventative used over a long period of time.

In a study involving triathletes, daily oral treatments for 28 days using pressed juice of *Echinacea purpurea* or magnesium supplements was undertaken. Flow cytometry measurements revealed slight changes in peripheral T-lymphocytes but enhanced exercise-induced increases in urinary IL-6 and serum cortisol. None of the treated athletes developed upper respiratory infections compared to the control group (Berg *et al.*, 1998). The contrast between the use of the alcoholic root tinctures in the preceding study and the use of fresh pressed juice of plant tops in this study should be noted.

A randomized, double-blind, placebo-controlled trial of 559 volunteers was conducted to determine the effectiveness and safety of *Echinacea purpurea* preparations in the treatment of the common cold (Brinkeborn *et al*. 1998). During the study period, 246 volunteers contracted a cold. They were treated with either echinacea preparations at different doses versus placebo. The preparations were taken until symptoms improved or until seven days had passed; no preparation was given for more than one week. The echinacea preparation produced a reduction of 60% of complaints in the complaint index as measured by physicians. The investigators concluded that echinacea preparations are effective in reducing the severity of symptoms; they did not measure reduction in the duration of the cold.

A randomized control trial assessed the effects of echinacea versus placebo on the incidence and severity of colds and upper respiratory tract infections. A total of 109 patients with a history of 3 or more colds or respiratory infections in the preceding year were randomized to receive *E. purpurea* expressed juice or placebo. No significant differences were recorded in the number and severity of infections between the two groups. The investigators concluded that echinacea is no better than placebo for prevention of the common cold, once again confirming previous investigation.

A meta-analysis of echinacea controlled clinical trials identified nine treatment trials and four prevention trials for efficacy in upper respiratory tract infections (Barrett *et al.*, 1999). Eight of the nine treatment trials reported generally positive results. Three of the four prevention trials reported negative results or marginal benefits. It was concluded that echinacea may be beneficial for the early treatment of acute upper respiratory tract infections, but there is very little evidence to support the long-term use as a preventative. Echinacea for early treatment of infection was cautiously supported.

A randomized, placebo-controlled, double-blind trial evaluated the effects of an echinacea herbal tea combination for efficacy in early onset of cold and flu symptoms (Lindenmuth and Lindenmuth, 2000). Ninety-five volunteers received either echinacea tea or a placebo. In the echinacea group, subjects reported that acute symptoms such as stuffiness, scratchy throat, and fever seemed to subside in a day or two. In the control group acute symptoms lasted six to ten days without relief. The study had several flaws including limitations in blinding, simplicity of measured outcomes and self-reporting, and lack of quantifying measures. Nevertheless it pointed to a favorable outcome in reducing the severity and duration of cold and flu symptoms when taken at early onset of symptoms.

Turner et al. (2000) assessed the effectiveness of echinacea (species, plant part and form not specified) and showed that treatment had no significant effect on either the occurrence of infection of the severity of illness in 117 subjects. No significant side effects were recorded.

A recent meta-analysis of clinical studies using echinacea concludes that the available work does not convincingly establish the value of echinacea in immunostimulation and the prevention/relief of colds. The review suggests that a major source of the confusion stems from uncertain identity of the material being evaluated and lack of information on the mechanism of action. Some preparations are definitely of value in reducing the severity of symptoms, but only some. The positive trials appear to include mainly fresh juice and isolated polysaccharides (Percival, 2000).

Another recent review concluded that many reported trials have methodological deficiencies ranging from too few participants to unknown sources of medication. Twelve studies reported efficacy for treating the common cold. These studies also were judged to have procedural inadequacies. Despite clear-cut evidence of efficacy, apparent lack of adverse effects suggested that the lay use of echinacea was probably harmless and should not be discouraged (Giles *et al.*, 2000).

The most recent randomized blinded clinical trial reported that echinacea was no better than placebo in treating the common cold (Barrett *et al.*, 2002). One hundred forty-two college students were randomized to receive either echinacea or placebo at the onset of an upper-respiratory tract infection. The endpoints of this study were self-reports of symptoms with severity over the treatment. Mean cold duration was 5.75 days in the placebo group and 6.27 days in the echinacea group. After controlling for severity and durations of symptoms before study entry, sex, date of enrollment, and use of non-protocol medications, researchers found no statistical significant treatment effects for echinacea. The authors concluded that compared with placebo, unrefined echinacea provided no detectable benefit or harm in college students who had contracted the common cold. Of note, the study medication was analyzed for content and was not found to contain any polysaccharide fraction, which is believed to be a very important immune-stimulating component. It is conceivable in this trial, the study drug containing echinacea was not in the active form.

In commenting on the problems of variability in results observed in various echinacea clinical studies, Rininger *et al.* (2000) identified two key problems of echinacea clinical literature irrespective of study design, including the administration of different echinacea extracts with varying phytochemical profiles, and a lack of *in vitro* studies characterizing the immunomodulatory activity of echinacea test material. Based on their *in vitro* work with various echinacea products and/or raw material, they found that *E. purpurea* herb and powders clearly stimulated macrophage cytokine activation; however, finished products and raw materials standardized to contain 4% phenolic compounds or to echinacoside/alkylamides were inactive. In conclusion, while efficacy studies are important, studies need to be designed to elucidate the action of echinacea *in vivo,* and methods should be devised to standardize active ingredients with a sensible reporting system prior to designing further clinical trials. Then and only then will the results of clinical efficacy trials be useful in guiding health care practitioners in the proper administration and dosing of echinacea.

C. Current Concerns and Future Directions

1. Variability in the Herbal Industry

Considerable variability exists in the preparation of the available echinacea products. Most products in Europe contain the expressed juice of *E. purpurea* aerial parts or alcoholic tinctures of *E. pallida* or *E. purpurea* roots. In the United States, either dried whole plant products or tinctures from the roots are sold (Bauer, 1998). As a result, there is considerable variability in the product used in the reported research (Tragni *et al.*, 1988; Egert and Beuscher, 1992; Steinmuller *et al.*, 1993; Burger *et al.*, 1997) or the studies do not state in what form or from what part of the plant the echinacea product is obtained (Stahl *et al.*, 1990; Lersch *et al.*, 1992; Melchart *et al.*, 1998). The variability in extraction methods makes it necessary to establish botanical and chemical standardization in order to obtain reproducible pharmacological and therapeutic results.

Another obstacle to a systematic approach to the study of echinacea is that neither its active component nor the mechanisms of action for treatment of infections have been defined. Several constituents of echinacea have been evaluated and shown to have various biological activities. Unless an active constituent or combination of constituents can be identified and a desired biological activity defined, it is difficult to address such fundamental issues as dosing, bioavailability, or pharmacokinetics. In the absence of this information, it is difficult to generalize the results of an individual study beyond the specific conditions under which the study was conducted (Turner, 2002).

A wide variety of products are in use involving various echinacea species and plant parts in the form of alcoholic tinctures, hydroalcoholic extracts, teas, and expressed juice (Bauer, 1998). Unfortunately, although many laboratory studies have been carried out on root-derived materials, in the clinic the most convincing results have come for the expressed juice of the aerial parts. In Germany today, health authorities approve the use for health purposes of the expressed juice of *E. purpurea* aerial parts in treating relapsing infections of the respiratory and urinary tract and for external use in poorly healing superficial wounds. Also approved is the use of tinctures of *E. pallida* roots for adjuvant therapy of common cold and similar ailments. Conclusions based upon the references cited fail to allow a convincing choice of the best species, the best plant part, the best dosage forms, and the best means of preparation (Foster, 1991; Melchart *et al.*, 1994; 1995; Bauer, 1998; Barrett *et al.*, 2002; Turner, 2002).

1. Contamination and Adulteration

Fungal contamination is known to occur secondary to improper harvesting, handling, and processing techniques (Roy, 1998). It is imperative that controlled growing, processing, and manufacturing techniques be established.

Also of concern is intentional adulteration of herbal products. The best known is the use of *Parthenium integrifolium* as an adulterant in echinacea products (Hobbs, 1989; Foster, 1991; Bauer, 1998). Adulteration by *P.* can also be detected readily in the same manner based upon the presence of sesquiterpene esters, which are not present in echinacea (1987). Identification of widespread adulteration of *E. purpurea* root with that of *P. integrifolium* led to development of macroscopic, microscopic, and chemical methods to differentiate echinacea species and potential adulterants. Though Parthenium is not similar in appearance to echinacea, once the root is cut and sifted, it has an uncanny resemblance to *E. angustifolia* or *E. pallida* roots, though it possesses a characteristic flavor and fragrance. It does not resemble the root of *Echinacea purpurea* (Foster, 1991). Lower-quality echinacea root materials wild harvested from the southern half of the United States overlap with Parthenium in distribution and are most likely to be contaminated.

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Threats to Wild Echinacea Populations

Kelly Kindscher

The popularity of echinacea medicine has repeatedly risen and fallen in recent history, cyclically renewing concerns that unregulated harvesting will decimate wild stands. Although wild-harvested *Echinacea angustifolia* has been an important medicine for many Native American tribes, predating the 1800s, their historic use did not constitute a threat to existing wild stands. The first concern regarding over-harvest of echinacea occurred over 100 years ago, when questions were raised about over-harvesting *E. angustifolia* in Kansas (Sayre 1903; Kindscher 1989). These worries passed, but the most recent cycles of popularity are causing concern for the sustainability of wild stands which are threatened by consumer preference for wild over cultivated *E. angustifolia,* with resulting price spikes spurred on by research and product development by large pharmaceutical and natural product companies, expanding domestic and international markets, overgrazing, and loss of habitat. These threats are exacerbated by high levels of unemployment, which is as high as 60%–80% in the rural countryside, especially on Great Plains Indian reservations that are close to some of the best stands of *E. angustifolia* (Kolster 1998; Kolster and Youpee 1998).

Habitat Loss

Conversion of land to other uses (farmland, housing, industry, roads)and degradation caused by overgrazing are the biggest causes of habitat loss for echinacea stands of all species over the last few decades. This loss is probably substantially greater than the loss due to over-harvest, which has seldom been the sole reason for extirpation of an echinacea population. *Echinacea angustifolia* has thrived through the centuries by establishing a niche among grasses and slow-growing native plant species, but grasslands, open woodlands, and other echinacea habitats in North America, once extending from Canada to the Mexican border and from near the Rocky Mountains to western Indiana, Wisconsin, and the Southeast, have dramatically declined in area. Some states and provinces in North America report less than one-tenth of 1% of the historic area of native grassland is still intact (Samson and Knopf 1994). In some areas the decline has not been as dramatic, but consider some of the stark losses of prairie habitat revealed by the U.S. Department of the Interior's *Endangered Ecosystems of the United States* (Noss et al. 1995):

90% of original 58 million ha of tallgrass prairie destroyed; remaining 10% mostly in fragments.

99% loss of tallgrass prairie east of the Missouri River; 85% loss west of the Missouri River.

90% loss of native grassland in North Dakota.

47% loss of native grassland in South Dakota by 1977; significant but undocumented losses since then; bluestem prairie declined by about 85% and wheatgrass-bluestem-needlegrass prairie by about 70%.

82% loss of tallgrass prairie in Kansas.

97% loss of tallgrass prairie that once covered the eastern one-third of Nebraska.

Loss of prairie and grassy open woodland habitat also hinders the ability of echinacea populations to interbreed, greatly reducing genetic diversity. The long-term effects of this are speculative, but what is known is that genetic diversity greatly enhances the ability of a population to adapt to fundamental changes in the ecosystem and changing weather patterns. Species range and habitat maps (see the Biology chapter, in this volume) clearly indicate that some populations have limited ranges and therefore limited opportunity for developing genetic diversity. It has been shown that limited genetic diversity in *Echinacea tennesseensis* may be a population constraint for these species when compared to the other *Echinacea* species (Baskauf et al. 1994).

Of the remaining prairie landscape fragments (and other echinacea habitat fragments made up of open woodlands, barrens, and similar habitats), many have been lost to expansion of agricultural fields, roads, and subdivisions, which typically leaves only islands of native habitat. When prairies are fragmented in this way, there is no buffer between the cultivated and natural landscape to prevent soil erosion and chemical runoff. When fertilizers contaminate native prairie, invasive plants are given a competitive edge. In particular, non-native cool-season grasses are favored in echinacea stands, and this has hurt some *E. angustifolia* habitat where the non-native cool-season brome grass, *Bromus inermis*, has invaded some stands.

Fragmentation also opens up native prairies to potential disease organisms that have not evolved with the plant communities. Although there is no historical record of wild stands of *E. angustifolia* being wiped out by disease or insect pests, the blight that decimated the American chestnut is a worst-case scenario for what can happen when new organisms invade an established ecosystem. Currently, aster yellows (a plant disease caused by a microorganism that yellows and stunts echinacea and other plants) and root borers are known to attack individual *E. angustifolia* and *E. purpurea* plants, but they are not considered a threat to whole populations.

Cattle grazing is another stress on echinacea species, especially in remaining areas of native grasslands in the Midwest and Great Plains. *E. angustifolia* has been recognized as a species that declines under heavy grazing (Weaver and Fitzpatrick 1934; Baskin et al. 1994; Fraser and Kindscher 1997). Spring grazing may be particularly detrimental since flowering shoots get damaged and overall seed production is reduced (Kolster 1998; Hurlburt 1999). Grazing later in the year, however, when leaves and stems are tougher and less palatable, does not seem to affect the plant. I have observed that in pastures where there has been continuous heavy grazing, especially spring grazing over many years, *E. angustifolia*, *E. pallida*, and *E. atrorubens* are not seen in habitats where they are found locally in similar situations. Under these conditions, the species mix will shift, and echinacea will loose its competitive niche. In pastures that have been lightly to moderately grazed, echinacea stands continue to thrive. The presence of echinacea can be an indicator of good pasture health, especially when echinacea is observed in grassy areas of a pasture, not just on remaining rock outcrops.

The Echinacea Market as a Threat to Wild Populations

Increased domestic and international demand for echinacea (see the Markets chapter, in this volume) has put pressure on native stands over the last decade. With such large national and international demands, echinacea expert Steven Foster asks, “Who is going to supply the global market?” (Foster 1997). While cultivation fills some of the heavy demand, most commercial supply of *E. angustifolia* still comes from the wild (American Herbal Products Association 2003). Despite cultivation efforts, wild populations throughout the Great Plains constitute the majority of commercial supply of this species and are potentially threatened by over-harvest (Fuller 1991; Kolster 1998).

Local population declines due to root digging of wild *E. angustifolia* stands have been observed in Montana, North Dakota, Wyoming (Crawford 1998; Kolster 1998), Oklahoma, Arkansas, Kansas, Nebraska, and Texas (McGregor 1968; Foster 1991), as well as for *E. pallida* and other species (Foster 1991). Fortunately for the survival of *E. angustifolia* (and possibly the other tap-rooted *Echinacea* species), we have observed root re-sprouting after commercial harvest (Kindscher, personal observation in Montana and Kansas; Hurlburt 1999). We have recently completed field experiments which found a 50% rate of re-sprouting for harvested populations in both eastern Montana and north-central Kansas (Kindscher, et al. preparation).

Although research on echinacea medicinal effects has been insufficient to drive the market for echinacea, it someday might. Imagine how the market would change if *E. angustifolia* was proven efficacious for whooping cough, tuberculosis, leukemia, tumors, or infectious diseases. Already, initial results look promising (see the Medical chapter, in this volume). Some specific results will clarify this. In a study involving over 500 children treated for tuberculosis, echinacea treatment resulted in acute signs of immunostimulation, and an increase of 40%–100% increase in blood leukocyte count, with no other adverse events observed (Parnham 1999). As isolated compounds, polysaccharides from *E. purpurea* stimulated T-cell activity 20%–30% more than a highly potent T-cell stimulator (Luettig 1989). The profoundly positive effects of treatment in disease abatement suggest the therapeutic potential of *E. purpurea*, at least with respect to leukemia, if not other tumors (Currier and Miller 2001). What if these experiments were replicated using *E. angustifolia* or other *Echinacea* species and the results were even better? If one of the *Echinacea* species with a much smaller range, such as *E. atrorubens* or *E. paradoxa,* were found to have a much higher content of some active medicinal constituent, it could be driven onto the endangered species list.

The medical community is not convinced that echinacea or other medicinal plants are valuable therapeutic substances. Pharmaceutical companies are unlikely to be able to patent a wild and historically useful medicinal plant and have been reluctant to fund clinical trials on *Echinacea* species. Before most doctors in the United States will prescribe *Echinacea* species for any condition, more research will be necessary. But if funding does become available for clinical trials using *E. angustifolia,* and if wild *E. angustifolia* is discovered to be the most efficacious of the species available, how long would it take before there is intense pressure on wild stands?

The strong demand for *E. angustifolia* has come from Europe, where it has been widely used and where much of the research has been conducted in Germany. *Echinacea purpurea* is used in many European medicines, but there is strong demand for *E. angustifolia* over *E. purpurea* because it is believed to be superior owing to its use by Native Americans and its status as a wild plant. The inability of commercial growers in Europe to produce marketable quantities of *E. angustifolia* is due to the climate being too moist, which—coupled with a large cult-like following for *E. angustifolia,* even though there is no conclusive evidence that it is better than *E. purpurea* (Foster 1991)—has led to continued strong demand for this species.

The suitability of cultivated *E. angustifolia* to replace wild-harvested roots of the same species has not been established. Myths have persisted that wild-harvested roots are better, especially because they are wild. But in defense of this idea, one broker confided to us in the summer of 2002 that a European buyer of roots cancelled an order for 40,000 pounds of cultivated *E. angustifolia,* (irrigated under a center-pivot in southwest Kansas) asserting that it takes five times more cultivated roots than wild roots to supply the desired results. It is known that well-watered and fertilized plants (of most species) have higher yield but lower content of secondary compounds. This rejection of cultivated *E. angustifolia* roots was the result of chemistry-profile testing that some European firms use to make sure they get the right species and high-quality material. In addition, cultivation of *E. angustifolia* is not easy and requires some labor and skill. Because this wild plant grows slowly, it takes 3 years or more to get marketable roots. Price fluctuations due to demand also make cultivation difficult. When the echinacea boom in the 1990s was sustained for a few years, a considerable amount of *E. angustifolia* was planted by growers. Unfortunately, much of it was plowed up when it was mature enough for harvest because the echinacea market had crashed, and no one would buy or pay a sufficient price for the harvest of the roots.

Wild Harvest as a Threat

Another real threat to the wild *E. angustifolia* is the price harvesters are paid for the roots. When the price is high (see the graph in the History of Kansas Harvest chapter, in this volume), or when economic conditions are poor, harvesters can decimate a stand in a relatively short amount of time. Echinacea digging has been likened to a “Gold Rush” (Crawford 1999) that begins abruptly, occurs intensely, and spreads to other potential root mining sites when resources become depleted.

After sweeping the central Great Plains states, *E. angustifolia* root digging spread northward in the mid-1990s and increased greatly when the demand doubled from 1997 to 1998. The demand brought buyers into the essentially untouched stands in eastern Montana and western North Dakota. In the northern range of this species, these two states were the last places with large *E. angustifolia* stands, and they became the center of the digging and buying frenzy. The Fort Peck Reservation in northeast Montana is a good example of the influence of the expansion of commercial markets. In 1995, two herbal brokerage companies approached the tribes and offered money for the root of a plant that was being studied for AIDS research and other uses (Kolster 1998). The Fort Peck Reservation was the third reservation to be approached after Turtle Mountain and Fort Berthold Reservations (Kolster 1998).

Local root buyers around the Ft. Peck Reservation held contests to find the largest root, and in one competition, the winner was awarded a $100 prize, second place going to a 6-year-old who claimed to “be heavily into rooting” (Stewart 1999). The Fort Peck tribal newspaper, *Wotanin Wowapi,* published a picture of a 38-inch echinacea root that was part of the contest (Kolster 1998; Stewart 1999).

It was estimated that about 350–400 people were harvesting *E. angustifolia* on native prairie lands in the Ft. Peck Reservation area in the spring of 1998 (Kolster 1998). They would harvest anywhere from a couple of hours to over 40 hours per week. Echinacea root harvesting was a family event, and in many respects it is a traditional practice of Native Americans, so many people on the Reservation initially endorsed the activity but became concerned when root-harvesting continued over several years, causing stands to decline. I was told by an elder that at the height of the harvest on the Reservation, the pickup trucks lights were sometimes used at night to illuminate the last remaining flowering cones could be seen and the roots harvested. One local person predicted that echinacea would be gone from the Reservation in another 2–3 years (Kolster 1998).

Digging was not just a Native American or Indian Reservation phenomena. By 1999, coneflower digging was reported in 14 counties in North Dakota, and U.S. Fish and Wildlife Service workers there reported cases of poaching in both Wells and Stutsman Counties (Torkelson 1999). Montana also had significant activity, and it was estimated that 100,000 pounds—at least 700,000 live roots—were harvested during this period (Crawford 1998). One company with a Fort Peck, Montana, address bought as much as 1,200 pounds of root a day and paid out over $1.1 million to coneflower diggers in 1998 (Solberg 1999).

The harvest, and especially the illegal harvest of *Echinacea angustifolia* on U.S. Forest Service lands, became a problem. When the demand for echinacea reached its highest level of activity in Montana in 1998, commercial harvesters from Texas—who had requested a commercial permit the previous day but had not yet received it—were arrested in the Ashland

District of the Custer National Forest with 84 pounds of roots in gunny sacks that they said were for "personal use." They had dug an estimated 6,000 roots and left shovel holes about 6–8 inches deep throughout the area that they harvested (Stewart 1999; Scott Studiner, Custer National Forest Service ranger, pers. com., July 2002). The holes from the harvest were still visible when I visited the sites in July 2002, 4 years after the harvest. Fortunately, the site still had flowering echinacea because small plants had not been harvested and were still present, and a few harvested roots had re-sprouted and were noticeable squarely in the middle of the holes.

Echinacea harvest during this peak time was not limited to Montana, North Dakota, Wyoming, or Kansas. I received a call from Dave Ode, a botanist with the Natural Heritage Program in South Dakota, asking me why "my people" (people from Kansas, or, more technically, vehicles with Kansas license plates) were in Buffalo Gap National Grasslands and elsewhere in South Dakota harvesting *E. angustifolia* roots. I later found out that at least some of the Kansas "diggers" were harvesting roots on their way to the Black Hills Motorcycle Rally held every July in Sturgis, South Dakota, to pay for the trip.

Root diggers were observed in other areas, harvesting other *Echinacea* species. During a previous upswing in the echinacea market in 1987, about 7,000 yellow coneflower plants (*E. paradoxa* var. *paradoxa*) were poached from Ha Ha Tonka State Park in Missouri. This variety is known only from thirteen counties in Missouri and four in Arkansas. (The other variety of *E. paradoxa* [var. *neglecta*] is known only from four counties in the Arbuckle Mountains of Oklahoma.) There were at least two or three cases in the Ouachita National Forest in Arkansas in 1997 and 1998, where diggers were charged for illegal harvest and roots were confiscated (J. Hicks, patrol office, Ouachita National Forest, pers. com. 2002). Well outside the range of *E. angustifolia*, the harvested roots of several *Echinacea* species were sold to buyers as "snakeroot" and then sold to some herbal product company as *E. angustifolia* because that is what the market wanted. It should be noted that for the last decade, only *E. angustifolia* and *E. pallida* have had a market for wild-harvested roots.

The initial threats due to wild harvesting were caused by the sheer number of lost plants. Considering that over 145,000 kg (320,000 lbs) of dried roots of *Echinacea angustifolia* were wild-harvested during the four years of harvest from 1998 to 2001 inclusive (American Herbal Products Association 2000, 2003), and that it may take over 100 plants to make 1 pound (0.45 kg) of dried Echinacea root (determined from roots that we have weighed that were wild-harvested in western Kansas by harvesters), we believe that over three million *E. angustifolia* plants were harvested.

But more than just the loss of plants, the threat to echinacea populations is that the largest plants (with the largest roots) are the ones that flower and make the most seed, and these plants are harvested first. Diggers select for these plants, and if the harvest pressure is sustained, the reproductive class of plants can be reduced, or in some cases, eliminated, at least for a while. The loss of flowers could also negatively affect the rare Dakota skipper butterfly (*Hesperia dacotae*), which finds a major source of nectar from these flowers.

Where shovels are used to dig (primarily in areas where there is a frenzy of activity), 6–8-inch holes are often created, and we could still observe these years after harvest (on both the Ft. Peck Reservation and the Custer National Forest in Montana, and on some harvested rangeland in north-central Kansas). These holes may cause rot in any remaining roots in the hole (Kolster 1998), thus eliminating the chance of root re-sprouting. In addition, disturbance by vehicle ruts and other human harvesting activity provides an opportunity for noxious weeds, such as musk thistle, *Carduus nutans*, or leafy spurge, *Euphorbia esula*, to establish on these areas.

The presence of weeds, even a few, can result in herbicides being applied to rid pastures of all weeds, which further endangers the health of native echinacea stands because most herbicides used in rangeland will kill all broad-leafed plants. In addition, all these disturbances can locally degrade the prairie ecosystem.

The more intensely an area has been harvested, however, the less likely “diggers” are to scour that area again for remaining plants because the returns for time invested and the likelihood of finding large roots diminish (Hurlburt 1999). This may provide inherent protection for wild stands, just as rocky, dry prairies escape the plow. This economy of diminishing returns will likely spare the species from extinction, but the effect of such intense harvesting could be deleterious to the local gene pool. I have found that skilled “diggers” in north-central Kansas visit favorite areas to dig about once every 3 years because it then becomes easier and more worthwhile time-wise to harvest. They also know by looking at the tops which roots they can harvest, and they tend to harvest moderately because they will be coming back sometime. Hurlburt (1999) determined from these stands that there is a sustainable rate of harvest: when 6%–7% percent of medium- to large-sized roots are harvested, populations can sustain themselves. Many experienced diggers are sustainably harvesting. Educating diggers and brokers about sustainable rates of harvest could be good information to share.

Since 2000, demand for wild-harvested echinacea root has decreased dramatically (American Herbal Products Association 2003). Following past cycles, it will rise again and will serve as a catalyst for wild harvest. During the summers of 2001–2003, I made reconnaissance trips to areas with the most intense wild harvest of *E. angustifolia*, areas described as being over-harvested (Kolster 1998). These areas included sites at Fort Peck Indian Reservation and Custer National Forest in Montana, the Missouri National Grasslands in North Dakota, and the Smoky

Hills of north-central Kansas. I looked for echinacea stands during the growing season but after the most recent harvest (except in Kansas, where the harvest season was ongoing but uneven). At all sites, I looked for areas where echinacea was known to have been made locally extinct by over-harvesting. I found no local extinction; at all sites I saw flowering echinacea plants. At some sites (areas of harvested populations in north-central Kansas), stands appeared robust and plentiful, even though evidence of past harvest could be observed. At other sites, stands persisted where they were unlikely to be overgrazed or plowed. At a few sites, such as those on the Ft. Peck Reservation, echinacea stands were very thin and sparsely populated. One could only guess how large or robust any of these populations had been prior to repeated harvesting. I was encouraged to find echinacea plants remaining at all harvested sites visited; it provides hope that the potentially important genetic diversity of these populations has persisted despite over-harvesting.

Conservation Status and Rankings

One good way to ascertain threats to species is to look at the conservation status rankings by Natural Heritage Programs. These rankings indicate that various *Echinacea* species are imperiled in their states (Table 1). In most cases these are *Echinacea* species that have never been abundant or that are at the edge of their ranges in the states in which they have been evaluated. Still, these populations could be very significant for their genetic diversity, or for the diversity of their chemical constituent makeup, and so these rankings are instructive and could certainly change in a negative direction if the demand for wild echinacea were to increase significantly.

Table 1. Conservation Status Ranking of *Echinacea* Species in U.S. States and Canadian Provinces

Species	State/Province	Status
Echinacea angustifolia		
	Manitoba	S3?
	Saskatchewan	S3
	Iowa	S3
	Wyoming	S3
Echinacea laevigata	Federally endangered	
	Pennsylvania	SX
	North Carolina	S1
	South Carolina	S1
	Georgia	S2
	Virginia	S2
Echinacea pallida		
	Ontario	S1
	Nebraska	S1
	Tennessee	S1
	Alabama	S2
	Wisconsin	S3
	Iowa	S4
Echinacea paradoxa var. *neglecta*		
	Oklahoma	S1S2
Echinacea paradoxa var. *paradoxa*		
	Arkansas	S2
Echinacea purpurea		
	Michigan	SX
	Kansas	S1
	Florida	S1
	North Carolina	S1
	Iowa	S2
	Louisiana	S2
	Alabama	S3
	Georgia	S3?
	Mississippi	S3
	Kentucky	S4
Echinacea sanguinea		
	Arkansas	S2S3
Echinacea simulata		
	Georgia	S2S3
	Tennessee	S2
	Kentucky	S3S4
Echinacea tennesseensis	Federally endangered	
	Tennessee	S2

Source: NatureServe Explorer at www.natureserve.org/explorer/index.htm (accessed February 15, 2005). States and Provinces that have not ranked *Echinacea* species or that are reviewing their rankings are not included in this table. Definitions of State/Province Status: SX: Presumed Extirpated; S3?: Vulnerable Inexact or Uncertain; S1: Critically Imperiled; S1S2: In between Critically Imperiled and Imperiled; S2: Imperiled; S2S3: In between Imperiled and Vulnerable; S3: Vulnerable; S3S4: In between Vulnerable and Apparently Secure; S4: Apparently Secure.

Mitigation of Threats

Because research on the efficacy of *E. angustifolia*, *E. purpurea*, *E. pallida,* and the other echinacea species for the treatment of human disease is ongoing but not conclusive, the market demand for wild-harvested echinacea has not exceeded the apparent supply. Nor have wild stands of echinacea shown much vulnerability to massive pest infestation, disease, or invasion by noxious weeds. Destruction of habitat is still slowly growing, owing to conversion of habitat to agricultural lands, home building, and other development, but is not am eminent threat for most remaining stands, which are usually now in remote habitats.

Based on current threats, evidence is not sufficient to suggest listing any additional *Echinacea* species under the federal Endangered Species Act or the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), even though the greatest wild-harvest demand is on *E. angustifolia* and, to a much lesser degree, on *E. pallida*. These two species have large ranges, and there are numerous large stands of *E. angustifolia* and numerous populations of both species. The two least-common species, *E. tennesseensis* and *E. laevigata*, are protected by the Endangered Species Act. It is the other somewhat uncommon species, *E. atrorubens*, *E. simulata*, *E. paradoxa*, and *E. sanginuea*, that need to be watched, not so much for the threat of medicinal trade harvest, but for the variety of threats that affect their habitats, which are often small and could be lost because of competing land uses.

The status of all *Echinacea* species will need to be reevaluated if their popularity booms again as a result of new research findings or greatly increased use of medicinal plants and herbal products. Some future problems could be eliminated or reduced if both diggers and consumers are educated about sustainable harvest practices. Growers could be encouraged to cultivate echinacea if demand increases beyond a sustainable level. Ongoing monitoring programs should be in place to observe population changes for both less common species and for the more common *E. angustifolia* and *E. pallida*, especially in years when buyers are advertising for echinacea roots.

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The Echinacea Market

By Maggie Riggs and Kelly Kindscher

Echinacea has a long history of being one of the most important medicinal herbs in the market, often undergoing sharp spikes and subsequent drops in demand. Although echinacea sales have been flat or in decline since 2002, another upswing in demand is inevitable and expected. When it occurs, pressure on native echinacea stands will increase.

Even during a downturn in demand, echinacea is one of the most sought-after herbal remedies. In 2002, a lower-demand year (and the last year for which detailed data are available), echinacea resulted in almost $140 million in sales and ranked behind only ginkgo as the leading medicinal herbal product (Blumenthal 2002). Earlier in the last demand cycle, in 1996, sales accounted for 9.6% of the total sales of herbs in health food stores, making it the number 1 best-selling herb in America. One year later, echinacea products had garnered about $325 million in sales, 9% of the $3.6 billion in U.S. consumer sales (Blumenthal 1997). The year 1998 brought 151% sales growth in echinacea products (Blumenthal 1998). Sales fell off sharply across the industry in 2001, but echinacea remained the top seller of the twenty best-selling herbs, together they accounted for 62% of sales in U.S. natural food stores (Richter 2003).

Herbal product use continues to be important worldwide. Recent trends show dietary supplement usage has continued to increase from 14.2% of U.S. households in 1998–1999 to 18.8% of households in 2002 (Kelly et al. 2005; see Table 1 for a list of currently available echinacea products found in the United States). In China alone, traditional herbal preparations account for 30%–50% of total medicinal product consumption, and the World Health Organization (2003) predicts that at some time during their lives, 70% of the population in Canada and 90% of the population in Germany will have used a natural remedy.

Table 1: A Sample of Commonly Available Echinacea Products

Brand Name	Echinacea Species	Plant Parts Used	Amount Recommended	Product Type
Alvita	*E. angustifolia, E. purpurea*	root, herb	not specified	tea bag
Celestial Seasonings	*E. purpurea*	root, herb	775 mg	tea bag
Frontier	*E. purpurea*	herb	788 mg	bulk tea*
Frontier	*E. purpurea*	root	717 mg	bulk tea*
Herbs Etc.	*E. angustifolia*	root	15-40 drops	alcohol tincture*
Herbs Etc.	*E. angustifolia, E. purpurea, E. pallida*	root, herb, seeds	40 drops	alcohol tincture*
Herbs for Kids	*E. purpurea*	root	1 mL	non-alcohol tincture†
Hy-Vee Health Market	*E. angustifolia, E. purpurea*	leaf, root	250 mg[1]	capsule
L'il Critters	*E. purpurea*	root, aerial parts	25 mg	gummy bear
Naturade	*E. angustifolia*	root	not specified	drink formula
Nature Made	not specified	root	180 mg	capsule
Nature's Bounty	*E. purpurea*	aerial parts	400 mg	capsule
Nature's Bounty	*E. angustifolia, E. purpurea*	root, herb	not specified	capsule
Nature's Resource	*E. purpurea*	aerial parts	350 mg	capsule
Nature's Resource	*E. purpurea*	aerial parts	125 mg	capsule
Nature's Resource	*E. purpurea*	aerial parts	510 mg	capsule
Nature's Resource	*E. purpurea*	aerial parts	100 mg	capsule
Nature's Resource	not specified	root	35 mg	lozenge
Nature's way	*E. angustifolia, E. purpurea*	stem, leaf, flower, root	2 mL	alcohol tincture
Nature's way	*E. purpurea*	stem, leaf, flower	2 mL	alcohol tincture
Nature's way	*E. angustifolia, E. purpurea*	stem, leaf, flower, root	1 mL	alcohol tincture
Nature's way	*E. angustifolia, E. purpurea*	stem, leaf, flower, root	1 mL	non-alcohol tincture
Nature's way	*E. purpurea*	stem, leaf, flower	400 mg	tablet
Now Foods	*E. purpurea*	root	1.6 mL	non-alcohol tincture
Now Foods	*E. angustifolia*	root	1.2 mL	alcohol tincture
Now Foods	*E. purpurea*	root	1.6 mL	alcohol tincture
Now Foods	*E. purpurea*	root	125 mg[2]	tablet
Now Foods	*E. purpurea*	root	400 mg	tablet
Nutrition Now	*E. purpurea*	root, aerial parts	50 mg	tablet
Olympian Labs	*E. purpurea*	not specified	400 mg	capsule
Quantum	*E. purpurea*	whole plant	100 mg	tablet
Solar Ray	*E. purpurea*	aerial parts	380 mg	tablet
Solar Ray	*E. angustifolia, E. purpurea*	root	460 mg	tablet
Spring Valley	*E. purpurea*	aerial parts	700 mg	capsule
Spring Valley	*E. purpurea*	aerial parts	1,140 mg	capsule
Spring Valley	*E. purpurea*	aerial parts	not specified	capsule
Sundown	*E. purpurea*	aerial parts	400 mg	capsule
Traditional Medicinals	*E. angustifolia, E. purpurea*	root, herb	1,132.5 mg	tea bag
Traditional Medicinals	*E. purpurea*	root	600 mg	tea bag‡
Walgreens Finest Natural	*E. purpurea*	leaf	125 mg	tablet
Yogi Tea	*E. angustifolia, E. pallida, E. purpurea*	root	326 mg	tea bag*
Yogi Tea	*E. angustifolia, E. pallida, E. purpurea*	root	26 mg	tea bag*

Source: These data were gathered from a large grocery store, a food co-op, a discount retail store, and a drug store in Lawrence, KS, during the week of 2/13/2005, compiled by Scott Howell.

[1] Standardized to 4% echinacosides and 4% phenols.

[2] Standardized to 4% echinacosides.

* Organic.

† Organic or ethically wild harvested.

‡ 56% organic.

Although echinacea has remained a popular herb, the marketplace has thrown some curves to those who risk cultivation. *Echinacea purpurea* is relatively easy to grow in both the United States and Europe, and most of its demand has been met by growers. There is a potential market for *E. angustifolia*, but it is difficult to grow. It takes 2–3 years after planting before *E. angustifolia* can be harvested, and the lag time between demand and harvest can create unanticipated surpluses. An excess of cultivated product began to accumulate in 1997, at the peak of consumer concern over harvesting pressures on wild stands. By 1998 and 1999, consumers were asking for products made from cultivated roots, and the harvest of cultivated *E. angustifolia* doubled both years. By 2001, the bulk market for raw materials was flooded with cultivated *E. angustifolia*, markets were few, prices were lower, and a few large growers and many small growers were forced to plow under crops they couldn't sell.

About this time, demand for wild roots began to increase after European manufacturers discovered that cultivated roots tested much lower for desired secondary compounds than wild ones, and they refused to buy cultivated *E. angustifolia* (Steven Foster, pers. com., September 2002).

It is hard to predict the market price for wild-harvested roots, but certainly it is affected by the quantity and quality of the roots collected throughout the country. In 1998, the price paid for a pound of dried *E. angustifolia* varied between $19 and $93 for organic and $16 and $56 for nonorganic roots (Dey 1999; Falk et al. 1999), suggesting a variance in root quality.

Owing to the multitude of individual collectors and remote methods of collection of wild *E. angustifolia* roots, it is hard to quantify how much *E. angustifolia* root is extracted from native stands annually, as well as the price paid for it (see Figure 1 for an example of the number of roots per weight class in a harvest). In an attempt to quantify wild medicinal plants harvested for commerce, the American Herbal Products Association (AHPA 2000, 2003) conducted a survey of regional buyers. These are the people who purchase roots directly from numerous wild crafters and sell them in large quantities to companies that distribute bulk raw herbs to manufacturers of various product lines. Although the studies were not scientifically controlled, they are the best indicators we have to date. A summary of these recent data is in Table 2.

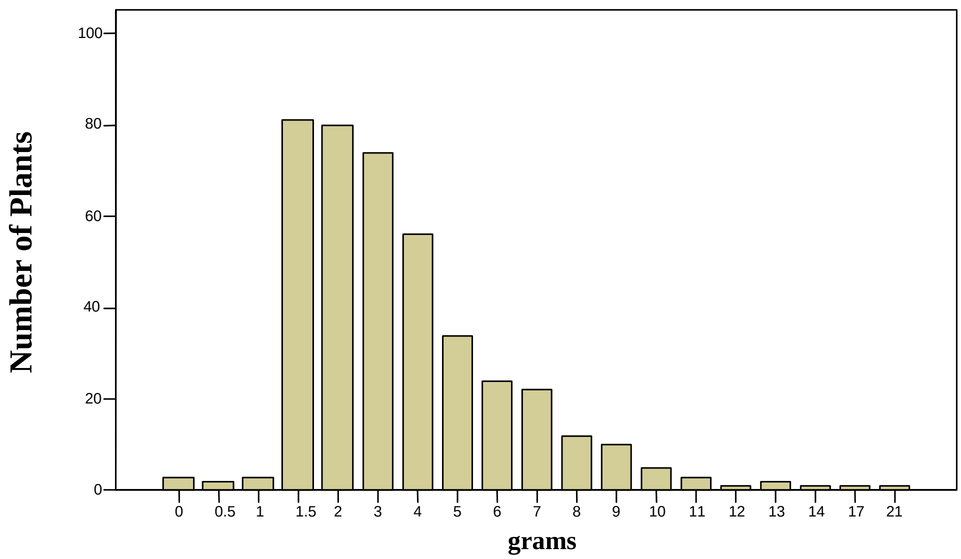

Figure 1. Average weight of *E. angustifolia* roots. This figure shows the number of harvested plants by groups of grams of weight of dried *E. angustifolia* roots grouped in equal weight classes for plants wild harvested by "diggers" near Hays, Kansas, September 2001. *N* = 415 roots sampled; mean weight = 3.65 g. For these roots that were to be sold to a broker, there are 112 roots per pound. Note that the majority of harvested roots are in the smaller weight categories.

Table 2 Dried *Echinacea* Traded by Regional Buyers (in lbs), 1997–2001

	1997	1998	1999	2000	2001
E. angustifolia:					
Root:					
Cultivated	54,644	104,858	219,211	36,081	38,778
Wild	0	226,372	49,984	9,337	33,554
Herb:					
Cultivated	18,388	45,756	24,108	11,167	7,000
Wild	5,000	3,034	0	1,300	2,000
E. pallida:					
Root:					
Cultivated	18,350	45,896	3,100	0	0
Wild	0	11,200	0	11,000	14,092
Herb:					
Cultivated	0	0	0	0	0
Wild	0	0	0	0	0
E. purpurea:					
Root:					
Cultivated	163,428	338,914	390,066	53,291	40,156
Wild	0	0	0	2,545	0
Herb:					
Cultivated	1,088,144	2,538,872	1,591,922	398,382	8,634
Wild	0	67,200	0	0	0

Source: American Herbal Products Association (2000, 2003).

The results of three consecutive tonnage surveys conducted by the AHPA between 1998 and 2001 provide a rough estimate of the combined tonnage of wild-crafted *E. angustifolia*, *E. purpurea*, and *E. pallida* commercially sold during those years. There was a radical shift in preferences in 1998, for cultivated roots rather than wild harvested. By 2000–2001, the markets dropped dramatically for both cultivated and wild-harvested echinacea (AHPA 2003). The market for cultivated roots had been saturated. The tonnage survey indicates that the market for wild-crafted *E. angustifolia* root was robust in 1998 but crashed by 80% in 1999 when cultivated *E. angustifolia* peaked in popularity (see Table 2).

By 2000, however, sales of cultivated roots fell 85% from the peak of 219,000 pounds of dry cultivated root in 1999. Cultivated dried leaf sales peaked in 1998 at over 1,300 tons and fell in 2001 to less than 1% of the volume reported 3 years earlier (AHPA 2003). This boom-and-bust trend has had an almost 100-year history (see the History of Harvest chapter, in this volume) and, unfortunately, will likely continue.

One of the most compelling reasons for the rapid growth in the herbal market, particularly in the mass-market channels, has been the substantial investment in advertising dollars by large companies entering the market. Blumenthal (1998) notes that "companies with deep resources and accustomed to large advertising budgets for mass market launch have changed the industry because they have brought an increased awareness of these products to the average American." Increased market awareness has brought free advertising in the form of magazine cover stories (such as "The Herbal Medicine Boom," featured on *Time Magazine*'s cover on November 23, 1998) and segments on prime-time television shows like 20/20.

Since the majority of consumers using botanicals are self-medicating, what they read in the popular press has a significant influence on their herbal buying habits. Unfortunately, journalists, rather than scientists or medical professionals, write much of what the consumer reads, and "their ability to interpret scientific studies is limited and the information they provide is frequently not cited. These publications are not peer reviewed and are barely monitored by the FDA or the scientific or medical communities," observes Rowena K. Richter (2003), in her book, *Herbal Medicine: Chaos in the Marketplace*.

Much of the popular literature on herbal treatments implies claims that lead consumers to high expectations. Without understanding much, if anything, about the mechanisms of various herbal treatments, consumers can be let down when results are less than expected. Although an inadequate outcome could well be related to the quality of the product, dosage, or time of day taken, a disappointed consumer generally dismisses the herb as not efficacious. Negative publicity—in reports of ineffective or mixed results, or in the publication of adulterants—has hurt the market, and some issues could potentially be used by the medical establishment to deliberately hurt the herbal products market by discrediting the efficacy of herbal use (Blumenthal 2003).

It is hard to predict what trends the popular magazines and talk shows will launch. Just announcing sales figures can drive the market, such as when the *New York Times* referred to St. John's wort as the herbal rival to Prozac, noting that in Germany it outsells Prozac four to one (Richter 2003). But the best possible publicity is positive results from clinical trials. If the research is done at a prestigious institution, all the better. Although echinacea has consistently led herbal sales since 1995, it was not until 2003 that it became the subject of clinical trials funded by the National Institutes of Health (NIH; Richter 2003). The Center for Dietary Supplements Research at the University of California, Los Angeles, received NIH support to conduct pilot research on specific immune-enhancing actions of echinacea, and Iowa State University, in collaboration with the University of Iowa, received a 5-year NIH-funded grant to establish a botanical center to study both echinacea and St. John's wort. This and other research results, some of which is reported in the Appendix to this volume, provide both positive and negative findings on the efficacy of the use of echinacea products.

The effect of publicity resulting from positive results of clinical trials on echinacea sales could be profound. It is important to stay informed about any ongoing or planned research or clinical trials involving wild-harvested *E. angustifolia* root or other wild echinacea species because positive results could lead to increased demand and increased price, thereby causing wild harvesting to sharply increase.

Another consideration related to the future market is the increasing interest of insurance companies and managed-care organizations in reimbursing use of herbal products. This will probably be key to widespread use and acceptance of herbal products. Richter (2003) notes that "health insurance rarely covers consultations on herbal medicines or the products themselves. Even individuals who are aware of botanical treatments may not be able to afford to pay out of pocket for them." At a time when so many Americans cannot afford health insurance, the lower-cost botanical treatment alternative may become increasing relevant. If major medical insurance companies acknowledge the savings and begin to cover visits to naturopaths and other herbal consultants as well as reimbursements for the herbs they prescribe, the market for echinacea products would likely significantly increase.

In 1997, Dr. Larry Kincheloe in Oklahoma City did a small survey of the cost savings associated with usage of botanical medicine instead of pharmaceuticals in his clinic. His conservative estimate showed a savings in direct yearly drug costs of between $500,000 and $750,000 for his clinic, which contracts to cover 60,000 members of an HMO (Kincheloe 1999). As of 1998, a few of the companies covering acupuncture, naturopathy, and chiropractic care also covered reimbursement for doctor-prescribed nutritional supplements, including botanicals. American Specialty Health Plans of San Diego, CA, for example, covers a complete line of Chinese herbal formulas.

In great part, it was consumers demanding unrestricted access to botanicals that shaped the Dietary Supplement Health and Education Act of 1994 (DSHEA). That same political force may drive major insurance companies to provide coverage for herbal and homeopathic consultations and products.

It is clear that the market and the influences of research findings and publicity on the market will determine the future demand for echinacea. Because there is a long history of safe use of echinacea, because some research does show effectiveness, because there is current NIH research on its efficacy, and because there is already an industry built on wild harvest and cultivation, it is hard to imagine a future marketing scenario that would not include echinacea in it.

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Cultivation of *Echinacea angustifolia* and *Echinacea purpurea*

Kelly Kindscher and Maggie Riggs

Although *Echinacea purpurea* is easily grown from seed, and many gardeners grow it, *E. angustifolia* is notoriously hard to germinate and labor intensive to cultivate. For these reasons, cultivation of *E. angustifolia* has historically and primarily been limited to collectors of medicinal plants on a very small scale. However, by 1991, a handful of commercial plantings were in place (Foster 1991), but the suitability of cultivated *E. angustifolia* to replace wild-harvested roots of the same species had not been established. Many people believed that the wild-harvested roots were better. As we learned from an Echinacea root broker, one buyer of roots recently cancelled an order for 40,000 pounds of cultivated *E. angustifolia*, asserting that it takes five times more of the cultivated roots than wild roots to supply the desired results.

Although *E. angustifolia* and *E. purpurea* both have a well-documented history of use for a variety of medicinal protocols, no consensus exists about which active constituents are responsible for their efficacy. Some secondary compounds can be increased by certain agricultural practices (El-Gangaihi et al 1998, Berbec et al 1998), yet the medical community does not know of any compound or group of compounds for which selection is a known benefit. Adding to the difficulties of supplying cultivated roots for commerce, medicinal components of cultivated *E. angustifolia* roots vary considerably from harvest to harvest. Depending on seed stock, soil type, time of planting, viability of seed, moisture variability, temperature variability, fertilization techniques, insect controls, harvest times, and post-harvest handling, constituent levels rise and fall. Additionally, it takes 3–4 years before *E. angustifolia* roots can be harvested, during which time the market and going price can change radically. Several large commercial growers have shied away from future plantings of *E. angustifolia* and prefer to stick with the cultivation of *E.*

purpurea, which is much easier to grow, considerably less labor intensive, and has no commercially significant wild-harvested equivalent.

By analyzing the natural growing conditions of *E. angustifolia*, we may learn what effect surviving in rocky limestone soils through persistent drought and long, tough winters play in the chemical composition of wild Echinacea. Growers typically try to emulate natural conditions in their planting schemes, so how does one duplicate the qualities of the wild-harvested roots in cultivation? The following overview of cultivating techniques for *E. purpurea and E. angustifolia*, the main species of commerce, is intended to stimulate dialogue and further research. Perhaps, in the future, cultivated *E. angustifolia* will satisfy a portion of the market demands for this popular medicinal plant.

Seed Choice

It is important to begin with pure live seed. If you gather your own seed, collect cone heads that easily release their achenes or seeds. If the achenes are difficult to dislodge from the head, the seeds are probably immature. The ideal time for collecting seeds in northern states is a week or two before or after the first hard frost. Seed maturation in Kansas and Nebraska tends to be a few weeks later than in the northern states. If seeds are harvested prematurely, it is likely that none will be viable. Check some of the seeds you are collecting by breaking open the achenes and examining the seeds. If most of the achenes are empty or the seeds look shriveled, they are probably not viable and will not germinate. Another reason to delay seed harvesting is to collect less debris. The brown florets that are attached to each seed will wither and fall off the head if harvest is delayed. The seeds are also released as the cones dry, so harvest in dry weather, or collect the head and shake them when dry.

Collect your seeds from several different plants, as viability varies from plant to plant. If possible, collect from different sites of the same species to increase the genetic diversity of your future stand (Cech 2002). You must be sure that you are harvesting the same species and also that there are no stands of other Echinacea species in the vicinity. Store your seeds in a cool dry place, preferably not for more than 6 months. However, if placed in cold storage, seeds should remain viable for about 60 months (Foster 1991).

If you are purchasing seeds, first decide if you want seeds from wild or cultivated sources. Commercial seed has historically been collected from wild stands, but cultivated seed sources are readily available. (See Table 1). Depending on growing conditions, wild seeds may reflect the dry conditions typical in July and August, likely resulting in more dried or shriveled seeds or empty achenes. Seeds from cultivated stands are more likely to be filled out, reflecting adequate moisture and nutrients during the time they were developing. If you choose wild-harvested seeds, try to make sure that the seeds were harvested in a sustainable manner.

When purchasing seeds, the buyer should establish that seeds have been tested for purity and viability. Require 90% or better pure live seed, a precise identification of seed source, and certified verification of species. The buyer can easily test for empty achenes by crushing seeds of a representative sample with a fingernail and looking for live moist endosperm. The buyer might ask if the seller is aware of the South Dakota State University germination protocol, which is described below. Find a seed company that has expertise in working with wild species and experience cleaning seeds. Ask when the seeds were harvested and how they have been stored. Suggestions for seed sources are also listed at the end of this chapter. Wholesale seed prices for *E. angustifolia* have ranged from $170 to $750 per pound. The price of seed for *E. purpurea* is considerably less, available for around $24/pound. There are approximately 145,000 seeds in 1 pound of *E. angustifolia* seeds, and approximately 117,000 seeds in 1 pound of *E. purpurea* seeds.

Seed Germination and Stratification

One basic obstacle facing field cultivation is poor and erratic seed germination. In order to germinate, seeds must be viable. Research conducted by Richard Little (1998) at South Dakota State University on seed viability indicates that low test-weight seed might indicate that seeds within the achenes are undeveloped or missing altogether. Test weights above 200 $g\text{-}cm^{-3}$ should be fairly free of empty achenes. In early experiments it was observed that heavier seed germinated at a greater rate than light seed. Empty achenes were an obvious cause of the low germination rate of lighter seed. Damaged or undeveloped embryos could also contribute to the lower germination rates of lighter seed. Little also observed during his research on germination of *E. angustifolia* seed that there is evidence that some populations have inherently lower germination rates. Germination of seeds from one South Dakota location has been consistently 30% lower than seeds from a second South Dakota location (Little1998). Germination also varies by species. For example, the percentage and speed of germination of six lots of *E. purpurea* were unaffected by seed weight or light (Wartidiningsih and Geneve 1994a, 1994b).

Because Echinacea seeds are embryo dormant, they require a period of cold, moist stratification for optimum germination. In the wild, seeds would be exposed to temperature extremes and varying moisture conditions. There are several methods of simulating the conditions of winter and spring that cause the seed covering to break open in the wild. Several variations will be presented in this section, beginning with the recommendations from South Dakota State University (SDSU).

The protocol established at SDSU describes placing seeds on blotter paper moistened with a solution made from 3 grams Ethrel per gallon of distilled water. The moistened blotter paper is placed in covered plastic seed boxes with transparent friction tops. The boxes are placed under continuous light (75–200 foot candles, cool-white fluorescent lamps) in a cold environment (2–6ºC) for 14 days followed by placing the seed boxes under continuous light (400–700 foot candles, warm and cool fluorescent lamps) at 25ºC. Using this protocol, researchers found that seedlings were ready to transplant to the field within 9 weeks after placing them on blotter paper; over 95% of viable seeds germinated. An advantage of this protocol was that all seedlings were the same size when transplanted to the field. A detailed account of this protocol is described in Feghahati and Reese (1994).

Foster (1991) describes a method that entails placing seeds in a mix of sand and peat and placing them outdoors (covered with a mesh screen to keep critters out) and left over the winter. Another method described by Foster is to place seeds in moist but not wet sand (or peat) in a plastic bag and refrigerate for 60–90 days, which he finds is adequate under household rather than laboratory conditions. Then rinse the sand off the seeds in a strainer with fine enough mesh to retain the seeds, but large enough to let the sand pass through.

In a study done as part of a doctoral dissertation at Vanderbilt University in 1976 (cited in Foster 1991), Thomas E. Hemmerly showed that the longer the stratification period was (up to 4 months), the less important temperature became as a factor in seed germination. Light was found to stimulate germination, but it was less significant than temperature or stratification. Hemmerly determined that the optimum temperature for germinating Echinacea seed under light is around 20–25ºC (about 68–79ºF).

Smith-Jochum (1987) showed that 1-month stratification in peat moss or sand, followed by soaking for 24 hours in water, showed significantly higher germination rates than 2-month stratification in sand or peat moss followed by soaking for 24 hours in potassium nitrate or treatment with gibberelic acid. There is a theory that the Echinacea seed harbors a water-soluble germination inhibitor that naturally leaches out during the winter snow-and-thaw cycles and that soaking the seeds until a certain osmotic pressure is achieved, then reducing moisture to a predetermined level, might enhance germination. However, Little (1998) at SDSU found no evidence of this water-soluble germination inhibitor in his research.

Higher germination rates were also achieved simply by soaking the seeds in water prior to stratification. Presoaking the seeds for 24 hours improved germination compared to moistening the seeds only at the time of stratification, presumably allowing increased water imbibitions (Sari, Morales, and Simon 1999).For a recent review of stratification requirements without the use of ethylene, see Parmenter *et al.* (1996).

Direct Seeding of Unstratified Seeds

Unstratified seeds are best sown directly into the field or garden in the fall, allowing for a period of exposure to cold, moist outdoor conditions to naturally break seed dormancy. A fine seedbed along with a dressing of ground limestone directly under the row enhances chances of germination. Bed preparation and seed sowing is often easier in the autumn when the soils are relatively dry. Be advised though: direct seeding is a challenge, even to the most experienced grower, owing to fluctuations in weather and other factors.

Alternatively, unstratified seeds can be sown into flats or plug trays in an unheated greenhouse (or outdoors in the shade protected by screen) in February, the ideal soil temperature being a cool 55–60ºF. *E. angustifolia* and other species with taproots must be planted in deep pots or "conetainers" so that the root will not touch the bottom of the container before transplanting. Therefore, it is best to transplant tap-rooted species in the fledgling stage. These plants should be ready to transplant into the field by May (Cech 2003). Most germination failures can be traced to planting in soils that are too warm, which lowers the germination rate even when the seeds have been artificially stratified (Cech 2003). *E. purpurea* germinates readily in a cool greenhouse without stratification, but germination of the other species is improved by at least 30 days of freezing conditions.

Planting seeds on top of the soil and tamping them down onto the surface without soil cover will generally yield the best germination, as light may aid the germination process. Seeds tamped into the soil will germinate in approximately 5 days, but when covered with only 1/8 inch of soil, germination can take between 2–4 weeks (Foster 1991). Space seeds 2 inches apart in rows 18–24 inches apart. *E. angustifolia* are best thinned to 8 inches apart, while species with a fibrous root, such as *E. purpurea*, are optimally placed 1–2 feet apart in the row. By the autumn of the first year, plants become self-mulching.

It is possible to propagate Echinacea by dividing and transplanting the crowns, but since this is not feasible for a field-scale operation, it will not be discussed here..

Transplanting

Echinacea prefers to grow in full or part sun, but *E. purpurea* is sometimes found in lowland, riparian areas, which are often partially shaded. There are several advantages to transplanting seedlings over direct seeding. *E. angustifolia* seed is expensive and is used more efficiently by transplanting. Slow-growing *E. angustifolia* will not compete well with weeds, and solid-seeded beds may be more difficult to weed. It is easier to mulch a space-planted crop than a direct-seeded one, as placing straw or mulch around uniformly emerging plants is much easier than mulching around random, direct-seeded plants.

If you choose to transplant, do as much soil preparation in the fall as possible to be prepared for transplanting the next spring. Building beds or ridges, laying landscape fabric, and seeding a perennial cover crop in wheel tracks can all be accomplished in August or September (Cech 2003).

Soils

Ideal soils for *E. purpurea* have a pH value between 6 and 7. *E. angustifolia* prefers more alkaline conditions with a pH value between 6.5 and 8. Although sandy loam, rocky clay, and limestone substrates have all been known to support healthy populations of Echinacea (Cech 2003), it is imperative that *E. angustifolia* be grown in well-drained soils. Species with fibrous roots, such as *E. purpurea*, are better adapted to growing in poorly drained situations. Given that the soil is well drained, abundant moisture improves overall plant size, health, and seed production, but there are questions as to whether drought cycles increase levels of beneficial constituents in the roots. Generally, dry, low-nitrogen soils produce higher concentrations of essential oils, while moist, nitrogen-rich soils produce high levels of alkaloids (Foster 1991).

Fertilization

Side dressing with organic compost and composted manures increases drought tolerance and overall health of the plant. Dilute foliar feeds, manure tea, and seaweed tea also improve plant health and yield (Cech 2003). Since fertilization and time of harvest appear to have the greatest effect on the chemical composition of cultivated Echinacea, however, it is important to keep accurate records of all applications when marketing to medicinal manufacturers. There are several interesting examples of specific fertilization regimes affecting a particular chemical constituent. When Dr. Rudolf Bauer tested samples of both wild-harvested and cultivated *E. angustifolia* from several locations in Kansas, which were collected in March 1998, he found that the application of biodynamic compost resulted in isobutylamide levels that were "off the chart" (pers. comm., Terry Pitts, Sterling, KS, farmer, October 1998). There was a variance from .2% in the wild-harvested *E. angustifolia* root to >2.3% in the sample root from cultivated *E. angustifolia*, which had been fertilized with biodynamic compost. The plants treated with biodynamic compost also had a more balanced pH of 7.2, which was attributed to the buffering of the compost. Compared to wild-harvested plants, the cultivated *E. angustifolia* plants fertilized with biodynamic compost also had the lowest levels of echinacosides. In other analysis, El-Gangaihi et al. (1998) found that increasing nitrogen and potassium via fertilization will alter alkyl amides. Berbec et al. (1998) reported that differences in soil type (sandy vs. loamy) and fertilization also had an impact on the presence and amounts of phenolic acid compounds. This study looked at the composition of chlorogenic, caffeic, and ferulic acids.

Mulching

If you are direct seeding *E. angustifolia*, it is important to keep mulch light and loose since *E. angustifolia* requires light for germination. One suggested method is to sow seed into wheat stubble in the fall and to flail-chop the stubble to provide mulch.

Disease and Insect Problems

Bringing Echinacea into production has resulted in increased disease and plant problems, compared to wild stands. Although mulches will help retain moisture and reduce weeds, they might cause insect and disease problems. One grower has reported aphid problems where wheat sprang up using wheat straw mulch. A grower in British Columbia noted a high incidence of cutworms only where newspapers were used as mulch. A grower in Iowa used black plastic mulch that he claimed caused roots to rot while nearby plants without plastic were rot-free. Air circulation under landscape fabric should prevent this problem.

E. purpurea appears to be the most susceptible of all Echinacea species to aster yellows, causing the stem to become yellow to red in color. As the disease progresses, the flowers stop producing seeds and become leafy. This disease is spread by leafhoppers and appears to develop over a year or two. Where some growers have controlled disease spread by removing infected plants as soon as they are identified to prevent spread of the disease, other growers have reported near complete losses in areas of heavy infestation. Resistant cultivars are not available, and control of the diseases can only be achieved by controlling leafhoppers (Sari et al. 1999).

Wilt, or blight (*Fusarium oxysporum*), causes the formation of dark tissues along the leaf edges that eventually die. Wilting of the shoots is also evident. If you cut through the stems or roots near their base, the tissues contain dark blotches in and around the vascular system. This has been observed only in wetter soils or during wet years.

Weed Control

Weeds can be controlled by mulching, hand pulling, and hoeing and cultivation. Attempts to cultivate with a tractor and row-crop cultivator are often unsuccessful because stems easily break off at the base. Herbicides are not labeled for use on *E. angustifolia*, nor do organic certifiers approve them.

Harvest and Storage

When plants are grown from seeds, it may take 3–4 years for roots to reach harvestable size (Foster 1991). Some growers observe that older cultivated *E. purpurea* roots may become pithy and woody, but the taproots of *E. angustifolia* grow larger and deeper the longer they are in the ground. Tops of flowering *E. purpurea* can be harvested the second year.

Fall is the best time to harvest roots when the moisture content is lower. A sturdy spade, pick ax, or modified potato digger are a few of the tools developed to lift the roots. Roots should be cleaned with water and a brush or a power hose and piled in the shade. Large crowns should be broken apart in order to allow access to dirt.

The roots can be dried in open air under shade or under low forced heat or fans (Cech 2003). An herb dryer set at 110° F degrees is also effective, and faster. Taproots are usually dried whole, but the fibrous roots (*E. purpurea*) are best dried in pieces. Dry the roots until they snap, and store the roots in plastic bags in a cool, dark location.

There is a growing demand for the tops of flowering *E. purpurea*. Echinacea leaf and flower are best harvested at the peak of flowering, which is usually in midsummer. The stems are cut just above the first discolored leaves of the rosette, and the leaf and flower are stripped from stem and used fresh or dehydrated. The flowers must be split at least once before drying, or they will rehydrate from internal moisture once put into storage (Cech 2003).

It is known that time of harvest (season) affects alkamide levels. Samples collected in June will be different from samples collected in October or November. Fall harvest seems to produce both greater quantity and quality of essential oil (see Smith and Jochum's studies, cited in –Foster [1991],p. 78). The time of day a plant is harvested can also affect the quality of chemical constituents and concentrations in various plant parts, as can weather conditions (Foster 1991). In his notes regarding chemical tests on cultivated vs. wild-harvested *E. angustifolia* roots, Bauer (1999) records that, in order to draw general conclusions, it would be necessary to examine samples of plants that were harvested in the same year of growth, dried by the same process, using uniform mode and length of storage.

Not only does cultivation affect chemical constituents, but so does treatment of harvested material. For example, *E. angustifolia* contains a glucoside and an essential oil, both of potential pharmacological significance. Slow drying will retain the essential oil, but quick drying will help retain higher quantities of the glucoside since enzymes present in the plant will rapidly hydrolyze them.

Conclusion

In spite of the fact that there is considerably more practical information available in 2003 than a decade ago, growing *E. angustifolia* remains a challenge. Growers cultivating for commerce should research markets well (see the Markets chapter, in this volume), be critical when choosing seeds, and take care with harvesting procedures. It is also a good idea to become "certified organic" before planting in order to assure your harvested *E. angustifolia* roots are suitable for the health food market. Begin slowly when growing *E. angustifolia*, learn from your mistakes, and then expand your operations. Keep detailed growing and harvest records and, if possible, have harvested roots and flowers tested for pharmacologically active constituents. In this way, growers will continue to correlate process with results and secure the future market for cultivated Echinacea.

***Echinacea* Seed Bulk Suppliers**

This list was compiled from a series of Internet searches during February 2005 for suppliers selling Echinacea seed (*E. angustifolia*, *E. purpurea*, or *E. pallida*) in quantities of at least 1 pound.

American Meadows, Inc.
223 Avenue D, Ste. 30
Williston, VT 05495
Phone: (802) 951-5812; Fax: (802) 951-9089

Critical Site Products
16245 S 71 Highway
Belton, MO 64012
Phone: (816) 331-9738; Fax: (816) 331-9739

D. Landreth Seed Co.
P.O. Box 16380
Baltimore, MD 21210-2229
Phone: (800) 654-2407; Fax: (410) 244-8633

Elixir Farm Botanicals
Brixey, MO 65618
Phone: (417) 261-2393; Fax: (417) 261-2355

Hamilton's Native Nursery & Seed Farm
16786 Brown Road
Elk Creek, MO 65464
Phone: (417) 967-2190; Fax: (417) 967-5934
hamilton@train.missouri.org

Headwaters Herbs Medicinal Growers
Bozeman, MT 59715
Phone: (406) 585-3389

Horizon Herbs, LLC
PO Box 69
Williams, OR 97544
Phone: (541) 846-6704; Fax: (541) 846-6233

Johnny’s Selected Seeds
955 Benton Avenue
Winslow, ME 04901
Phone: (800) 879-2258

Missouri Wildflowers Nursery
9814 Pleasant Hill Road
Jefferson City, MO 65109
Phone: (573) 496-3492; Fax: (573) 496-3003

Prairie Moon Nursery
RR 3, Box 163
Winona, MN 55987-9515
Phone: (507) 452-1362; Fax: (507) 454-5238

Pure Air Native Seed Co.
24882 Prairie Grove Trail
Novinger, MO 63559
Phone: (660) 488-6849; Fax: (660) 488-5548
oberle@nemr.net

Seedland, Inc.
9895 Adams Road
Wellborn, FL 32094
Phone: (800) 820-2080; Fax: (386) 963-2079

Sharp Bros. Seed Co. of Mo., Inc.
396 SW Davis-Ladue
Clinton, MO 64735
Phone: (800) 451-3779; Fax: (660) 885-8647
sales@sharpbro.com

Western Native Seed
P.O. Box 188
Coaldale, CO 81222
Phone: (719) 539-1071; Fax: (719) 942-3605

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Establishment of Baseline Monitoring

Kelly Kindscher and Dana M. Price

No comprehensive long-term data exists on wild populations of echinacea. The effects of harvesting are not fully understood. We have set up a model for monitoring wild echinacea populations. This monitoring will help to determine the impact future wild harvesting has on Echinacea populations. We present an overview of the first year's survey of *Echinacea angustifolia* stands on private lands in Kansas and on the Little Missouri National Grasslands in North Dakota as an example of a monitoring program.

Echinacea angustifolia was a natural choice for this initial study because it is the most widely harvested wild echinacea species and the most economically important.. Its wide distribution throughout the Great Plains allows for a larger sample size than is possible with other species of wild echinacea such as *E. tennesseensis* or *E. atrorubens*.

Monitoring echinacea harvesters' work is impractical because the region of harvest is large and harvesters are numerous when the price for echinacea roots is high. Therefore, we must rely on population surveys and reported sales of echinacea roots to estimate harvest activity. The study requires data detailed enough to reliably measure population changes for each plant size class, and for the entire population. This information can be useful for estimating the total population size, estimating the sustainable yield of the roots, and comparing responses of different populations to changing environmental conditions.

In order to monitor populations of echinacea species, the study employed a simple monitoring scheme that involved teams of two people who counted plants in permanent marked plots. With some flexibility, this plan can be easily applied to monitoring the other eight echinacea species as well.

Terms

Site: A study area in the field that includes a population of echinacea. The 20 small plots at a site are used to estimate information about the population at the site as a whole.

Plot: The small, 1m x 1m study area in which all echinacea plants are counted. There are 20 plots located at each site.

Population: The assemblage of individual echinacea plants found at a site. These plants may or may not be genetically isolated from other nearby populations.

Patch: The area at a site on which a chosen dense stand of echinacea plants grows.

Methodology

During the summer of 2002, teams of workers from the University of Kansas established plots at four different sites in north-central Kansas and four additional sites in southwest North Dakota. These eight sites were selected because they have a history of wild harvest on private land in Kansas, and on federal land in North Dakota--the Little Missouri National Grasslands). In North Dakota, three sites were chosen in the vicinity of Medora and Stony Butte. In Kansas, the sites chosen were in the vicinity of Plainsville, Codell, and Natoma.

Specific site selection was based on density of echinacea populations and ease of access. Proximity to permanent, man-made structures (e.g., fence lines, telephone poles, road signs) was also considered as it made marking and relocating plots easier.

For each echinacea patch, the observers recorded signs of harvest or other disturbance, a description of the soil, the slope and aspect of the patch, a notation of surrounding dominant vegetation, and a clear description of the site location referencing GPS and triangulation readings. A sample data sheet has been included as a model (see Table 1). Sites were also marked on a topographic map. All project notes were typed soon after fieldwork. Twenty plots per site were established. Based on Kansas *Echinacea angustifolia* data collected by Dana Price Hurlburt in 1996–1998 for her dissertation (Hurlburt, 1999), twenty plots per site were determined sufficient as sufficient sample size. This number of plots will allow researchers to detect a change in population size from one year to the next of 10% or greater, with greater than 90% certainty and a less than 10% false-change error rate (see Table 2).

Plot size was $1m^2$, and metric units were used for measurement as they are considered the scientific and international standard. This size is large enough so that most plots will include at least some plants. At each site these plots were placed at 5m intervals along a 100m measuring tape so that they can easily be found again. For odd-shaped populations of echinacea, two or three shorter-length transects were used.

To determine the starting point for each transect, field surveyors observed the population to assess the general shape of the patch, choosing a line through it. Starting points were located a random distance and a few meters away from a fence or permanent post to avoid cattle trails and overgrazing, which are common adjacent to fences. Having decided on the starting point, surveyors then identified two permanent fixed objects nearby to use as the other two points for triangulation. I recommend using points on a fence line because they are easy to locate, but any obvious landmark is suitable. Steel posts are also recommended because they do not rot and can be added if other obvious landmarks are not available. I suggest marking both triangulation points with spray paint for easy relocation. We spray painted the top 1/3 of the steel posts. For a full list of supplies needed for the work, see Table 3.

Surveyors then ran separate measuring tapes from each of the two fixed objects to the starting point. The exact starting point is where these two tapes met to form a triangle. At that point, a piece of steel rebar, about 1 foot long with a brightly colored plastic tape tied to its top end, was hammered into the ground, designating the exact starting point. This can be located with a metal detector upon return to the site, providing definite confirmation of the starting point. Clear descriptions of the fixed triangulation points, distances from each triangulation point to the starting point, a map showing these three points and their relationship to the road, or the feature, and GPS (Global Positioning System) coordinates were recorded in the field notes. Although the research team recorded GPS data, most global positioning system units do not currently offer the accuracy needed to locate a plot within inches or centimeters. Hopefully that will change in the near future, and GPS data can then be used to easily establish and relocate plots. This GPS location information was later transferred to a field data file. (The reason a tall steel post is not just pounded in at the starting point is because cattle tend to rub against the post and disturb the site. Also steel rebar is pounded flush with the ground so that it is not tripped on and moved by cattle or vehicles.).

From this starting point, a 100m tape measure was laid out in the direction that passes through most of the patch (Note: the aim is to sample the population by randomly locating plots in the population.). A compass was used to determine the direction of the line, and this was recorded in the field notes. Flags were placed along the 100m tape at 5m intervals, the first being the starting point. At each flag, a 1m x 1m plot frame, made of 1 inch PVC pipe held together with elbow joints and glue, was placed alongside and on the right side of the tape. Field surveyors walked along the left side of the tape to avoid trampling vegetation in the study plots.

At every plot, a GPS measurement was taken and recorded. A 10" long piece of ½" diameter rebar with plastic flagging tape tied to its top was pounded into the ground. The ends of the plastic tape and a centimeter of the steel rebar were left sticking out of the ground. This system, used in conjunction with a metal detector (an inexpensive model is sufficient) will allow for locating plots more easily in future years.

One team member walked the perimeter of each patch taking GPS measurements. These measurements were later used in conjunction with mapping software to determine the size and location of the patch. Where there was a distinct line at the edge of the echinacea patch, the surveyor followed it. In areas where there was no clear line, the surveyor made a judgment call and walked along the edge of the patch encircling the vast majority of plants and the entire dense patch.

For the actual process of recording data, we found that two people working together improved the quality of work. When available, a third and fourth team member increased efficiency, particularly in laying out the plots. Often these extra team members were in charge of laying tapes, taking GPS readings, and marking plots.

Plants were divided into five size classes using calipers, as per Dana Price's dissertation (Hurlburt,1999), and plant sizes were recorded on data sheets. The size of the root crown was measured for each echinacea plant using calipers and recorded on data sheets as well. Size classes were determined as follows:

Seedlings: Small, identified by cotyledons, which persist into summer.

Small: Pre-productive plants with root crown less than 3 mm diameters, rarely having multiple stems per crown, and not flowering.

Medium: Root crown measuring 3–5 mm diameters.

Large: Root crown greater than 5 mm diameters.

Dormant or dead plants: can be recorded when re-sampling occurs.

Data sheets were prepared in advance. A copy of the sheet used to record data has been included (Table 4). The number of plants in each of the size classes and the number of flowering individuals in each plot were tallied. Plants rooted in the plot, whether or not the tops lie completely in the plot, were counted “in,” whereas all those rooted outside the plot, even if they overhung the plot, were considered “out” and not counted. In some cases a single echinacea plant will occasionally fork from its underground caudex, and it was counted “in” if the majority of the crown was in the plot. In these cases, where separate individuals grew very close to one another, underground probing revealed whether the stems were connected to one root or two, and thus were counted by the number of roots. In addition, for each plot, plant cover estimates up to 100% were taken for the following categories: bare ground, grass, forbs, woody plants, and echinacea plants. Species other than echinacea were listed individually.

Results

Results from our baseline data collection in Kansas and North Dakota in the summer of 2002 show an average density of 11.05 *E. angustifolia* plants per square meter in North Dakota (Table 5) to 12.59 *E. angustifolia* plants per square meter in Kansas (Table 6), with density as high as 20 plants per meter. The ratio of small to large plants is noticeably high, approximately 6:1. We do not know if this is do to the fact that most small plants never make it to maturity or whether past harvests are having an effect on population. Data for species cover of echinacea and all other species are in Table 7 for North Dakota and Table 8 for Kansas.

Continued sampling over the next few years would help clarify the population dynamics of echinacea species at this site or any other. Ideally, every plot should be sampled every year as this would make it easier to identify signs of current harvesting, but even periodic sampling would be useful. Sites should be informally monitored on a more frequent basis so measurements can be taken after years of particularly heavy harvest It is important to create data sheets with species previously observed and maps before one returns to the field for unexpected sampling.

Since our initial observations are the only firm data we currently have, we need repeated measurements to be able to determine what sustainable harvesting parameters might be. We believe these observations should be applied to all species of *Echinacea*, even those without the economic importance and harvest pressure of *E. angustifolia*, since many species of echinacea are confused with *E. angustifolia* and harvested mistakenly.

Literature Cited

Hurlburt, D. P. 1999. Population ecology and economic botany of *Echinacea angustifolia*, a native prairie medicinal plant. Dissertation. University of Kansas, Lawrence, 154 pages.

Table 1: Sample Data Sheet for Monitoring Echinacea Plots

Observers: Date:

Site: T______ R______ Section_________

Patch

Slope: State __________________

Aspect:

Size: County ________________

Shape:

Location within site:

Soil type:

Soil description:

Surrounding dominant vegetation and other comments:

Transect

Triangulation readings:

Compass direction:

Shape and layout within patch:

GPS readings:

0) ____
1) ____
2) ____
3) ____
4) ____
5) ____
6) ____
7) ____
8) ____
9) ____
10) ____
11) ____
12) ____
13) ____
14) ____
15) ____
16) ____
17) ____
18) ____
19) ____

Table 2: Number of Plots Needed for Detecting a 10% Change in Echinacea Plant Density

Plot Number

Using Dana Price Hurlburt's data from 1996, 1997, 1998 as pilot plots (Hurlburt 1999), we determined the number of plots needed for detecting a 10% change in echinacea plant density. To do this, we first used the statistical figures:

1-B = .90: 90% sure of missing a false change

a = .10: 10% chance of missing a change that happens

Using the most reasonable of possible standard deviations from Price's data, we need 11 plots in order to detect the change. With 20 plots we would be able to statistically detect an average change of 1.16 plants per square meter, which is about 7% in Price's study.

Permutations

Using the best of the standard deviations, we would technically need only 4 plots. 20 plots allow us to detect a change of .2 plants per plot (about 2% in Price's data, but 4% if we only average 5 plants/m^2). Using the "worst" of the standard deviations (which includes some incomplete data and seedling data and were not applicable), we would need 53 plots. Using this standard deviation, however, we would need only 14 plots to note a 20% change, so 20 plots was deemed to be the most useful.

Using the "reasonable" standard deviation value, we would need 17 plots to increase our power to .95 and decrease alpha to .05. To detect a 10% change at the stats .99/.01 levels, we would need 31 plots.

Table 3: Equipment and Supplies Used in Baseline Monitoring

Data sheets printed in advance on waterproof paper

Pencils and erasers

Waterproof clipboards

2 long (100m) tape measures

1m x 1m lightweight plot frame

Pins to hold the starting point of the tape in place

Nails, bolts, and 10" long rebar

Heavy hammer or sledge (if rock is present) for pounding in rebar

Brightly colored plastic flagging tape

Outdoor spray paint in a non-natural color

GPS unit

Compass

Marking flags in bright colors (for marking plots while sampling)

Metal detector

Calipers

Steel posts for permanent location markers

Galvanized nails (long) for marking any individual plants that can be tracked over time

Plant press for preserving unknown plants for identification

Species list was a guess from the literature of the area.

Site:

T R Sec

Date:

Observers:

Bare Ground										
Aster ericoides										
Astragalus										
Bouteloua gracilis										
Calyophus serrulatus										
Carex ___________										
Carex eleocharis										
Carex filifolia										
Chrysopsis										
Cirsium ___________										
Dalea candida										
Dalea purpurea										
Enchinacea augustifolia										
Elymus lanceolatus										
Erigeron ___________										
Erysimum asperum										
Liatris punctata										
Opuntia polyacantha										
Plantago ___________										
Pseudoregneria spicata										
Psoralea ___________										
Ratibida columnifera										
Schizachyrium scoparium										
Senecio ___________										
Solidago canadensis										
Solidago ___________										
Sphaeralcea coccinea										
Stipa comata										
Stipa viridula										
Other Species:										
Echinacea:										
Seedlings										
Small (to 3 mm dia.)										
Flowering										
Medium (3-5mm)										
Flowering										
Large (>5mm)										
Flowering										

Table 5: Summer 2002 *Echinacea angustifolia* Data – Totals
Baseline Data for Echinacea Found in plots in North Dakota and Kansas in Summer 2002.

North Dakota: 4 sites, 20 plots each

	Sum (80 plots)	Average/plot
Seedlings	128	1.60
Small (to 3mm dia)	483	6.04
flowering	0	0.00
Medium (3-5mm)	166	2.08
flowering	18	0.23
Large (>5mm)	107	1.34
flowering	52	0.65
Total all Echinacea	884	11.05

Kansas: 4 sites, 20 plots each

	Sum (80 plots)	Average/plot
Seedlings	7	0.09
Small (to 3mm dia)	612	7.65
flowering	0	0.00
Medium (3-5mm)	266	3.33
flowering	2	0.03
Large (>5mm)	122	1.53
flowering	5	0.06
Total all Echinacea	1007	12.59

Grand Totals for Kansas and North Dakota: 8 sites,160 plots

	Sum (160 plots)	Average/plot
Seedlings	135	0.84
Small (to 3mm dia)	1095	6.84
flowering	0	0.00
Medium (3-5mm)	432	2.70
flowering	20	0.13
Large (>5mm)	229	1.43
flowering	57	0.36
Total all Echinacea	1814	11.34

Table 6: Site by site baseline data for *Echinacea angustifolia* found in plots in North Dakota and Kansas in summer 2002
Sum = number of plants added over a site

North Dakota — 20 plots per site

	Medora 1 Sum	Average/plot	**Medora 2** Sum	Average
Seedlings	45	2.25	10	0.50
Small (to 3mm dia)	124	6.20	68	3.40
flowering	0	0.00	0	0.00
Medium (3–5mm)	33	1.65	39	1.95
flowering	5	0.25	3	0.15
Large (>5mm)	21	1.05	27	1.35
flowering	8	0.40	16	0.80
Total all Echinacea	223	11.15	144	7.20

	Medora 3 Sum	Average	**Stony Butte** Sum	Average
Seedlings	20	1.00	53	2.65
Small (to 3mm dia)	77	3.85	214	10.70
flowering	0	0.00	0	0.00
Medium (3–5mm)	55	2.75	39	1.95
flowering	6	0.30	4	0.20
Large (>5mm)	27	1.35	32	1.60
flowering	11	0.55	17	0.85
Total all Echinacea	179	8.95	338	16.90

Kansas — 20 plots per site

	Plainsville Sum	Average	**Codell 1** Sum	Average
Seedlings	3	0.15	2	0.10
Small (to 3mm dia)	43	2.15	275	13.75
flowering	0	0.00	0	0.00
Medium (3–5mm)	15	0.75	95	4.75
flowering	0	0.00	1	0.05
Large (>5mm)	19	0.95	24	1.20
flowering	0	0.00	1	0.05
Total all Echinacea	80	4.00	396	19.80

	Codell 2 Sum	Average	**Natoma** Sum	Average
Seedlings	2	0.10	0	0.00
Small (to 3mm dia)	110	5.50	184	9.20
flowering	0	0.00	0	0.00
Medium (3–5mm)	56	2.80	100	5.00
flowering	0	0.00	1	0.05
Large (>5mm)	43	2.15	36	1.80
flowering	1	0.05	3	0.15
Total all Echinacea	211	10.55	320	16.00

Table 7: Vegetative composition of four *Echinacea* sites in the Little Missouri National Grasslands of North Dakota.
Twenty plots of 1m^2 were sampled at each site. Data were collected in June 2002. Names are from *Flora of the Great Plains*, 1991.

Latin Name	Common Name	Sites			
		Davis	Medora	Magpie	Stony Butte
Achillea millefolium	western yarrow	Trace	Trace	1.6%	0.3%
Agoseris glauca	pale agoseris	Trace			Trace
Agropyron cristatum	crested wheatgrass		0.3%	0.1%	Trace
Agropyron dastychyum	thickspike wheatgrass				Trace
Agropyron smithii	western wheatgrass	1.5%	1.1%	Trace	Trace
Agropyron spicatum	bluebunch wheatgrass	0.7%	Trace		
Allium textile	prairie wild onion	0.1%	0.2%	0.1%	
Amelanchier alnifolia	Saskatoon serviceberry				Trace
Andropogon scoparius	little bluestem	12.5%	9.8%	6.0%	0.5%
Androsace occidentalis	western rock jasmine			Trace	
Anemone cylindrica	candle anemone		Trace		0.5%
Anemone patens	pasque flower		Trace	2.1%	1.6%
Antennaria microphylla	littleleaf pussytoes	0.1%	2.2%	0.2%	0.4%
Antennaria neglecta	field pussytoes			0.4%	0.3%
Arabis holboellii	elegant rockcress		Trace		Trace
Arenaria lateriflora	bluntleaf sandwort	3.3%	0.4%	0.2%	Trace
Artemisia biennis	biennial sagewort		0.1%		Trace
Artemisia campestris	prairie sagewort			Trace	0.3%
Artemisia cana	silver sagebrush		1.0%	0.7%	
Artemisia frigida	fringed sagebrush	0.4%	0.6%	0.6%	0.3%
Artemisia ludoviciana	Louisiana sagewort				0.3%
Artemisia tridentata	big sagebrush	0.7%			
Asclepius ovalifolia	oval-leaf milkweed				0.1%
Aster ericoides	heath aster	0.7%	0.6%	4.0%	1.5%
Aster laevis	smooth blue aster			1.6%	
Aster oblongifolius	aromatic aster	0.1%		1.7%	0.7%
Astragalus adsurgens	prairie milkvetch	Trace	0.1%	2.4%	0.1%
Astragalus bisulcatus	two-grooved milkvetch	0.1%			
Astragalus crassicarpus	common ground plum			0.2%	
Astragalus gilviflorus	plains milkvetch	Trace	Trace		
Astragalus missouriensis	Missouri milkvetch	0.1%			
Astragalus vexilliflexus	bentflower milkvetch			Trace	0.3%
Bouteloua curtipendula	side oats grama	13.9%			
Bouteloua gracilis	blue grama	0.1%	7.6%	1.8%	1.3%
Bouteloua hirsuta	hairy grama	Trace			
Bromus inermis	smooth brome	0.5%			0.5%
Calamovilfa longifolia	prairie sandreed	0.8%	2.4%	0.8%	6.2%
Calochortus nuttallii	sago lily	Trace			
Calylophus serrulatus	yellow evening primrose			0.3%	0.4%
Campanula rotundifolia	harebell		0.2%	0.2%	0.2%
Carex filifolia	threadleaf sedge	3.6%	11.5%	4.7%	0.3%
Ceratoides lanata	winterfat	0.9%		0.6%	

Table 7 (con't): Vegetative Composition of Four *Echinacea* sites in the Little Missouri National Grasslands of North Dakota

Latin Name	**Common Name**	**Sites**			
		Davis	**Medora**	**Magpie**	**Stony Butte**
Chrysopsis villosa	golden aster	3.6%	0.2%	2.4%	0.6%
Cirsium altissimum	tall thistle		Trace		0.3%
Comandra umbellata	false toadflax	1.9%	2.3%	0.8%	1.1%
Dalea candida	white prairie clover		Trace		
Dalea purpurea	purple prairie clover	0.1%	0.4%	0.5%	0.9%
Danthonia spicata	poverty grass				0.8%
Delphinium bicolor	little larkspur		0.2%		
Distichlis spicata	salt grass	0.8%	0.2%		
Echinacea angustifolia	purple coneflower	2.2%	3.0%	3.7%	2.5%
Erigeron ochroleucus	buff fleabane	0.3%			0.8%
Eriogonum flavum	alpine buckwheat			0.1%	0.1%
Erysimum asperum	western wallflower	Trace			
Gaillardia aristata	common gaillardia			0.1%	
Galium boreale	northern bedstraw				4.3%
Geum triflorum	old man's whiskers		0.1%	0.2%	0.2%
Grindelia squarrosa	curly top gumweed		Trace	0.1%	Trace
Gutierrezia sarothrae	broom snakeweed	0.6%	0.1%	Trace	0.1%
Haplopappus spinulosus	ironplant goldenweed		Trace		
Helianthus rigidus	stiff sunflower	0.4%		0.2%	0.4%
Heuchera richardsonii	alum root		Trace		
Hymenoxys acaulis	stemless hymenoxys	0.4%		0.2%	
Juniperus horizontalis	creeping juniper		11.4%		
Juniperus scopulorum	Rocky Mountain Juniper	4.3%		Trace	
Juniperus virginiana	red cedar	4.8%			
Koeleria pyramidata	Junegrass	3.0%	3.3%	1.8%	Trace
Lactuca oblongifolia	chicory lettuce		0.3%		0.1%
Lesquerella ludoviciana	Louisiana bladderpod	Trace	0.1%	Trace	0.1%
Liatris punctata	dotted gayfeather	0.1%	0.9%	0.1%	0.4%
Linum perenne	blue flax	1.3%	0.9%	1.6%	0.5%
Linum rigidum	stiff stem flax	0.1%	0.1%	Trace	0.1%
Lithospermum incisum	narrowleaf gromwell	Trace	Trace	Trace	Trace
Medicago lupulina	black medic				1.6%
Melilotus officinalis	yellow sweet clover	1.2%	0.2%	0.1%	
Monarda fistulosa	wild bergamot				1.0%
Muhlenbergia cuspidata	plains muhly	2.6%	Trace	2.5%	0.4%
Opuntia polyacantha	plains prickly pear	Trace			
Orthocarpus luteus	yellow owl's clover	Trace	0.1%	0.1%	Trace
Oxytropis lambertii	Lambert's locoweed			Trace	0.1%
Oxytropis sericea	white locoweed	0.2%	0.5%	Trace	0.4%
Phlox hoodii	spiny phlox	Trace			
Plantago patagonica	woolly plantain		0.1%		
Poa pratensis	Kentucky bluegrass	2.7%			28.7%

Table 7 (con't): Vegetative Composition of Four *Echinacea* sites in the Little Missouri National Grasslands of North Dakota.

Latin Name	Common Name	Sites			
		Davis	**Medora**	**Magpie**	**Stony Butte**
Polygala alba	white milkwort	0.5%	0.1%		Trace
Potentilla arguta	tall cinquefoil			0.3%	0.1%
Potentilla pennsylvanica	Pennsylvania cinquefoil				Trace
Psoralea esculenta	prairie turnip	0.1%			0.1%
Ratibida columnifera	Mexican hat	Trace	0.1%	0.2%	0.2%
Rosa acicularis	prickly rose		1.1%	2.7%	5.0%
Schedonnardus paniculatus	tumblegrass			Trace	
Senecio canus	gray ragwort		Trace		0.1%
Senecio interregimus	lambs tongue groundsel	Trace	0.7%		
Shepherdia canadensis	russet buffaloberry			0.3%	
Sisyrinchum montanum	Colorado blue-eye grass			Trace	Trace
Smilacina stellata	spikenard			0.2%	
Solidago canadensis	Canada goldenrod		1.4%		0.1%
Solidago missouriensis	Missouri goldenrod	0.1%	0.1%	0.1%	0.2%
Solidago ptarmicoides	prairie goldenrod				0.6%
Solidago rigida	stiff goldenrod		Trace		4.3%
Sphaeralcea coccinea	scarlet globe mallow	Trace			
Sporobolus cryptandrus	sand dropseed		Trace		
Stipa comata	needle-and-thread	10.0%	10.3%	30.4%	23.0%
Stipa viridula	green needlegrass	2.0%	0.3%	3.5%	0.2%
Symphoricarpus occidentalis	wolfberry		1.0%	3.2%	
Thermopsis rhombifolia	prairie thermopsis			0.6%	
Tragopogon dubius	yellow salsify		0.1%		
Vicia americana	American vetch	Trace			Trace
Viola adunca	hooked spur violet			Trace	
Yucca glauca	soapweed	0.2%		1.1%	
Bare Ground		15.6%	21.9%	12.5%	4.2%
Total Plant Cover		84.4%	78.1%	87.5%	95.8%
Species Richness*		59	60	63	70

*Species Richness is the total number of plants observed at a site.

Table 8: Vegetative composition of *Echinacea* population in north-central Kansas. Twenty plots of $1m^2$ were sampled at each site. For a fourth Kansas site, only totals were collected. All data are from June 2002. Names are from *Flora of the Great Plains*, 1991.

Latin Name	Common Name	Sites		
		Codell 1	**Plainsville**	**Codell 2**
Ambrosia psilostachya	western ragweed	0.3%	1.7%	Trace
Amorpha canescens	lead plant	0.1%	3.1%	0.2%
Andropogon gerardii	big bluestem	21.3%	15.4%	17.9%
Andropogon scoparius	little bluestem	15.00%	5.6%	46.7%
Arenaria stricta	rock sandwort		0.3%	0.7%
Aristida purpurea	purple three awn		1.0%	
Asclepias asperula	spider milkweed	0.8%	0.1%	0.1%
Aster ericoides	heath aster	0.1%		
Aster fendleri	western prairie aster	0.1%	Trace	Trace
Aster sp.	aster	Trace	1.7%	0.7%
Astragalus sp.	locoweed			0.1%
Bouteloua curtipendula	side-oats grama	6.7%	14.5%	8.1%
Bouteloua gracilis	blue grama	7.7%	23.0%	Trace
Bouteloua hirsuta	hairy grama	19.8%	0.1%	
Bromus japonicus	Japanese brome		3.2%	
Buchloe dactyloides	buffalo grass	4.5%	3.1%	
Calylophus serrulatus	plains evening primrose	0.2%	0.4%	
Ceanothus herbaceous	New Jersey tea			0.4%
Cirsium undulatum	wavyleaf thistle	0.2%	1.4%	0.1%
Clematis fremontii	Fremont's clematis	0.8%	Trace	2.5%
Comandra umbellata	bastard toadflax	Trace	Trace	0.5%
Croton monanthogynus	one-seeded croton	0.1%	Trace	0.1%
Dalea candida	western prairie clover	Trace		
Dalea enneandra	nine anther dalea			Trace
Dalea purpurea	purple prairie clover	0.6%	0.1%	Trace
Echinacea angustifolia	purple coneflower	1.5%	1.2%	1.7%
Erigeron strigosus	daisy fleabane		0.1%	Trace
Evolvulus nuttallianus	rabbit tobacco	0.3%	0.2%	
Gaura coccinea	scarlet gaura	Trace		
Geranium carolinianum	Carolina cranesbill		Trace	
Gutierrezia sarothrae	broom snakeweed	1.2%	0.7%	0.2%
Hedeoma drummondii	false pennyroyal	0.4%	0.1%	0.3%
Hedyotis nigricans	narrowleaf bluets	0.1%	Trace	0.7%
Helianthus maximilianii	hairy sunflower			1.3%
Hymenopappus scabiosaeus	old plainsman	0.2%		
Hymenoxys scaposa	smooth hymenoxys	0.1%	Trace	
Lactuca ludoviciana	Louisiana lettuce			Trace
Leucelene ericoides	white aster	0.5%	1.8%	
Liatris punctata	dotted gayfeather	0.2%	0.2%	
Linum rigidum	flax	Trace	0.1%	

Table 8 (con't): Vegetative Composition of *Echinacea* Population in Western Kansas. Twenty plots of one meter square were sampled at each site

Latin Name	**Common Name**	**Sites**		
		Codell 1	**Plainsville**	**Codell 2**
Linum sulcatum	grooved flax	0.1%		
Lithospermum carolinense	hoary gromwell		0.1%	Trace
Lithospermum incisum	narrowleaf gromwell	0.5%	Trace	Trace
Lomatium foeniculaceum	carrot leaf lomatium			Trace
Melilotus officinalis	yellow sweet clover		0.5%	
Mentzelia oligosperma	stickleaf mentzelia			Trace
Muhlenbergia cuspidata	plains muhly		3.5%	0.2%
Oenothera macrocarpa	Missouri evening primrose			Trace
Oxytropis lambertii	Lambert's locoweed	0.2%	0.4%	
Panicum virgatum	switchgrass		0.2%	
Paronychia jamesii	James' nailwort	0.1%	0.2%	
Penstemon cobaea	cobaea beardtongue	0.1%	Trace	Trace
Plantago patagonica	woolly plantain		Trace	
Poa pratensis	Kentucky bluegrass		0.8%	
Polygala alba	white milkwort			Trace
Psoralea esculenta	prairie turnip	0.4%	0.1%	0.1%
Psoralea tenuiflora	many-flowered scurfpea	0.8%	1.2%	0.2%
Ratibida columnifera	yellow prairie coneflower	Trace		
Rhus glabra	smooth sumac			0.7%
Salvia azurea	blue sage			0.1%
Andropogon scoparius	little bluestem	15.0%	5.6%	46.7%
Schrankia nuttallii	sensitive briar	0.1%	0.2%	
Scutellaria resinosa	resinous skullcap	1.9%	0.8%	1.0%
Senecio plattensis	plains groundsel	0.2%	0.3%	0.2%
Silphium laciniatum	compass plant			Trace
Sitanion hystrix	squirreltail		0.2%	
Solidago missouriensis	Missouri goldenrod		0.1%	
Solidago rigida	stiff goldenrod		1.7%	0.5%
Sorghastrum nutans	Indian grass			1.8%
Sporobolus asper	rough dropseed		0.1%	
Stenosiphon linifolius	stenosiphon	0.2%	0.1%	0.2%
Thelesperma megapotamicum	greenthread	0.1%	0.3%	
Townsendia exscapa	Easter daisy	Trace		
Toxicodendron radicans	poison ivy	0.6%	0.3%	0.1%
Tragia betonicifolia	noseburn	0.2%	0.2%	0.3%
Verbena stricta	woolly verbena	Trace	0.2%	
Yucca glauca	small soapweed		0.9%	0.1%
Bare Ground		11.4%	7.8%	11.8%
Total Plant Cover		88.6%	92.2%	88.2%
Species Richness*		47	56	46

*Species Richness is the total number of plants observed at a site.

Legal Protection of Echinacea and Other Medicinal Plant Species

By Robyn Klein and Kelly Kindscher

At least 175 plants native to North America are for sale in the nonprescription medicinal market in the United States. Many of these collectors harvest from the wild in large quantities (hundreds of thousands of plants) for commercial markets in the United States and abroad. For example, during the last few years, about 65 million goldenseal plants and 34 million ginseng plants have been harvested from the wild in the forests of the eastern United States on an annual basis (Robbins 1999). The sale of lower pine branches to form rope for wreaths and garlands has been estimated at $1.5 million, black walnut at $2.5 million, and ginseng at $18.5 million dollars a year (Chamberlain *et al.* 2002). The commercial value of special forest products in the Pacific Northwest may be in excess of $190 million (Vance *et al.* 2001). Black cohosh was identified in 1998 as one of the fastest growing herbal products with an annual increase of over 511 percent from sales in 1997. Between 300,000 and 500,000 pounds of black cohosh root were wild collected in 2001 (Schlosser 2002).

Over 85,000 people enter the public forest each year to collect plant material and mushrooms for their own personal use (Vance *et al.* 2001). Considering the high level of harvesting that occurs on public lands, especially in the national forests, it is important to maintain forest complexity, ecosystem health, and species diversity by protecting plants and fungi from over-harvest. Not only does such protection help maintain healthy, usable forests, but it also engages members of the public who represent all of the values for which public forest lands are managed. The harvest of *Echinacea* species and legal efforts to protect them provide a case study for such involvement.

Millions of echinacea roots have been wild harvested over the last decade. The average harvest of *Echinacea angustifolia* alone was 155,000 pounds per year from 1997 to 2001 (American Herbal Products Association 2003), and this does not include other *Echinacea* species that we know have been wild harvested. We know from weighing echinacea roots in the field that there are about 100 roots in a pound of dried echinacea root, which would mean that an average of 15.5 million *E. angustifolia* roots have been harvested per year from 1997 to 2001, and that's just one species. It is this very high demand and harvest that has driven the discussion of the need for laws to protect against the over-harvest of wild echinacea.

The Need for Laws to Protect Medicinal Plants

Almost every country in the world is experiencing increasing population and agricultural expansion, resulting in habitat degradation and deforestation (Hamilton and Schmitt 2000). Poverty places further pressure on natural resources. Inadequate land-use planning and law enforcement are problems for all nations trying to preserve native plants. Over-harvest of medicinal plants significantly affects plant diversity and conservation.

Wild ginseng was once naturally abundant in hard maple forests throughout southern Ontario and Quebec. The entire population of wild ginseng is now greatly reduced owing to both poaching and wildcrafting. The same is true for the wild leek population. In Quebec, it is difficult to find either wild ginseng or wild leeks in most forests, and both species are now considered threatened or endangered (Ontario Ministry of Agriculture and Food 2000).

In the United States, habitat loss and fragmentation lead the list of obstructions to plant conservation. For *Echinacea angustifolia*, the most widely harvested echinacea species in the wild, private land ownership is the primary protection offered this species. But in its northern range, huge tracts of private and public lands became easy targets for over-harvesting in the late 1990s because of lack of fencing, lack of monitoring, and low law-enforcement capability.

A concern for the adverse influences on the ecological functions of our medicinal plant resources—such as interactions between pollinators and plant populations, or among wildlife, food, and habitat—and promotion of sustainable harvest practices and techniques can imbue persons with an attitude of stewardship. General harvest guidelines that take into account proper plant identification, harvester responsibilities, techniques that minimize disturbance, and observation impacts over time can all work to protect these resources. Unfortunately, stewardship of echinacea is problematic in that harvest details and sustainable amounts of echinacea harvest are not fully known, which is why legal protection has been suggested.

Federal Regulation and Laws Related to Plant Species

In the United States, most government landowners (U.S. Forest Service, and Bureau of Land Management and the state) require both commercial and noncommercial harvesters to ask for permission to dig, collect, or harvest plant material, with some exceptions given for personal use. That is, permits are needed for commercial harvest, and personal use permits are technically for personal use. Within the US Forest Service, echinacea would be considered an “other forest product” or “non-timber forest product” and would require a permit for commercial collection.

U.S. Forest Service policies and plans, including those specified in this chapter, are meant to be consistent with all state or tribal laws, treaties, and regulations that influence management of special forest product resources. That is, the intention is to ensure that policies on special forest products are developed in compliance with all applicable laws and regulations. There is as well a concern for personal, subsistence, commercial, scientific, and recreational use of National Forest System lands.

U.S. Fish & Wildlife Service

The U.S. Fish and Wildlife Service is the principal federal agency responsible for conserving, protecting, and enhancing fish, wildlife, and plants and their habitats for the continuing benefit of the American people. In addition to managing the 95-million-acre National Wildlife Refuge System, which encompasses nearly 540 national wildlife refuges, thousands of small wetlands, and other special management areas, the service also operates 70 national fish hatcheries, 64 fishery resource offices, and 78 ecological services field stations. The agency enforces federal wildlife laws, administers the Endangered Species Act, manages migratory bird populations, restores nationally significant fisheries, conserves and restores wildlife habitat such as wetlands, and helps foreign governments with their conservation efforts.

The key to protecting endangered and threatened plant species, including *Echinacea* species, is the federal Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1973). In Section 2 (b) it states that

> *the purposes of this Act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions set forth in subsection (a) of this section.*

The U.S. Fish & Wildlife Service (2004) recognizes the value of plants:

> *Native plants are important for their ecological, economic, and aesthetic values. Plants play an important role in development of crops that resist disease, insects, and drought. At least 25 percent of prescription drugs contain ingredients derived from plant compounds, including medicine to treat cancer, heart disease, juvenile leukemia, and malaria, as well as those used to assist in organ transplants. Plants are also used to develop natural pesticides.*

The threatened and endangered *Echinacea* species listed under the Endangered Species Programs of the U.S. Fish & Wildlife Service (2005) are:

Scientific Name	*Common Name*	*Listing Status*	*Current Range*
Echinacea laevigata	Smooth coneflower	Endangered	GA, NC, SC, VA
Echinacea tennesseensis	Tennessee purple coneflower	Endangered	TN

Recovery plans are created after species are federally listed and provide the steps that need to be taken in order so those species can be removed from the endangered species list. For *E. tennesseensis*, the recovery goal is for 15 protected populations in natural habitats that are determined to be healthy, self-sustaining, and each containing three colonies of plants (U.S. Fish and Wildlife Service 1989). For *E. laevigata*, the recovery goal is for 12 geographically distinct self-sustaining populations in natural habitats in at least two counties in Virginia, North Carolina, and South Carolina and in one county in Georgia (U.S. Fish and Wildlife Service 1995).

U.S. Forest Service

The U.S. Forest Service is responsible for maintaining viable populations of plants and animals on the 191 million acres of national forests and national grasslands in 43 states and for developing and disseminating up-to-date information on the status, distribution, stewardship, and biology on threatened, endangered and sensitive species. This information is essential for the Forest Service to foster wise management of these great natural resources. Utilizing the vast and up-to-date national and international imperiled species data maintained by cooperators is imperative for implementing adequate management of National Forests and Grasslands. The Forest Service strives to enhance populations and habitats for plants and animals officially designated as being threatened or endangered with extinction, and it provides special management for the 3,250 plant and animal species on its 2005 Regional sensitive species lists. The management of these vulnerable links in the biodiversity chain is crucial to implementing the Forest Service vision of ecosystem management.

There are four laws that particularly address non-timber harvesting activities in the national forests: The Organic Act of 1897, the Multiple-Use Sustained Yield Act of 1960, The Forest Rangeland Renewable Resources Planning Act of 1974, and the National Forest Management Act of 1976 (Chamberlain *et al.* 2002). Though these laws imply that national forests will manage non-timber forest products, there is "no explicit mandate to include these products in forest management plans and activities."

Chamberlain and his colleagues determined the extent to which non-timber forest products were addressed in national forest management plans. They recognized that ecological and economical effects need to be significant in order to justify allocating resources for managing non-timber forest products. Additionally, they identified issues that hinder efforts to manage these products: "lack of knowledge about the biology and ecology of the flora from which these products originate; diverse nature of the products and the collectors; lack of market knowledge; and insufficient personnel and fiscal resources to assign non-timber forest products management" (Chamberlain *et al.* 2002).

In March 2001, the Forest Service published an executive summary entitled, "National Strategy for Special Forest Products" (USDA, Forest Service 2001) to encourage improved management. Recently the Pacific Northwest Research Station published a guide detailing wild harvest methods, alternatives to wild harvest, and uses for over 60 plants and fungi (Vance *et al.* 2001). In 2002, the Forest Service Handbook (2409.18 Chapter 18) added new direction for non-timber forest products by including requirements that they be managed sustainably, incorporated into forest plans, and that their harvesting activities by subjected to National Environmental Policy Analysis (McLain and Jones 2005). It defined non-timber forest products as: "Non-timber vegetative products, such as mosses, fungus, and bryophytes, echinatia [sic], rots, bulbs, berries, seeds, wildflowers, beargrass, salal, ferns, and transplants (USDA 2005). It also encouraged forests to assess impacts of management activities on non-timber forest products (McLain and Jones 2005).

Tribal Laws

Tribes rank above states but below the federal government in legal jurisdiction. In many respects they are legally sovereign. Each tribe has its own unique laws concerning the harvest of medicinal and edible plants. For example, harvesting medicinal plants is a serious concern to both the Salish Kootenai and Northern Cheyenne tribes in Montana. In fact, the Salish Kootenai have a written record of plant use in Salish. Laws on both of these reservations are not favorable to commercial harvesting even by tribal members.

Because of concerns about echinacea harvesting, the Fort Berthold Reservation in North Dakota passed a resolution in the late 1990s that prohibited echinacea digging on their reservation (Crawford 1998). The Rosebud Sioux Tribal Council also has made a law that harvesting medicinal plants on their reservation in South Dakota is allowed only under the supervision of an elder. The mass harvesting of *Echinacea angustifolia* in the mid to late 1990s, however, occurred without these restrictions on the Fort Peck Reservation in northwest Montana, where over-harvesting has been cited as a significant problem.

State Laws

In the United States, fifteen states have no laws regarding harvesting or protection of native plants. Twenty-one states have laws regarding the wild harvest and cultivation of ginseng (*Panax quiquefolium,* Araliaceae).

Missouri’s state law was written partially in response to echinacea digging. It prohibits the harvesting of the underground parts of wildflowers from highway rights-of-way. Collecting is also illegal in state parks, national forests, and conservation areas. On private lands, collecting is prohibited without landowner permission (Clubine 1993; Dietrich and Colombini 2000).

Florida law protects the fruit of saw palmetto (*Serenoa repens*, Arecaceae) in its agricultural laws because it is a valuable product on the medicinal product market. Florida law also protects other native plants that are commercially exploited.

Many states have laws concerning the transporting and ownership of forest products such as coniferous trees, Christmas trees, saw logs, poles, cedar products, pulp logs, and fuelwood. But these do not specifically target other forest products such as wild plants harvested for the culinary, medicinal, or floral markets. For example, in Kentucky, with the exception of a ginseng law, collecting permits for wild plants are for approved research and volunteer projects only (pers. comm., Bree K. McMurray, Kentucky State Nature Preserves Commission, November 2001).

North Dakota responded to the poaching of *Echinacea angustifolia* by passing a law that makes it illegal to gather it on state lands. The North Dakota State Legislature signed the emergency measure, House Bill 1200, into law on March 23, 1999.

Idaho, Washington, and Montana require commercial harvesters to have written permission to harvest all wild plants. Ten states have laws specific to the removal of forest or native plant products. For example, Michigan law protects all “medicinal and native plants.” Laws in Maine, Michigan, and South Carolina law are concerned with trespass in connection with native plant collection. Thus, many states seem to be aware of the interest in wildcrafting and harvesting of wild native plants.

The state prosecutor, usually located in the state capitol, tries state civil cases. The local county prosecutor tries state criminal cases. The problem with civil law cases is that they cannot be prosecuted at the county level, which makes it difficult to bring violators to justice. This is one reason that the Montana Governor's Task Force on Wild Medicinal Plants (established primarily due to the over-harvest of *Echinacea angustifolia* and other medicinal plants) suggested that a wildcrafting law be criminal, not civil. The other important reason is that the value of wild plant material can be in the thousands of dollars. Such a law is not directed at personal use of plant material but, rather, at commercial use.

In 1999, the Montana State Legislature passed Senate Bill 178, which placed a moratorium on the harvesting of *Echinacea angustifolia* and six other medicinal wild plants, and Regions 1 and 4 of the Forest Service (Northern and Inter-Mountain regions) issued an interim policy mirroring the state's moratorium. No personal or commercial permits have been given out for *Echinacea angustifolia* in these regions.

Senate Bill 178 also set up a volunteer task force that reported back to the Montana governor and legislature. Task force members spent a year educating themselves about issues related to wildcrafting. They then recommended that the legislature pass Senate Bill 197, which requires commercial wildcrafters and harvesters to obtain written permission prior to harvest.

Twenty-two states have laws regarding protection of native plants (see Table 1). Twenty-one states specifically mention ginseng in their legislation: Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Maine, Maryland, Michigan, Minnesota, New Hampshire, New York, North Carolina, North Dakota, Ohio, Oregon, Tennessee, Virginia, Washington, West Virginia, and Wisconsin. Ten states have laws specific to removal of native forest products: California, Hawaii, Idaho, Maine, Michigan, Montana, New Hampshire, Oregon, South Carolina, and

Alabama	ginseng
Alaska	none
Arizona	protection of native plants
Arkansas	ginseng; protection of native plants
California	protection of native plants; California Desert Native Plants Act; harvesting permit; control of commercial harvesting of native plants
Colorado	protection of native plants
Connecticut	none
Delaware	none
District of Columbia	none
Florida	protection of native plants; protection of native plants that are commercially exploited; permission to harvest saw palmetto (*Serenoa repens*)
Georgia	protection of native plants
Hawaii	introduction and transportation of native plants
Idaho	protection of native plants; sale of native plants
Illinois	ginseng; smoking herbs control act
Indiana	ginseng
Iowa	ginseng
Kansas	none
Kentucky	ginseng
Louisiana	protection of native plants
Maine	ginseng; trespass and removal of forest products
Maryland	ginseng
Massachusetts	none
Michigan	ginseng; trespass and protection of all medicinal and native plants
Minnesota	ginseng; wild rice
Mississippi	none
Missouri	protection of plants along highways
Montana	regulation of wildcrafting of native plants; preservation of native plants
Nebraska	none
Nevada	protection of native plants from harvesting on private land without permission
New Hampshire	ginseng; native plant protection act (includes sale of native plants)
New Jersey	protection of native plants
New Mexico	protection of native plants
New York	ginseng; protection of native plants
North Carolina	ginseng; protection of medicinal and native plants
North Dakota	ginseng; protection of Echinacea species
Ohio	ginseng; protection of native plants
Oklahoma	none
Oregon	ginseng; regulation of special forest products; unlawful transport of special forest products
Pennsylvania	none
Puerto Rico	protection of botanical gardens
Rhode Island	none
South Carolina	trespass for gathering native plants
South Dakota	peddling license needed for herbs
Tennessee	ginseng; protection of native plants
Texas	protection of native plants
Utah	none (collected native plants are defined as "nursery" materials)
Vermont	none
Virgin Islands	none
Virginia	ginseng; protection of native plants
Washington	ginseng; specialized forest products; theft of specialized forest products; transport into state
West Virginia	ginseng
Wisconsin	ginseng; wild rice
Wyoming	none

Note that 15 states have no laws regarding harvesting or protection of native plants.

Washington. Three states, Maine, Michigan, and South Carolina, have trespass laws in connection with native plants.

Of the 22 states that have laws concerning native plant protection, only North Dakota specifically lists *Echinacea angustifolia*. This law includes the non-native *E. purpurea* species because its focus is on the theft of cultivated property; native plant protection is secondary. So while there are 22 states that protect native plants in general, and 29 states that are concerned with the removal of native plants for profit, the remaining states have no law addressing native plant harvest problems.

Privately Owned Land

Any proposed laws relating to native wild plant harvest must consider private property rights thoroughly, as well as the likely outcomes of the law and its effectiveness. Both Montana and North Dakota have passed laws aimed at curbing illegal harvest of wild native plants.

Private landowners have vigorously defended their rights to manage their own lands, despite federal laws protecting rare species. Montana serves as a good state to discuss private property rights related to echinacea because of the attention this issue received in the late 1990s. In Montana, some landowners saw the proposed state law to require commercial wildcrafters to attain a permit from private landowners as a breach of their rights and interference by government, while other landowners were relieved to have a law with which they could prosecute lawbreakers more strongly than for simple trespass.

It is important to note that the Federal Endangered Species Act does not prohibit the "take" of listed plants on private lands, but landowners must comply with state laws protecting imperiled plants. Consultations with the Fish and Wildlife Service are necessary for private and other landowners only when federal funding or permits are required for activities that may affect listed species. Therefore, the federally listed *Echinacea laevigata* and *E. tennesseensis* are technically allowed to be harvested on private lands.

The Montana law concerning permit requirements for commercial wildcrafters (76-10-101) placed a restriction on the liability of the landowner in order to encourage the harvest industry. Landowners would be hesitant to allow wildcrafting activities on their property if wildcrafters were injured in the activity and chose to sue the landowner. Therefore, the following section of the state code pertains to liability relief for landowners:

> *76-10-106. Restriction on liability of landowner. (1) A person who uses private property for wildcrafting purposes, with or without permission, does so without any assurance from the landowner that the property is safe for any purpose. The landowner owes the person no duty of care with respect to the condition of the property, except that the landowner is liable to the person for any injury to person or property for an act or omission that constitutes willful or wanton misconduct. (2) A person who uses public property for wildcrafting purposes, with or without permission, does so without any assurance from the landowner that the property is safe for any purpose. The landowner owes the person no duty of care with respect to the condition of the property, except that the landowner is liable to the person for any injury to person or property for an act or omission that constitutes willful or wanton misconduct.*

North Dakota passed a law in 1999 especially with landowners in mind, since poaching was seriously affecting their properties. Therefore, it was supported by private landowners.

Enforcement

Illegal wildcrafting is a minor concern for law enforcement agencies, which are staffed by too few personnel and too many other, and more important or serious, crimes and other issues. There has been an attempt, though, to educate all law enforcement personnel, from state troopers to federal national forest employees, about poaching of wild plant material. One particular problem is that officials generally have little botanical training. Additionally, it is not clear how much plant material constitutes “commercial use” versus “personal use.” These are challenges that can be met with some basic guidelines.

Perhaps the most important factor affecting the efficacy and strength of a wild-harvesting law is whether violators can be prosecuted locally. For instance, the state land laws are enforced by game wardens, and the prosecution of violators is the responsibility of the state attorney's office. Since the state attorney, located at the state capitol and away from national and state wildlands, is the only agent who can prosecute violation of state civil laws, prosecution rarely occurs for minor violations like plant poaching. The only way county law enforcement officials will be able to prosecute illegal wildcrafting is to make relevant state laws criminal, not civil.

In Montana, efforts were focused on a law that would criminalize commercial violators, who then could be prosecuted locally and with severe consequences in order to deter poaching and encourage fair and sustainable industry practices; citizens harvesting for personal consumption are not the target of the law.

Generally, law enforcement agencies are either unaware of the problems of poaching wild plants or do not have the budget or personnel to address these problems, except when requested. A major consideration for law enforcement staff is the level of impact or damage to property, and harvested roots do not look like items of significant value to most officials.

There are several impediments to apprehending poachers. First, law enforcement personnel must know on which property violators are harvesting. Second, the question of whether the purpose of the harvest is commercial or personal cannot easily be determined. Violators often must be caught in the act of selling before they can be charged. If poachers leave federal lands, law enforcement officials may not be able to chase after them. This is one reason that the Montana law made illegal harvesting a criminal offense, so law enforcement officials from all agencies (state and federal) could apprehend violators.

Experienced commercial harvesters are very savvy and have been known to set up lookouts in order to evade law enforcement. Both buyers and harvesters may carry guns. Permit compliance is very difficult to figure out. Only one huckleberry harvester was known to have purchased a permit in the Flathead Valley in Montana one year, despite an estimated 8,700 pounds being harvested that summer by local businesses (Klein 2000). Most wildcrafters chaff at regulations, especially concerning products on public lands they believe to be their property since no one else is exploiting them, but several laws may be broken if poaching occurs on federal lands. The U.S. Forest Service, Bureau of Land Management, and state lands all have permit systems in place.

The U.S. Forest Service penalties for lack of permits start with a warning. If a permitless and previously warned harvester is caught again, or a large quantity of harvested material is confiscated, this can be considered a federal offense. But violators are not usually fined, and penalties for commercial use violation are often no more severe than penalties for personal use violation. For instance, the Forest Service personal use (firewood) permit specifies that "violation may result in the forfeiture of all permitted product, issuance of Notice of Violation, termination of the permit, and/or criminal prosecution with a fine of not more than $5,000, or imprisonment for not more than six months, or both." Violation of the commercial permit may carry the same penalties (Klein 2000).

It is possible that both state and federal charges could be brought against a violating harvester. But this depends on the state laws. Federal enforcement agencies support state laws, so if a state law is violated, federal and state law enforcement agencies can work together.

Recommendations for Legal Protection

Legal protection of native plants is extremely difficult to enforce since plants are easily taken, but it helps that state and federal laws support each other. The presence of a state law sets the intent of the state with regard to how valuable it considers its wild native plants. It informs would-be harvesters that these resources are valuable and that attention is paid to them. Conversely, the absence of a state law protecting native wild plants sends a message to potential harvesters that the state is not concerned and places a low value on plant resources. Wild ginseng and echinacea both provide examples of wild native plants that are stressed by overharvesting and may need legal protection.

Because of the consistent high value of wild ginseng, there is constant pressure on wild populations. The fierce demand for wild ginseng roots has led to laws in 21 states regarding its harvest and sale. *Echinacea angustifolia,* however, is under intense harvest pressure for a few years at a time before the market is flooded and prices drop, discouraging harvest. It seems that laws and regulations become necessary when harvested plant material becomes so valuable that significant other illegal activity (trespass, theft, etc.) accompanies harvest. Legislation that limits property rights, including the right to harvest, is typically not very popular and difficult to get passed. In many respects, educational efforts may be the best way to help conserve echinacea on private lands where the majority of plants occur.

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Recommendations Regarding the Conservation Status of *Echinacea* species

Kelly Kindscher

Echinacea is one of the most important plants in the herbal product industry today. A sizable portion of the demand for echinacea roots is for wild-harvested plant material, especially roots of *Echinacea angustifolia* and to a lesser extent, *E. pallida*. Because of the large quantities harvested, the conservation status of *Echinacea* species has been of concern. Owing to a lack of quality standards and quality controls, most *Echinacea* species have been harvested and sold as echinacea, or "snakeroot," to some buyers and medicinal plant brokers and then resold as *E. angustifolia.* Some of the less-common species that have been harvested do not have large geographical ranges, which means that overharvesting is possible and can create concern for their conservation status.

With the exception of the two federally protected species, *E. tennesseenis* and *E. laevigata,* there is little scientific information available related to the actual amount of echinacea in the wild. It really is difficult to determine to what extent the harvest of echinacea has affected its conservation status. Concern by the U.S. Forest Service, other agencies, and the public for the status of *Echinacea* species in light of market-driven harvesting has prompted funding of this study.

In our analysis of the status of *Echinacea* species, we have uncovered several important points relevant to the continued health of echinacea populations, and we have several recommendations to make.

Improved maps of Echinacea species ranges. We have surveyed for echinacea throughout its known ranges. While we have found no major range extensions for any species, we have more thoroughly documented actual ranges by studying collections of herbarium specimens and reevaluating species determinations for locations that appeared to have unexpected species of echinacea. We have produced accurate maps with county distributions for all states and provinces for which these species occur. These maps are available online (at http://www.kbs.ku.edu/people/staff_www/kindscher/echinacea/maps2.htm)and will be updated when new information is available; they are also cited in volume 21 (2005, in press) of the *Flora of North America*, which covers echinacea.

Recommendation 1**.** Based on our study, we recommend that more surveys be conducted and collections made to aid in the study of *Echinacea* species ranges, especially in some undercollected areas where several species co-occur, as in central and southeastern Texas and throughout the Southeast.

The need for ecological research. After reviewing the literature on the biology, ecology, and conservation status of echinacea, my colleagues and I are concerned by the lack of data and studies. While there has been some research, it is primarily related to whether *Echinacea* species have been placed on the endangered species list. There have been few ecological studies, and consequently there is little understanding of how *Echinacea* species survive in their environment.

Recommendation 2**.** Clearly more research is needed, especially on the plant population dynamics related to wild harvest, sustainability, and rates of recovery by seeds and root resprouts for all species in different habitats. The Natural Heritage Programs will continue to compile data on state and province distributions of all state or federally cited *Echinacea* species. These data will continue to be useful for tracking the species' health, but without further ecological investigation, we will not know how to improve species health when populations are overharvested or otherwise in decline. In addition, there will still be a need for tracking the marketable *E. angustifolia* and *E. pallida* species, which are relatively common throughout much of their ranges.

The need for population monitoring and specimen collection. Perhaps our greatest understanding of the status of *Echinacea* species in the wild has come from our research opportunities to collect and monitor them. One of our most compelling findings is that historic populations continue to exist as long as land use does not change significantly. We were able to find populations of *E. angustifolia, E. pallida, E. atrorubens,* and *E. paradoxa* at sites previously identified by older herbarium collections at the University of Kansas.

Much of our work has focused on *E. angustifolia* because it has supplied 80%–90% of the wild-harvested roots on the national and international market. Our monitoring data from North Dakota, Montana, and Kansas show us that echinacea plants are abundant in areas where their populations are healthy, and we have seen many healthy populations of *E. angustifolia,* especially in north-central Kansas, eastern Montana, and western North Dakota. We have collected plot data and made plots permanent with buried steel markers at sites in North Dakota and Kansas. We are confident that these stands can be monitored again in the future. In addition, recent data that we have collected, supported by statistical analysis (Kindscher et al. in preparation) demonstrates that 50% of monitored wild-harvested roots re-sprouted at our study sites in both Kansas and Montana. These results are important and need to be verified and studied under other conditions, weather patterns and locations to see if they are typical.

<u>Recommendation 3</u>**.** We have developed a monitoring protocol that can be used for all species (see "Establishment of Baseline Monitoring," in this volume). It is a suitable tool for monitoring use in federal and state lands and in private reserves held by conservation organizations. We especially encourage its use for *E. angustifolia, E. pallida,* and the less

common *Echinacea* species as a way of monitoring the health of those populations. We also encourage continued monitoring of echinacea sampling sites we have established and the sharing of echinacea data. In that respect, we will gladly share our echinacea data with other researchers upon request.

Ethnobotanical information. There is at present strong interest in the ethnobotany of echinacea, and much is known, especially about the most widely studied species, *Echinacea angustifolia*. The ethnobotanical knowledge of other species is weak or lacking, in part because Native Americans were removed from many of their homelands in the lower Midwest, Southeast, and Texas before anthropologists and scientists could record information on how echinacea was used.

Recommendation 4**.** There should be further ethnobotanical studies of less common *Echinacea* species, as well as continued study into the ethnobotanical uses of *E. angustifolia*. These ethnobotanical uses are not just historical; I have observed *E. angustifolia* being used on the Rosebud, Ft. Peck, and Crow Reservations. We need further research on contemporary Native American harvest use and preparation of *E. angustifolia* in addition to studies of the use of other *Echinacea* species, as well as further conservation studies.

Sustainability of wild harvest. In documenting the commercial harvest of wild *E. angustifolia* in Kansas for the past 100 years, we have shown that wild harvest can be sustainable and that there are at least some areas that have robust populations that can be periodically intensively harvested. In addition, the culture and economics that surrounds wild harvest are important in some rural communities. Historic and ongoing market cycles of demand—high prices followed by market collapse—also affect wild harvest.

Recommendation 5. We encourage the production of educational material for wild harvesters, brokers, businesses, and especially consumers that encourages the sustainability of wild harvest.

Effectiveness of medical treatment. Much of the future interest in echinacea will be related to what is discovered in medical research about its effectiveness in treating a variety of diseases and ailments. Current research is somewhat mixed in its results, but many applications appear promising, and the quality of the plant material tested has been raised as a research issue that must be addressed by researchers and industry. A conservation perspective on how echinacea is used as a medicine could help maintain wild stands. Most of the potentially active compounds in the echinacea plant are not only in the root but also in the aboveground portion of the plants, especially in the flowers and seed. The yield of these compounds from leaves and stems is slightly less than that from the roots, and it takes a little more weight to get the same desired result, but if manufacturers of echinacea products could be influenced to use the aboveground portion of the plants, the resulting nature of echinacea market demand would change, and harvesting would leave roots to continually resprout while taking the plant tops that are now discarded. These long-lived plants could resprout throughout their 10–30-year life spans.

Recommendation 6. We encourage the continued study of echinacea's active medicinal compounds and efficacy, and we further encourage using that information to influence the sustainability of its harvest.

The market for Echinacea. Market cycles and demand for echinacea have fluctuated in recent years, caused by both cycling in the herbal products industry and reaction to studies relating the efficacy of echinacea use to fighting the common cold and other ailments. Market cycling is likely to continue, and it will greatly affect the demand for wild-harvested echinacea.

Recommendation 7**.** Given the variability of demand, we commend the American Herbal Products Association for tracking the amount of echinacea harvested and used by at least a significant portion of the herbal products industry, and we strongly encourage that such tracking be continued.

Legal protection. The legal status of echinacea is mixed. Due to their truly threatened condition, the rarest two species, *E. tennesseensis* and *E. laevigata*, are federally listed as endangered. Three states, Missouri, North Dakota, and Montana, have given *Echinacea* species in their states some degree of protection on state-controlled lands. There have been no recent proposals for further state protection.

Recommendation 8**.** We do not think that it is necessary to propose listing any other species at this time, either federally or in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Further educational efforts—on wild-harvesting ethics and sustainability and on the threats and harm caused by overgrazing and broad-scale herbicide use—might be more productive than additional legislation, unless demand skyrockets. If new medicinal or herbal research findings result in a substantial increase in demand, the legal status of *Echinacea* species might need to be reevaluated.

Cultivation of Echinacea. Cultivation in place of wild harvesting could provide relief to wild stands, but the difficulty of cultivating *Echinacea angustifolia*, coupled with a very uncertain market and a recent history of inability to market cultivated crops when the market crashes, makes it difficult for growers to be very enthusiastic about growing a crop that ties up land for more than one year and may or may not have a market when it is ready to harvest. Wild stands of echinacea will continue to be used until there is a higher and more stable price for cultivated *Echinacea angustifolia*. Fortunately, we have come to believe that some wild-harvesting practices (such as those in north-central Kansas, where harvest has occurred for over 100 years) may be relatively sustainable.

Recommendation 9**.** We encourage both the cultivation of *Echinacea* species and the continuation of sustainably harvested wild echinacea to meet future market demand.

Species names. The taxonomy of echinacea and delineation of valid species names are matters of much discussion, but the general taxonomy of the species will not be substantially changed until additional molecular genetic data support suggested revisions that lump the majority of species. We have followed the current nomenclature in our work, which will likely be in use for some time, as volume 21 of the Flora of North America upholds the taxonomic status of all nine currently valid species.

Recommendation 10**.** To avoid confusion in the academic arena, the marketplace, and the public, we encourage the conservation of the current taxonomy unless it is very clearly determined to be incorrect. We also encourage additional studies on the taxonomic relations of *Echinacea* species.

Conservation of habitat***.*** Wild stands of echinacea have not shown much vulnerability to pests or disease. Invasion by noxious weeds is typically not a major threat to echinacea stands, but broad-spectrum herbicides to control noxious and other weeds is a cause of concern in some areas. Destruction of habitat is still slowly occurring, due to conversion of rangeland with echinacea to crop fields, houses, and other development, but it is not an eminent threat for the majority of remaining stands, which are usually now in fairly remote habitats. Some habitat is being degraded slowly by overgrazing, or by encroachment of brush and trees, but these trends are likely to decrease as they are not profitable long-term grazing practices. All these pressures could turn into threats, however, if circumstances change, especially if popularity of echinacea booms again due to new research findings or greatly increased use of medicinal plants and herbal products.

Recommendation 11**.** We recommend the conservation of echinacea habitats through land protection efforts, especially through the use of conservation easements, which allow private property to be privately owned and yet protected as native prairie or other echinacea habitat. All conservation easements should be voluntary, but state federal funds for conservation efforts to protect prairie and other echinacea habitat should be encouraged.

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Echinacea will probably continue to be an important medicinal plant that has a substantial wild-harvested supply. Educating diggers and consumers on sustainable harvest strategies for echinacea harvest could be very useful and would probably be more effective than regulation of harvest in the short term. Ongoing monitoring should be in place to observe population changes for both widespread and rare species, especially in years when buyers are posting want ads for buying echinacea roots. When these want ads appear, they are a signal that the demand for echinacea root is on the upswing, and it is time to monitor and reexamine the impact of wild harvesting on echinacea populations.

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