Kelly Kindscher *Editor*

Echinacea

Herbal Medicine with a Wild History

Springer

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To the Native Americans who learned about the benefits of Echinacea as a medicine long ago and have shared their traditional ecological and medical knowledge with us.

Foreword

> This drug, which has slowly wedged its way into attention is persistently forcing itself into conspicuity. The probabilities are that in a time to come, it will be ardently sought and widely used for it is not one of the multitude that have flashed into sight, been artfully pushed, then investigated, found wanting, and next dropped out of sight and out of mind. (Lloyd 1904)

I knew that the prophetic words of John Uri Lloyd, penned more than a hundred years ago, rang true when I first heard the word *Echinacea* mentioned on a television sitcom in the late 1990s. Lloyd is cofounder of Lloyd Brothers, Specific Medicines, Inc., of Cincinnati, and a respected and still influential figure in the development of an American *materia medica*. He and his brothers, Nelson Ashley Lloyd and Curtis Gates Lloyd, also founded the Lloyd Library and Museum in Cincinnati, the world's largest library devoted to medicinal plant-related topics. The Lloyds made the first pharmaceutical *Echinacea* preparation in 1895 sold only to physicians. One might also argue that *Echinacea* made the Lloyd Library. By the early 1920s that product became the most widely prescribed native plant preparation by physicians in the United States.

In America, medicinal plant preparations gave way to single chemical entity drugs in the 1920s. However, many American medicinal plants widely used today such as *Echinacea*, black cohosh (*Actaea racemosa*), and saw palmetto (*Serenoa repens*) were adopted by German phytomedicine firms and have a continuous use as ethical drugs—phytomedicines—which represent the totality of chemical constituents within a plant part, rather than a single isolated chemical entity. Throughout much of the twentieth century, we turned to German science for answers to questions about the chemistry, pharmacology, and clinical application of American medicinal plants.

In the 1930s *Echinacea* was adopted in Germany as an ethical drug, prescribed by physicians and dispensed by pharmacists, with over 60 years of market experience, and until the last decade, prescriptions were reimbursed through the German federal health-care insurance system. Products included ointments, salves, injectable product forms, tinctures, and other preparations from the fresh expressed juice of flowering *Echinacea purpurea*, grown in Germany in 1939, the serendipitous result of *E. purpurea* seeds mislabeled as *Echinacea angustifolia*.

Melvin Randolph Gilmore founded the first Ethnobotanical Laboratory at the University of Michigan in 1938. Gilmore was the first scholar to tease the relatively new discipline of ethnobotany away from the broader pursuits of ethnology and anthropology. In his classic 1919 work, *Uses of Plants by Indians of the Missouri River Region (Thirty-third Annual Report of the Bureau of American Ethnology)*, he penned the famous quote, "*Echinacea* seems to have been used as a remedy for more ailments than any other plant" (p. 131). That quote, too, proves to be a prophetic leap from indigenous society to modern culture.

In 1976, herbalist Ed Smith introduced me to *Echinacea* preparations. In the late 1970s he was the first to import modern *Echinacea* products from Europe and later the first to manufacture his own widely distributed *Echinacea* tincture under the Herb Pharm label which he cofounded with Sara Katz. At the time, *Echinacea* was but another arcane herb relegated to obscure academic pursuits.

In the summer of 1980 I had recently arrived in the Arkansas Ozarks and couldn't help but notice *Echinacea simulata* blooming along the roadsides. Its beauty was mesmerizing. That summer the late Richard Davis, an Arkansas Natural Heritage Commission botanists, and I rediscovered the yellow-flowered *E. paradoxa* var. *paradoxa* in Stone County, Arkansas.

When plant ecologist Kelly Kindscher and I met in 1982, he was an undergraduate in his sophomore year at the University of Kansas. He was keenly interested in and curious about native medicinal plants, and we enjoyed botanizing during his all-too-infrequent visits to the Ozarks and my even more rare excursions to Kansas. *Echinacea* was a mutual interest. It had been brought to my attention, but now *Echinacea* captured my undivided interest.

Herbs were just beginning to interest the public. Medicinal plant research had all but disappeared in North American academia, except for a handful of pharmacognosy programs in schools of pharmacy. USDA's one-man medicinal plant research laboratory, with James A. Duke as chief, ceased to exist in 1980. At the time, the late Norman R. Farnsworth (1930–2011), then considered the leading medicinal plant researcher in the United States, used a red rubber stamp on his correspondence which read "Save the Endangered Species Pharmacognosy." Dr. Farnsworth's European counterpart, Hildebert Wagner, at the University of Munich had published several papers in the late 1970s which suggested a modern chemical and pharmacological basis which helped to explain the potential of *Echinacea's* revival as a medicinal plant.

Still, as Kelly and I began to compare notes on the history, ethnobotany, biology, and ecology of *Echinacea*, far more questions than answers emerged. The extant contemporary scientific literature in many respects only added to the confusion. By 1983, as *Echinacea* products gained a modicum of popularity, we began to see serious declines in roadside *Echinacea* populations in the Midwest.

Just what is in those *Echinacea* products(?) became an important question arising from field observations. In a few short years, it became clear that products labeled *Echinacea angustifolia* in the commercial wholesale trade included other species all traded under the name "Kansas snakeroot." We documented that at least five species of *Echinacea* were included in the Kansas snakeroot trade.

Another wholesale herbal ingredient "Missouri Snakeroot" ended up in products labeled as containing *Echinacea purpurea* root. Yet, that species was not abundant in the wild, certainly not in the quantities necessary to develop a commercial supply source. Missouri Snakeroot was identified as *Parthenium integrifolium* based on herbarium specimens that I had sent to Prof. Wagner's research group in Munich, but not before they had presented and published two papers describing four new sesquiterpenes from the roots of *Echinacea purpurea*. The studies which relied on commercial samples were actually conducted on *P. integrifolium*, requiring a correction to the published research. Further research revealed that much of what had been published on *E. angustifolia* had actually been studies conducted on *E. pallida*. Those in academic disciplines relative to plant biology and photochemistry need to compare notes before heading to the lab bench.

Important lessons were learned and two Ph.D. candidates, Rudolf Bauer and Ikhlas Khan, produced dissertations which helped to answer questions about *Echinacea* species and their chemistry and biological activity leading to a new era of modern *Echinacea* research. It was to become in many respects Rudolf Bauer's life work.

About a year later, 26 April 1986, the Chernobyl nuclear disaster in the Soviet Union's breadbasket, Ukraine, consumed world attention. In late 1986 researchers at the University of Poltava, Ukraine, contacted me for seeds of *Echinacea* species that I had wild-collected in the Ozarks. Studying the potential of *Echinacea* preparations for use as immunomodulators to prevent or treat disease from exposure from Chernobyl radiation, they rapidly developed commercial supplies of *Echinacea purpurea* from wild native Ozark germplasm. A medicinal *Echinacea* vodka product soon followed. One question became: What are the chemical or biological activity differences between landrace wild *E. purpurea* plants and horticultural cultivars, the progeny of which had been in the nursery trade for nearly 300 years? That question awaits an answer.

Each turn of the evolving *Echinacea* story brings into focus new unanswered questions. Kelly and I continued to compare notes. Once he had attained his doctorate, he posed some of the growing list of questions to his graduate students, challenging them to design innovative research. Empirical observations of wildcrafters engaged in commercial trade of the roots suggested that if tap-rooted *Echinacea* species were lopped-off about eight inches below ground, the root left in the ground would sprout new vegetative growth. A road grader cut into an *Echinacea* population produced more plants the following year, when one might expect the population would have been destroyed. Do the roots regrow? Short of commercial cultivation, could a rational plan for sustainable wild harvest be feasible? Kelly's graduate student, Dana Hurlburt Price, Ph.D., studied this problem for five years, with intriguing results.

Other questions included how one could enhance commercial production of *E. angustifolia* by developing a pre-germination treatment for the hard-to-sprout seeds. What types of morphological variations correspond to chemical variations? Kelly not only asked these questions to his own students but invited graduate students from other institutions to informal colloquia to discuss research challenges and share results.

This book is the result of 35 years of asking broad-ranging questions about an intriguing plant group and how humans interact with it. The human experience of *Echinacea* encompasses all aspects of medicinal plant research, touching and drawing upon dozens of academic disciplines. Absorbing Kelly Kindscher's many-faceted *Echinacea* sojourn is like being on a hike without end. One pauses for a moment on a windswept prairie to admire how the distant horizon melds with the sky. The next step forward reveals more questions, and the journey continues.

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Steven Foster

Preface

Echinacea has been a central theme of my work, a long-term interest that is part of my Great Plains love affair. That love affair has led, step by step, by foot and by car, across a landscape of plants, to this book. I learned and appreciated pasture plants growing up on the 1871 Kindscher homestead farm near Guide Rock, Nebraska. In college, I read prairie ecology and Melvin Gilmore's 1919 book on Great Plains uses of plants by the Pawnee, Omaha, Lakota, and others (Gilmore 1977). I also learned about wild plants from friends (including Daniel Bentley, to whom I dedicated my first book, *Edible Wild Plants of the Prairie*: *An Ethnobotanical Guide*, published in 1989) and other colleagues. One of these was Steven Foster, and I have fond memories of trips to see him in the Ozarks when he was working on his own book, *Echinacea Exalted!* (Foster 1985). He would tell stories, and we would sample tinctures of all sorts of wild plants late into the night. And I am delighted that he has willing to write the Foreword to this book and provided beautiful photographs.

In the early 1980s, as a skilled gardener, I was growing food for the Lawrence, Kansas, farmers market and soon after directing a community garden program in Columbia, Missouri. I also experimented with many plants in my garden and found that my *E. pallida* and *E. purpurea* plants did fine, while my *E. angustifolia* plants did not survive long in the wet, humid environment of eastern Kansas. This got my attention.

My fascination with *Echinacea* grew as I saw it in wonderful places during my High Plains treks and encampments with Kansas Area Watershed (KAW) Council and friends at wonderful places that also had *Echinacea angustifolia* growing such as Horsethief Canyon, Castle Rock, Jacob's Well, and Cedar Bluff in Kansas; Pawnee Buttes in Colorado; and the Pine Ridge and Badlands in Nebraska and South Dakota. As I started doing research in the mid-1980s on *Edible Wild Plants of the Prairie* (Kindscher 1987), I also starting compiling information on medicinal plant uses. As that book was being published, and I did not have other good options for interesting work, I decided to go to graduate school at the University of Kansas in Systematics and Ecology and write a master's thesis and book that was titled *Medicinal Wild Plants of the Prairie: An Ethnobotanical Guide* (Kindscher 1992). And the most important chapter of this book was on *Echinacea* species. During this period, I started spending time during the summers with elder

Alex Lunderman in the Ring Thunder community on the Rosebud Sioux Reservation in South Dakota to learn about their medicine, and I also read extensively about *Echinacea* and other medicinal plants. I also wrote my first academic paper, on *E. angustifolia* and its ethnobotany (Kindscher 1989), and published it in *Economic Botany*.

For my dissertation, I originally proposed an autecological study of *Echinacea* species to my major advisor Phil Wells and my committee, but was persuaded to look at a broader ecological theme and so focused on the identification of guilds of prairie plant species based on morphological and ecological traits (Kindscher and Wells 1995). After completing my Ph.D., I started my research career at the Kansas Biological Survey at the University of Kansas. *Echinacea* continued as a subject of research for me. I explored herbal products that were adapted to production in Kansas, and I took part in an *Echinacea* safety review (Kindscher and Mitscher 1993) with Les Mitscher, a KU medicinal chemist, who also kindly reviewed the medicinal chemistry chapter of this book. Conducting population work on *E. angustifolia* became the central focus of Dana M. Price dissertation work (Hurlburt 1999) with me. We had previously met while she was a student at the Land Institute, and she also took the lead in writing a very fine history of *E. angustifolia* harvest (Price and Kindscher 2007) that we have updated for this book.

And two other graduate students became involved with me in *Echinacea* work and have collaborated with me on chapters in this volume. Rebecca Wittenberg, from Montana, decided to study botany with me at the University of Kansas, and one result of that work was our collaboration on the Taxonomy chapter in this book. And Rachel Craft, a graduate student in sociology at the University of Kansas, came to work with me to help with data entry for a variety of projects and then fieldwork, and our collaboration on medicinal plants grew. Medicinal plant use and health care have now also become a focus of her dissertation work, and with my encouragement, she has provided some very interesting insights into *Echinacea'* s media coverage and how that may impact markets, as a chapter in this book.

All of this *Echinacea* work resulted in significant fieldwork (which I thoroughly enjoy, in fact, live for). I was involved in the *Echinacea* Symposium that the American Herbal Products Association held in Kansas City, for which I lead a tour of local *E. pallida* stands and presented a paper. And then I led an unsuccessful effort with Dr. Jeanne Drisko of the University of Kansas Medical Center to obtain funding to establish a National Institute of Health (NIH) Botanical Center and five-year research program focused on *Echinacea* species at the University of Kansas. And that collaborative effort has led to other collaborations with Jeanne including our work together on the chapter in this book on the medical uses of *Echinacea*. And although we did not get funding for our botanical center, I was asked and agreed to serve on the outside review board of an NIH Botanical Center that was established at Iowa State University focused on *Echinacea* species and St. John's wort.

A very significant step in working on this book was funding by the US Forest Service for a conservation assessment of *Echinacea* species and especially for those populations on Forest Service lands, including the National Grasslands. This work allowed for some of the authors of this book to begin to pull all of this information together and also allowed us to conduct fieldwork on populations and density of *E. angustifolia* stands in the Smoky Hills of Kansas and on the Little Missouri National Grassland in North Dakota. That project, in turn, led to our study that documented significant root resprouting after plants were harvested in the wild in both Kansas and Montana (Kindscher et al. 2008). And I have very much enjoyed my work in Montana over the years, including work with Crow elder and author Alma Snell. I also had the opportunity to work on a multiyear biodiversity study in the greater Yellowstone ecosystem, for which Bozeman, Montana, became one of our research trading posts and recovery centers, and it was here, through encouragement of others, that I met herbalist and botanist Robyn Klein and developed one of the most intellectually rigorous discussion on herbal products that I have had. This, of course, led me to want to include Robyn in this book, and because of her legal protection work in Montana for *Echinacea angustifolia* and other species, I was delighted that she took the lead in our legal protection chapter.

And I would be remiss to mention, in this list of fieldwork in North Dakota and Montana, and especially in Kansas, the works and collaboration with graduate students and all of these other friends and researchers that my partner, Maggie Riggs, has played. She is an entrepreneur, a freedom fighter for plants, and a really good coauthor on both the Cultivation chapter and the Marketing chapter, as she has expertise in both. She has also played the essential role of consultant for many of the research activities in this book and in my other work. Her help has been invaluable.

Finally, with a new project in 2009, the Native Medicinal Plant Research Program, funded by Heartland Plant Innovations and the Kansas Bioscience Authority, my lab, and Barbara Timmermann Medicinal Chemistry lab at the University of Kansas looked again at *Echinacea* and many other medicinal plants as worthy research subjects for finding interesting secondary compounds. And in the Timmermann lab, one of the talented medicinal chemists was Congmei Cao, who has been a collaborator on many papers and is also a coauthor of the medicinal chemistry of *Echinacea* chapter. As part of my work in the Native Medicinal Plant Research Program, I revisited this *Echinacea* manuscript as an appropriate subject to work on again. Three years later, the Native Medicinal Plant Research Program—which enjoyed great successes and strong public support—had its funding cut suddenly and dramatically because of state political issues beyond our control. I realized, with encouragement and help from Kansas Biological Survey communications coordinator and skilled editor Kirsten Bosnak, that this *Echinacea* manuscript should be completed and published as a book. I have been working on it ever since, coordinating the various sections and chapters, editing, and writing and am very glad that it is now available to all of you. I have also written and placed vignettes in many chapters that add personal notes, and dimension, to the topics covered. Overall, this book is a collaborative effort by a wonderful team of researchers and writers, who worked with me on the range of important topics on *Echinacea*. I am grateful for their help in putting this work together.

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Lawrence, KS, USA Kelly Kindscher

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Information that was used to determine county distributions of *Echinacea* species within various states came from botanists and herbarium curators, including Wendy Applequist, Bruce Hoagland, Schuyler Kraus, Deb Lewis, Tim Lowry, Larry McGrath, Bert Pittman, Ken Richards, Tim Smith, Mark Widrlechner, Julia Yang, and George Yatshievych.

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Introduction

Kelly Kindscher

Echinacea has a rich cultural history, with widespread use by Native Americans in the Great Plains and Midwest for many ailments. Lewis and Clark recognized the plant as so important and potentially useful that they sent its roots and seeds to President Thomas Jefferson by boat from the Mandan village in North Dakota where they camped during the first winter of their epic (1804–1806) expedition. In less than 100 years, *Echinacea* did become an important patent medicine in the USA for snake bite, influenza, and other illnesses, and was popularized by the Lloyd Brothers and other early pharmacists. And by the 1990s, it became a best seller in the herbal products industry, largely because of consumer demand for a remedy for colds and flu, and with sporadic validation from scientific research.

Species in the genus *Echinacea* are highly valued as medicinal plants today. *Echinacea* sales over the last decade have regularly been in the millions of dollars per year, with wild-harvested material from the USA being a substantial part of the *Echinacea* market both here and in Europe (American Herbal Products Association 2003, 2012). The demand has brought about, at times, extensive and potentially unsustainable harvesting of wild populations of *Echinacea*. In addition, two species, *E. tennesseensis* and *E. laevigata*, are very rare and have been federally listed as threatened. More recently, *E. tennesseensis* has been delisted due to successful recovery efforts (U.S. Fish and Wildlife Service 2011).

Thus the need for such an up-to-date look at *Echinacea* as a useful medicinal plant and conservations assessment is clear, and it is fitting that this assessment should originate in Kansas, where more wild *Echinacea* is harvested—and it is a relatively sustainable harvest—than anywhere else. The foundation for work on this book is the research on *Echinacea* species conducted at the University of Kansas, the location of the most extensive *Echinacea* species herbarium collection. This collection was used to develop, in 1968, the most widely known systematic classification

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Fig. 1 *Echinacea angustifolia* sampling transect being set up by Kindscher for monitoring resprouting *Echinacea* plants near Plainville, Kansas (*Source*: Kelly Kindscher)

of *Echinacea* species by McGregor, a KU taxonomist and director of the herbarium, which eventually was named for him. More recent research, also at KU, has examined these species' ethnobotany, wild harvest, and plant population dynamics and safety (Hurlburt 1999; Kindscher 1989, 1992; Kindscher and Mitscher 1993; Kindscher et al. 2008). In addition, the Kansas Biological Survey at KU 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, as well as conservation elements throughout their ranges. And conservation has been the central theme of work as we developed a tool to ascertain whether *Echinacea* and other commercial medicinal plants were indeed of being "at-risk" of overharvest (Castle et al. 2014) (Fig. 1). But this is not just a Kansas work as the plant use and interest in *Echinacea* species is international. It is even more commonly found in pharmacies in Germany than the USA. And consumers in the USA are consuming an international supply as *Echinacea* grown in India and China is now being marketed in the USA.

Research Focus on *Echinacea*

If I were to name one plant that has been the heart of my research, it is *Echinacea*.

When I was a graduate student here at the University of Kansas, my major professor was Phil Wells, a famous plant ecologist who did lots of work on packrat middens and post-glacial plant communities studying and carbon-dating pine needles, acorns, and other plant materials in desert caves in the US West and Southwest. He used these materials to study the climate change 15,000 years ago. He fostered in me a great interest in learning and shared a wealth of information about plants and plant communities. And one day he gave me some great advice, something to this effect: "You know, Kelly, as a grad student, you should pick your group of plants that you want to work on and have that be something you study for your career and then write something about that."

Phil was talking in particular about figuring out the classic taxonomy or species identifications, and at the time he was finishing up a book on Manzanitas—a group of shrubs known primarily from California and the Southwest. That was his career plant group, so to speak. I heard his advice and immediately thought I ought to work on *Echinacea*. I already had published an ethnobotany of the species a year or two before.

Early in my graduate work I was going through the plants considered the most important medicinally in the Great Plains, and *Echinacea* clearly rose to the top. It is known to have been used by 16 Plains tribes; it was a cure-all—the icon of the region's medicinal plants, as an iconic genus I have chosen to work on.

This book is unique for the following reasons:

- It is based on fieldwork experience in Kansas, North Dakota, Montana, and across the region as we know these plants in their native habitats. In addition, we visited ranches in Texas, Oklahoma, Kansas, Nebraska, and Montana where *E. angustifolia* was growing. We also visited field sites in Missouri, Oklahoma, Tennessee, and Kansas of *E. atrorubens, E. pallida*, *E. paradoxa*, *E. purpurea*, *E. simulata*, and *E. tennesseensis*. And we visited specific locations where overharvesting is known to have occurred in north-central Kansas, Custer National Forest, and the Fort Peck Indian Reservation in Montana. All told, we know these species, their locations, habitats, abundance, and uses.
- The maps we have put together on the range of all the species are based on verified herbarium records and are the most accurate of any produced.
- We provide detailed overviews and offer new insights into the biology, life histories, cultivation, markets, legal protection, chemistry, and medical use of *Echinacea* species.
- The information on ethnobotanical uses of *Echinacea* species, and especially *E. angustifolia*, is the most thorough and well-documented on the topic to date. We have now provided documentation of 19 different tribes that used *Echinacea* in North America.

Fig. 2 Healthy *Echinacea angustifolia* population in eastern Montana northern mixed grass prairie with *Artemisia* species and *Juniperus scopulorum* (*Source*: Kelly Kindscher)

- Finally, we have developed and outlined conservation recommendations for all of the species (Fig. 2).

I hope this conservation assessment will contribute to the development of 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, managers of state-owned 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 key to its survival. As we learn more about the important medicinal uses of *Echinacea* species, we will likely one day be searching across the geographical range of its populations for germplasm that has the highest content of some secondary compound that has important health benefit, that may not even be identified yet.

I continue to support the sustainable wild harvest of *E. angustifolia*, especially in those areas with large native stands, such as the Smoky Hills of Kansas, as part of the future supply for herbal product markets. I greatly appreciate and support the work of conservation-minded harvesters who go by the names—diggers, rooters, or wildcrafters, depending on where one is, and who choose to work outside in these wild lands, in fascinating habitats and rock outcrop, and who choose to work in nature. And I greatly appreciate those who cultivate *Echinacea* species and even those who just appreciate the plant for its health-promoting properties and beauty.

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Part I
Cultural Use

The Uses of *Echinacea angustifolia* and Other *Echinacea* Species by Native Americans

Kelly Kindscher

In the Native American healing system, the uses of any plant are grounded in a religious or spiritual context. Spiritual forces, coming through the plant, are the healing agent. Though the vast majority of medicinal plants Native Americans have used in this region do have pharmacologically active substances (Kindscher 1992; Kindscher et al. 2013), these Native people have not used these plants for the sole purpose of benefiting from their active ingredients. Rather, these plants are primarily used for their spiritual healing properties and they have active ingredients that help heal ailments. But some plants are used more commonly because they have such powerful properties, and one that was the most important to Indians of the Great Plains was *Echinacea*.

Echinacea angustifolia, also known as *Echinacea* or the purple coneflower, has been the most widely used medicinal plant of the Plains Indians in North America (Kindscher 1989; note, parts of this chapter originally were in this article). It has a large number of common names and Indian names (Table 1), and has been used by at least 15 tribes in the region for a variety of ailments, including coughs, colds, inflammation, rabies, snakebite, sore throats, toothache, worms, and as a painkiller. In addition it was used to treat animals, especially horses.

The use of *Echinacea angustifolia* by Native Americans is not just a historical practice. The plant is still being harvested and used traditionally today on many reservations. Its use for medicine is known on essentially all reservations in or near the Great Plains. I have observed its use on the Rosebud Sioux Indian Reservation in South Dakota, the Crow Reservation in Montana, and on the Fort Peck Indian Reservation in Montana (Fig. 1). In the late 1990s and early 2000s, there was a large increase in the amount of wild-harvested *E. angustifolia* and great concern that was being overharvested (specifically in places like the Fort Peck Reservation) for the

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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
The following Indian names not only tell us that the plant was well known, but also information about its uses and importance
• *ashosikwimia'kuk,* "smells like muskrat scent" (Potawatomi)
• *ica'hpehu,* "something used to knock something down" (Lakota)
• *inshtogahte-hi* where *inshta* means "eye," in reference to use as an eye-wash (Omaha and Ponca)
• *ize. iso. he.,* "medicine makes you numb" (Kiowa-Apache)
• *ksapitahako,* "hand, to whirl" (Pawnee): reference to child play
• *mika-hi* "comb plant" (Omaha and Ponca)
• *o.hicise' ize,* "tooth-gum medicine" (Kiowa-Apache)
• *on'glakcapi,* "something to comb the hair with" (Lakota)
• *saparidu hahts,* "mushroom medicine" (Pawnee): reference to shape of seed head (similar to mushroom)
• *sapita-tahok* is compounded from *sapita*, "hand," and *tahok*, "to whirl." It is so named from a children's game (Arikara name)
• *shika'wi* (Meskwaki)
• *wetop,* "to comb the hair" (Meskwaki)
• *xopadi taidia*, "cold medicine" (Hidatsa)

herbal product trade (Kolster 1998). Additional observations, and my visit to the Fort Peck Reservation at that time, are discussed in the Chapter "Threats to Wild *Echinacea* Populations").

Loss of Tribal Knowledge

The history of North American settlement by Europeans is a history dominated by lack of interest in and even antagonism toward Native Americans traditional practices—and much information has been lost. Traditional medicinal plant use by Native Americans was carried out in the context of a spiritual worldview foreign to Europeans. As is well-known, conflicts emerged between people of European heritage and Native Americans soon after contact, and these conflicts ultimately resulted in tribes being forced to give up their lands, live on reservations, and Native cultures being stripped away. Often these reservations were not part of tribal homelands, where familiar medicinal plants grew. Therefore, Native cultures were no longer able to easily use their traditional medicinal plants, and maintenance of this knowledge was often not possible. In addition to loss of knowledge within tribes, the travelers, traders, and early doctors who came to the region seldom took the opportunity to

Fig. 1 Fort Peck Indian Reservation *Echinacea angustifolia* stand in *Stipa comata* native prairie grasslands northeast Montana. This population was reported to have been "wiped out" due to overharvest in 1998. This photograph was taken 2 years later and many *Echinacea* plants are still present due to roots resprouting after harvest, and small plants having grown up to flowering size (*Source*: Kelly Kindscher)

learn about medicinal plant resources from Native Americans. This occurred for a variety of reasons: warfare, attitudes of cultural and scientific superiority of those of European heritage, inability to communicate because of language barriers, and different spiritual and cultural practices. Settlers across the Midwest and Great Plains did not use *Echinacea* for its health benefits because they did not know about it, until patent medicine salesman, H.C.F. Meyer of Pawnee City, Nebraska popularized it.

Uses of *Echinacea* Reported by European/American Explorers

Along the Missouri River were the villages of the Arikara (Sahnish), Hidatsa, and Mandan. Lewis and Clark visited the Arikara village (that was located in northern South Dakota today), continued up the river and stayed near the Mandan village (in North Dakota today) during the winter of 1804. Although Lewis and Clark are viewed as some of the first European-heritage travelers up the river, the Arikara villages and people had already been decimated by smallpox (a European disease). When Lewis and Clark were at the Mandan village, an English trader from the North West Company arrived from the Assiniboine River outpost in Canada. He visited with William Clark and told him on December 16, 1804 about *E. angustifolia* root as "the cure of a Mad Dog" by the Indians (Journals of the Lewis and Clark Expedition 2005). Clark wrote in his journal (in quaint language) on February 28, 1805 that in addition to its use for rabies, it also was used for snakebite and other ailments:

> "this root is found on high lands and asent of hills, the way of useing it is to Scarify the part when bitten to chu or pound an inch or more if the root is Small, and applying it to the bitten part renewing it twice a Day. The bitten person in not to chaw or Swallow any of the Root for it might have contrary effect" (Journals of the Lewis and Clark Expedition 2005).

Merriwether Lewis was the first person to ship *Echinacea* roots back East from the Great Plains. From their Mandan village camp, he discussed *E. angustifolia* in his note that accompanied a botanical specimen (which was unfortunately lost), and sent back a "parcel of its roots, and seeds to President Thomas Jefferson." Lewis commented in these notes written on April 3, 1805, that an Arikara chief, who had accompanied them from his village up the river to the Mandan village, had told him that the root "pounded in either green or dried state makes an excellent poultice for swellings or sore throat" (Journals of the Lewis and Clark Expedition 2005). The significance of this is that Lewis and Clark sent back only those things that had the highest potential scientific or economic interest.

After Lewis and Clark, there were more observations, including Henry Brackenridge, who explored the Missouri River region by steamship, and who reported in June 14, 1811 that he also visited an Arikara village and observed their use of *Echinacea*:

> "In one of the lodges which we visited, we found the doctor, who was preparing some medicine for a sick lad. He was cooling with a spoon a decoction of some roots, which had a strong taste and smell, not unlike jalap. He showed us a variety of samples which he used" (Journals of the Lewis and Clark Expedition 2005).

And Prince Maximillian of Weid, a German province, also traveled up the Missouri River by steamboat in 1833 and reached Montana, and when at Fort McKenzie he met individuals of several Indian tribes and reported that the Blackfeet used several "efficacious medicines," including another root which is "said to be especially effective against snakebite." And again at Fort Clark in North Dakota on the way back down the river, and where they spent the winter, Maximillian reports on what is surely *Echinacea angustifolia*:

"The black root or snakeroot is a bitter medicine for the stomach and is said to be used by Indians against bites of poisonous snakes." He then provides more detail in his notes about the plant and its use by engages (boatmen):

> "The French call it *la racine noire*. It grows on poor stony, and dry heights. Its root, hardly finger-thick, descends perpendicularly deep into the ground. From a large plant, [the root] can be torn off [from] five feet deep in the ground. It is effective against toothaches and wounds. It is chewed and a little bit is put on the wound or on the tooth. Many engages maintain [that] one need only to suck the root or smear the shoes with the chewed root and no rattlesnake would touch a person but rather, [the snake would] flee right away (Wied and Witte 2008)."

Tribal Uses of *Echinacea* reported by Ethnobotanists

Ethnobotany (the study of cultural use of plant materials) is a relatively new science, so unfortunately there has been little funding, past or present, for it. In the Midwest and Great Plains, tribal members were seldom encouraged to share what they knew; in fact they were discouraged and at times persecuted for traditional practices. 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, dosage, and specific recipes for making preparations.

Two ethnobotanists who did study tribal uses of plants, while getting to know tribal members very well in the years between 1910 and 1935, were Melvin Gilmore and Huron Smith. Each of them took specific interest in respectfully learning the edible and medicinal plant uses of the tribes nearest them.

The Spirit That Heals

I worked with Alex Little Soldier or Alex Lunderman, a tribal elder on the Rosebud Reservation in South Dakota, from the time I was a graduate student until several years into my permanent position at the Kansas Biological Survey. During my first visit to Alex at Ring Thunder community, he was tribal chairman and very busy. I had Dilwyn Rogers' book on Lakota uses of plants and wanted to talk to Alex about plant use. After being there a couple days he said, "well, let's talk about plant use. What do you have to show me?"

So I got out the book, and I was really pleased because it had English names, scientific names, and Lakota names. I had this whole list of plants, all these different plants and their uses—Lakota uses.

Alex just kind of stopped and said, "well, this is interesting, but, you understand, it's not the plant that heals, it's the spirit." And I said, "yeah, I understand that, but don't you use *this* plant"—and I'm pointing to the manuscript—"don't you use this plant to treat this? And this one to treat this?"

And he said, "yes, I do, but you don't understand. It's not the plant that heals, it's the spirit." And so I said, "well yes, I mean I understand that, but don't you use this plant here to treat this?" And he says, "well yes, but you don't understand…"

It was a funny moment, but also a teaching moment for me. Finally what he was saying about the healing process began to sink in.

Melvin Gilmore—whose work in Nebraska took him to meet Omaha, Pawnee, Ponca, Winnebago, and Lakota (Sioux) elders—reported about *Echinacea angustifolia* in 1917 that the macerated root (method of preparation and dosage not given) was "used as an antidote for snakebite 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 *Echinacea* "for more ailments than any other plant" (Gilmore 1913a).

The Oglala Lakota (Sioux) on the Pine Ridge Reservation in South Dakota (also called the confusing Teton Dakota by Gilmore) applied the root to areas of inflammation to relieve the burning sensation. They applied the root (probably ground) for its "feeling of coolness" to areas of inflammation to relieve the sensation of burning (Gilmore 1913b). It should be noted that Gilmore described this as *Echinacea pallida*, but due to the location and taxonomy of the time, it was certainly *E. angustifolia*, (see discussion by Baskin et al. 1993, 1994). The root was also boiled with wild four-o'clock (*Mirabilis nyctaginea*) root for a vermifuge. It was taken for four nights and the next morning and the Lakota reported "the worms came away." If one has tapeworm, "it come away too." Boiled with *Echinacea*, the four o'clock was applied to swellings of limbs, arms, or legs, always being applied by rubbing downward, never upward (Gilmore 1913b). And Gilmore also reported that a spoonful of *Echinacea* was used for difficulties of delivery in childbirth, but he gave no more details on this use (Gilmore 1914). A more recently documented use on the Pine Ridge is that it was used for skin problems, such as washing away poison ivy, and it was still most commonly used to alleviate toothache (Red Cloud 1984, and Weasel Bear 1985; as cited in Morgan and Weedon 1990).

The Brule Lakota on the Rosebud Reservation used *Echinacea angustifolia* root and unripe seeds and flower heads for relieving thirst or perspiration and also as a painkilling remedy for toothaches, tonsillitis, stomachache, 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 25 years, I learned that *Echinacea* is still widely harvested by the Lakotas for the variety of medicinal uses listed above.

The Omahas—whose current reservation and historic villages were located in Nebraska near the city named after them—recognized two kinds of *Echinacea*: *nuga* ("male," being larger and having other masculine characteristics) and *miga* ("female," being smaller and a more efficient medicine; Gilmore 1913a). These male and female kinds were also recognized by Lakotas on the Rosebud Reservation with whom I have visited. The Omahas used some parts of the plant 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. Further up the Missouri River, on their reservation in northeast Nebraska, Winnebago medicine men also used it to make their mouths insensitive to heat so that they could take live coals into their mouths to demonstrate their power (Gilmore 1977). Both of these feats were not just trickery; they helped to create confidence in the medicine man's ability to call forth healing powers.

Moving west to the High Plains, the Kiowas have used *Echinacea* root as a cough medicine since prehistoric times. In the 1930s, on their reservation in western Oklahoma, 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 *Echinacea* root and letting the saliva run down the throat (Vestal and Schultes 1939; Grinnell 1962). The Kiowa-Apache (a distinct tribe) used a small 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 2008). It was reported that they dug the roots at any time of year, but the plants were most easily located in 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 2008).

The Cheyennes are a High Plains tribe with reservations in both Oklahoma and Montana, reflecting the widespread nature of their Great Plains culture and how reservations divided the cultural geography of people. They used *E. angustifolia* 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 Sun Dance ceremony required several days of dancing, while giving up food and drink, as a way to offer personal sacrifice as a prayer for the benefit of the community. The Cheyenne also drank an *Echinacea* tea for rheumatism, arthritis, mumps, and measles. A 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 *Echinacea* roots were mixed with puffball (*Lycoperdon* species) spores and skunk oil (that is oil from skunk fat), they were used to treat boils (Hart 1981).

Edwin Denig was a trader and trapper in Manitoba and Montana, married the daughter of an Assiniboine (Sioux) chief, lived at Fort Union along the Missouri River in eastern Montana for 21 years during the mid-1800s, and knew the Assiniboine people well. In discussing their medicine, he reported that *Echinacea* 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 *Echinacea*.

Other tribes that lived in the Great Plains and the Tallgrass Prairie region to the east also used *Echinacea* species. 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). Alma Snell also reported that in the old days, *Echinacea* root was used to treat rattlesnake bite, by chipping it into small pieces, boiling it and applying it as a poultice to the wound, and sometime also by adding tobacco to the poultice (Snell 2006).

Wolf Chief, an Hidatsa, reported to Gilbert Wilson in the early 1910s, that *Echinacea* was found all over the country, and although he was not versed in all of its uses, as the *Echinacea* plant "belonged to the outfit of the River Ceremony (Wilson 2014)." But Wolf Chief said he did know the plant and know why it was called *xopadi taidia* (cold medicine) in Hidatsa. Hidatsa warriors would dig up a section of the root, about two inches long and chew it as a stimulant when traveling all night:

> "When the warrior felt tired thus, he would chew a little piece of the root the size of one's fingernail and swallow the juice. The juice was very strong, and one could not take much of it. Also the warrior would wet the end of his finger in the juice of the chewed root in his mouth and with it moisten the upper eyelids and the inside of his ears and the paps of his breast. The juice felt cold and kept one awake and strong for the march. It has a rather stingy feel, like pepper but not so strong. When chewed and the breath was drawn into the mouth, the mouth felt cold. This I think, is why it is called by us cold medicine" (Wilson 2014).

The Comanches used the root for treating sore throat and toothache (Carlson and Jones 1939). The Blackfeet also used it for similar purposes as the roots were chewed to cause mouth numbness for toothaches (Johnston 1987). 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 *Echinacea* 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 (Fig. 2) (Meyer 1887; Foster 1991).

Echinacea species were also used outside 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 *Echinacea* was used by his people for snakebite (Gilmore 1913b). The native distribution of *Echinacea* 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.

Huron Smith, who studied all the native tribes to Wisconsin interviewed Meskwaki (or Fox) Indians who used the *Echinacea* (*Echinacea pallida*, rather than the reported *E. angustifolia*, due to its location), along with the roots of wild ginger (*Asarum canadense*), flowering spurge (*Euphorbia corollata*), and bee balm (*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), who reported that a Delaware elder called this plant "horse-hobble weed," and when combined with staghorn sumac (*Rhus typhina*) was used as

Fig. 2 Harvested plants of *Echinacea angustifolia* have a long history of being a prized medicine (*Source*: Kelly Kindscher)

a remedy for venereal disease, and that the patient should refrain from eating sour fruit and greasy foods, and that water should be taken freely and often. She also reported that *E. purpurea* was also called "Yuchi gonorrhea medicine" and that a tea made from this plant alone will cure an advanced case of venereal disease in 7 days." This report is also discussed by Jackson (2006), who interviewed a Yuchi tribal elder, Mose Cahwee, and reported that boiled *E. pallida* root was an important toothache remedy, and that an appropriately carved, shaped piece would be inserted directly into the open cavity to alleviate discomfort. And this root was also used for gum pain as a piece of the root, similarly prepared, could be wrapped in cloth, and then placed upon the gum to relieve pain. Referring to Tantaquidgeon's reference to "Yuchi gonorrhea medicine," he noted that: "during the period preceding Tantaquidgeon's work (as today), the Yuchi and Delaware were in limited contact with one another in Eastern Oklahoma. Both groups share many Woodland Indian customs and a history of coerced relocation from homelands in the Eastern Woodlands." This use is reported elsewhere in the ethnobotanical literature, but ascribing it to one tribe or another may also be making a negative comment about another tribe.

The Choctaw also used *E. purpurea* (Campbell 1951; Birch 2004) as recorded by a self-taught physician and trading-post operator, Gideon Lincecum, who lived in Mississippi and Georgia between 1800 and 1835 and made notes about medicinal plant uses associated with his 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).

Table 2 Ethnobotany of the three *Echinacea* species by tribes, and areas lived in (about 400 years ago, before European immigration)

Tribe	Area	Uses	Part used	Treatment	References
Echinacea angustifolia					
Arikara	SD/ND	Snakebite	Several	Chew and apply the root to bitten area for relief	Journals of the Lewis and Clark Expedition (2005)
Assiniboine	MT	Pain relief	Root	Root applied to inflamed area to reduce swelling	Denig (1930)
Blackfoot	MT	Toothache	Root	Chewed root to cause numbness for toothache relief	Johnston (1987)
Cheyenne	OK/MT	Pain relief	Several	Infusion made from powdered parts used as wash	Grinnell (1962)
Cheyenne	WY	Salivary stimulant	Root	Root chewed to promote salivation and ease thirst	Hart (1981)
Comanche	TX	Sore throat/toothache	Root	Root was used to alleviate toothache/sore throat	Carlson and Jones (1939)
Crow	MT	Cold/colic	Root	Chewed root for cold, prepared tea for colic	Hart (1976)
Crow	MT	Snakebite	Root	Cut, boiled, and mixed with tobacco for bite relief	Snell (2006)
Hidatsa	ND	Stimulant	Root	Warriors chewed root for stimulation during travel	Wilson (2014)
Kiowa-Apache	OK	Toothache	Root	Applied root to affected tooth to cause numbness	Jordan (2008)
Kiowa	OK	Cold/sore throat	Root	Chewed root and let saliva drip down throat	Vestal and Schultes (1939)
Lakota	NE/SD	Snakebite	Root	Pulverized root applied to affected area for relief	Gilmore (1913a, 1913b)
Lakota	NE/SD	Pain relief	Several	Parts used to alleviate toothache and stomach pain	Gilmore (1913a, 1913b)
Mandan	ND	Rabies	Several	Known as "the cure for the Mad Dog"	Journals of the Lewis and Clark Expedition (2005)
Omaha	NE	Local anesthetic	Roots	Anesthetic applied to feign supernatural ability	Gilmore (1977)
Pawnee	KS/NE	Medicinal purposes	Several	Taught medicinal uses of the plant to HCF Meyer	Meyer (1887)
Ponca	NE	Snakebite	Root	Remedy for snakebite, stings, and other poisons	Gilmore (1977)
Winnebago	WI	Local anesthetic	Roots	Anesthetic applied to feign supernatural ability	Gilmore (1977)
Echinacea pallida					
Fox	WI	Stomach cramps	Several	Mixed with several other plants to alleviate cramps	Smith (1928)
Yuchi	AL	Toothache	Root	A piece of root was applied directly to open cavity	Jackson (2006)
Echinacea purpurea					
Choctaw	MI	Cough	Root	A tincture of the root successfully remedied cough	Campbell (1951)
Delaware	DE	Venereal disease	Several	A tea of this plant would cure gonorrhea "in 7 days"	Tantaquidgeon (1942)

Conclusions and Future Study of *Echinacea* Use

It is very likely that almost all tribes in the Great Plains and Midwest, where access to *Echinacea* was pretty easy, used it as a medicine for a variety of treatments. In the South and eastern United States, it is likely that a variety of *Echinacea* species were commonly used. Overall, I have been able to document the uses of *Echinacea* species by 19 tribes. There were many more, and especially more tribes who used *Echinacea* species in the eastern and southeastern United States. Again, *Echinacea* use is not just a historical phenomenon. Many tribes in the Great Plains are still actively using it for medicine. Unfortunately, there has been little recent effort to learn about those practices; the work of Kolster (1998) is one fairly recent exception.

An additional factor in current information not being studied is that most Native American people, understandably, still have great concerns about sharing their knowledge. They often feel it is inappropriate to share this knowledge for published resources as it could be taken out of context. As mentioned previously, the Native American health and healing system does not separate spirit from substance. And as part of this, 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's knowledge is still of great interest and is an opportunity for insight (Table 2).

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Cultivation of *Echinacea angustifolia* and *Echinacea purpurea*

Kelly Kindscher and Maggie Riggs

Echinacea purpurea has fibrous roots and is much easier to grow than the tap rooted *E. angustifolia*. It can be harvested the first year for above ground herb and flowers. Surprisingly, a plant that is easy to grow and readily comes up from seed in gardens is uncommon in the wild. It is used widely by European companies for fresh squeezed juice among other protocols. But there is a preference among many for the root of the *E. angustifolia* species.

Opportunities for Growing *Echinacea*

Opportunities in the marketplace for cultivated *E. angustifolia* root are fueled by concerns that wild native stands will be over-harvested. However, *E. angustifolia* is notoriously hard to germinate and takes at least 3–4 years before roots are large enough to be harvested, during which time the market and going price can change radically. For these reasons, cultivation of *E. angustifolia* has historically been primarily limited to a few small scale growers, although the market for cultivated root is growing.

As with most plants cultivated for the market, there are many successful ways to grow them. We will share ours and what we have observed and learned from others. We recognize that other techniques work well too, and we also encourage any grower to experiment and work out cultivation techniques that work best for your situation.

There have been commercial plantings of *E. angustifolia*, but the suitability of cultivated *E. angustifolia* to replace wild-harvested roots of the same species had

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not always been accepted. Many people consider wild-harvested roots more desirable. As we learned from one Kansas *Echinacea* root broker in 2005, a European company cancelled an order for 40,000 lb of commercially cultivated *E. angustifolia* grown is Kansas (with center pivot irrigation and fertilizer), asserting that due to test results showing lower chemical content profiles, it would take 5 times more of these cultivated roots than wild roots to supply the same amount of active ingredients (Pat Thrasher 2002, personal communication). Independent studies of other wild species corroborate that higher quantities of secondary compounds are found in wild stands than in cultivated stands of the same species, such as wild raspberries in eastern Europe (Çekiç and Özgen 2010) and wild tomatillos in Kansas (Kindscher et al. 2014).

But this is not always the case. Many factors affect the outcome of cultivated *Echinacea* crops including soil type, seed stock, time of planting, viability of seed, rainfall, temperature variability, fertilization techniques, insect control, harvest times and post-harvest handling techniques. Some of these agricultural practices are also known to affect levels of beneficial secondary compounds (El-Gengaihi et al. 1998; Berbec et al. 1998). By mimicking the natural growing conditions of *E. angustifolia*, the well-drained rocky limestone soils, persistent drought and long, tough winters, a grower hopes to produce crops with the chemical composition of wild *Echinacea*.

Seed Collecting

It is important to begin with good seed. The ideal time for collecting seeds of *E. angustifolia* and other *Echinacea* species is sometime in late summer, or a little before the first frost. If seeds are harvested prematurely, it is likely that none will be viable. Seeds can be harvested when the stems become dry and brittle and the cone heads turn black. A few seeds may shatter and have fallen out of the cones, but this is a good indication of ripe seeds. Most seeds will still be held tightly in the cone when harvested and over time, as they dry, the seeds will loosen and can be shaken out of the cones.

While harvesting, one should check some of the seeds by breaking open the achenes and examining them. If most of the achenes are empty or the embryos look shriveled (one may want to look at them under magnification), they are probably not viable and will not germinate. Specifically, one should be able to see, especially with a hand lens or microscope, white endosperm inside the seed coat. And tasting them for a tiny bit of that wild tingly *Echinacea* taste, which is found in the endosperm, is another good test.

Seeds should be collected from several different plants, as viability varies from plant to plant. If possible, also collect the same species from several locations to increase the genetic diversity of one's plantings (Cech 2002).

It is important to keep species separate. Check to be sure only one *Echinacea* species grows in the region you are harvesting seeds from, avoiding border areas where two species ranges meet. For example, on the Konza Prairie near Manhattan, Kansas, *Echinacea angustifolia* and *E. pallida* both exist but 150 miles west, near Plainville, KS, there is only *E. angustifolia* and a lot of it! There are no stands of other *Echinacea* species in the vicinity of Plainville that could have bees or butterflies cross-pollinate them. Some of these pollinators can travel several miles. So harvesting *E. angustifolia* from these wild stands assures you have the right seed.

We know *Echinacea* species cross easily. When we have grown them next to each other in demonstration beds at our Native Medicinal Plant Research garden at the University of Kansas, after a few years we get mixed hybrids that come up, and we can no longer tell which species they are. They have purple flowers but a different mixture of denser and longer hairs that are not characteristic of native species planted. Hybrids are found in the wild and have also been archived for study at the University of Kansas R. L. McGregor Herbarium.

Harvest seeds in dry weather, collecting the cone heads and putting them in large paper bags or baskets, and then store them on screens or tarps with fans on, or use any storage solution that allows the drying process to continue. Shake cones vigorously when dry to collect seeds. Seeds should be stored in a cool dry place, preferably no longer than 6 months. However, if placed in cold storage, seeds should remain viable for about 60 months (Foster 1991).

Seed Purchasing

When purchasing seeds, you may have a choice between seeds from wild harvested or cultivated plants. Although germination rates are much lower from wild native stands, many growers prefer these seeds, hoping to propagate the genetics shaped by the duress of the natural environment such as drought tolerance, higher levels of secondary compounds and general potency. The down side of wild harvested seeds is they are more likely to have dried or shriveled seeds or empty achenes, a natural response to harsh prairie summers. Seeds from cultivated stands are plumper, reflecting irrigation and nutrients during the time they were developing, and have much higher germination rates.

When purchasing seeds, and especially when purchasing large quantities, establish that seeds have been tested for purity and viability. Require that the percentage of pure live seed (the percentage of the seed that is viable and will germinate) be identified, and if possible, a precise identification of seed source, and ideally certified verification of the species. Again, one can easily test for empty achenes by crushing seeds of a representative sample with a fingernail and looking for live moist endosperm.

Seeds can be purchased from many sources (see Table 1). Wholesale seed prices for *E. angustifolia* have ranged from $170 to $750 per pound. At times seeds are difficult if not impossible to locate, as many are collected from the wild, and drought years make viable seed scarce. The price of seed for *E. purpurea* is considerably less, available for around $25 per pound and more. For medicinal plant products,

Table 1 *Echinacea* seed bulk suppliers

American Meadows, Inc.
223 Avenue D, Ste. 30
Williston, VT 05495
Phone: (802) 951-5812; Fax: (802) 951-9089
http://www.americanmeadows.com
D. Landreth Seed Co.
P.O. Box 16380
Baltimore, MD 21210-2229
Phone: (800) 654-2407; Fax: (410) 244-8633
https://www.landrethseeds.com/
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
Horizon Herbs, LLC
PO Box 69
Williams, OR 97544
Phone: (541) 846-6704; Fax: (541) 846-6233
https://www.horizonherbs.com/
Johnny's Selected Seeds
955 Benton Avenue
Winslow, ME 04901
Phone: (800) 879-2258
http://www.johnnyseeds.com/
Missouri Wildflowers Nursery
9814 Pleasant Hill Road
Jefferson City, MO 65109
Phone: (573) 496-3492; Fax: (573) 496-3003
http://www.mowildflowers.net/
Outsidepride.com, Inc.
915 N. Main
Independence, OR 97351
Phone: (800) 670-4192; Fax: (503) 606-0659
http://www.outsidepride.com/
Prairie Moon Nursery
RR 3, Box 163
Winona, MN 55987-9515
Phone: (507) 452-1362; Fax: (507) 454-5238
https://www.prairiemoon.com/
Pure Air Native Seed Co.
24882 Prairie Grove Trail
Novinger, MO 63559
Phone: (636) 357-6433; Fax: (844) 357-6444
http://www.pureairseed.com/

(continued)

Table 1 (continued)

Seedland, Inc.
9895 Adams Road
Wellborn, FL 32094
Phone: (800) 820-2080; Fax: (386) 963-2079
http://www.seedland.com/
Sharp Bros. Seed Co.
1005 S. Sycamore St.
P.O. Box 140
Healy, KS 67850
Phone: (800) 462-8483
http://www.sharpseed.com/
Western Native Seed
P.O. Box 188
Coaldale, CO 81222
Phone/Fax: (719) 942-3935
http://www.westernnativeseed.com/

This list was compiled from a series of internet searches during January 2015 for suppliers selling *Echinacea* seed (*E. angustifolia*, *E. purpurea*, or *E. pallida*) in quantities of at least one pound

avoid all *E. purpurea* cultivars that have been recently selected for their flowers because they likely will have lower levels of medicinal constituents and may also be hybrid species (for more on cultivars, see Chapter "Naming and Classification of *Echinacea* Species"). There are approximately 145,000 seeds in one pound of *E. angustifolia* seeds, and approximately 117,000 seeds in one pound of *E. purpurea* seeds (Foster 1991).

Germination Rates

Since wild harvested *E. angustifolia* seeds can have germination rates as low as 10 %, increasing germination through pretreatment of the seeds has its practical applications. Some of the following techniques are labor intensive but worth trying if you have a small, limited supply of seed or the seed is very expensive or from a remote population of particular interest. If you are selecting for strong transplants, some of the following techniques for increasing germination rates will be helpful as well.

In order to germinate, seeds must be viable. Research conducted by Little (1998) to test viability of *E. angustifolia* as a graduate student at South Dakota State University found that low test-weight seed indicates undeveloped or blank (non-viable) seeds. Test weights above 200 g per cubic cm 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 one 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's research on germination of *E. angustifolia* seed also provided 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, all other variables apparently being the same (Little 1998).

Methods of Seed Treatment

Because *Echinacea* seeds are embryo dormant, they require a period of cold, and ideally moist, conditions for optimum germination (this is a process called stratification). In the wild, seeds would drop to the ground, interfacing with intermittently moist soils and temperature extremes which would crack the outer layer at some point during the winter. There are several methods of simulating these conditions of winter and spring that serve the purpose of stratifying harvested seed.

Why *Echinacea angustifolia* Is Difficult to Grow for the Market

There are a couple of reasons this species is rarely cultivated. One is climate. It needs to be dry. Lots of water and fertilizer don't make for a better crop. My involvement with medicinal chemist Rudy Bauer's comparison of roots collected from different sites, particularly his results that showed the potency of the roots from a biodynamic grower, many years ago, convinced me that it's within the realm of possibility to produce a highly medicinal crop. But any grower faces a typical problem, which is that it takes so long to get a crop—2–3 years—and the market is not steady. The price goes up and down. You're tying up land, and when your crop is ready, the price may be at its low end, if you can sell it at all.

Most *E. angustifolia*, the gold-standard species for medicinal value, is wild harvested, and I like that. I'd rather see people out there digging, out on the wild landscape, walking across those beautiful prairies of western Kansas. And we still, generally, see higher content in wild-crafted roots (this is the term used to refer to wild harvesting) than we do in cultivated product.

My experiences with Bauer's tests, along with my discussions about a grower who cultivated a field in southwest Kansas using a center pivot irrigation system, illustrate one reason the herbal product market has been criticized: There is great variation among the product, and in the mass market, you don't know the quality of what you're getting.

Dosage of medicinal plants is very important and should standardized. Standards could be developed, and with modern chemistry techniques, it would be possible to do chemistry work on every supply that's going to be used in products for the market. Even large amounts mixed together could be sampled and tested. Why not?

One of the simplest seed treatment methods is to leave the seeds outside during a cold winter, protected from rodents. Large metal garbage cans with secure lids serve this purpose well. The natural variations in daily temperatures and prolonged temperatures near or below freezing can be used to treat large quantities of seeds that will be ready for spring planting.

Steven Foster, a long-time *Echinacea* and medicinal plant enthusiast, photographer and writer, 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 animals out) and left over the winter (Foster 1991). 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 found could be carried out under household rather than laboratory conditions. But with these techniques, which do increase germination rates, seeds must be handled carefully to not damage the embryos or emerging root, and when planted, they must be kept continually moist so that the sprouting seeds do not die.

Higher germination rates were also achieved simply by soaking the seeds in water prior to stratification. Presoaking the seeds for 24 h improved germination compared to moistening the seeds only at the time of stratification, presumably allowing increased water absorption (Sari et al. 1999). For full a review of germination techniques, see Parmenter et al. (1996). For even more technical methods to increase germination rates, including the use of commercial growth regulators, see Feghahati and Reese (1994). These techniques could be helpful, but we think most growers will want to use simpler techniques and will just plant more seed.

Unless seeds are already germinated, it is important to plant *E. angustifolia* seeds when soils are still cool. According to Richo Cech, most direct seeded 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 2002).

In conclusion, low germination rates are common for *E. angustifolia*. They do not have to be a problem for establishing a crop, one just needs to know the rate and adjust the seeding rate accordingly.

Direct Seeding

If one has lots of seed and knows the germination rate, then direct seeding, the planting of seeds without any treatment (those that have not been cold and/or moisture treated) is fine, and requires much less work. In this case, 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 well-tilled seedbed increases seed and soil contact and enhances the chance of germination. Be advised, though, successful direct seeding is a challenge, even to the most experienced grower, owing to fluctuations in weather, rodent populations, weed competition, and other factors.

Planting seeds on top of the soil (with a mechanical planter or by hand) and tamping them down onto the surface (which most mechanical planters do) without soil cover will generally yield the best germination, as light speeds up the germination process. When the soil is moist, seeds tamped into the soil will germinate in approximately 5 days, but when covered with only 1/8 in. of soil, germination can take between 2 and 4 weeks (Foster 1991). Space seeds 2 in. apart in rows 18–24 in. apart. *E. angustifolia* are best thinned to 8 in. apart, while species with a fibrous root, such as *E. purpurea,* are optimally placed 1–2 ft apart in the row (Cech 2002).

Alternatively, unstratified seeds can be sown into flats or plug trays in an unheated greenhouse (or outdoors in the shade protected by screen). The ideal soil temperature for planting is 55–60 °F. *E. angustifolia* and other species with taproots must be planted in deep pots or "Cone-tainers" so that the root will not touch the bottom of the container before transplanting. 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 2002).

Soils and Transplanting

Ideal soils for *E. purpurea* have a pH value between 6 and 7. *Echinacea angustifolia* prefers more alkaline conditions with a pH value between 6.5 and 8. Although sandy loam, rocky clay, and limestone substrates are all places where we find healthy populations of wild *Echinacea* species, it is imperative that *E. angustifolia* be grown in very well-drained soils. Where the soil is well drained, abundant moisture improves overall plant size, health, and seed production, but it is believed that drought cycles and plant stress increase levels of beneficial constituents (see discussion in Kindscher et al. 2014). Species with fibrous roots, such as *E. purpurea*, are better adapted to growing in moderately to poorly drained situations, but well-drained soils are still generally better for production. Generally, dry, low-nitrogen soils produce higher concentrations of essential oils; while moist, nitrogen-rich soils produce high levels of alkaloids (Foster 1991). 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.

There are several advantages to transplanting seedlings over direct seeding. *Echinacea angustifolia* seed is expensive and is used more efficiently by transplanting. Slow-growing *E. angustifolia* will not compete well with weeds and it is easier to mulch around uniformly emerging plants than mulching around randomly emerging direct-seeded rows of very small seedlings. But transplanting also takes much more time and is more expensive.

If one chooses to transplant, they should 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 adding compost or crushed limestone can all be accomplished in August or September (Cech 2002). Loose soils at transplanting time in the spring will greatly speed up the work. Both *Echinacea* species do best in full sun, although *E. purpurea* can take some shade. Most times where there is shade there is also competition from the trees that produce it, so we recommend full sun for growing all *Echinacea* species.

Fertilization and the Effects on Plant Chemistry

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 2002). Fertilization and time of harvest appear to have an effect on the chemical composition of cultivated *Echinacea*. One should keep accurate records of production practices to learn which practices are most productive. Although commercial fertilizer will give yield boosts, one should be aware that they may reduce the secondary compounds per pound or per gram. Also, there is also a substantial market for organic production, which does not allow chemical fertilizer to be used in production.

There are several interesting examples of specific fertilization regimes affecting a particular chemical constituent. Rudolf Bauer has been the leading *Echinacea* researcher in Europe and his natural products research in both Germany and Austria has been very important to understanding the chemistry and health effects of *Echinacea* species. When he tested samples of both wild-harvested and cultivated *E. angustifolia* from several locations in Kansas, which we helped collect in March 1998, he found that the application of biodynamic compost resulted in isobutylamide levels that were "off the chart" (Terry Pitts, Sterling, Kansas, farmer, October 1998, personal communication). There was a range of content from 0.2 % in the wild-harvested *E. angustifolia* root to greater than 2.3 % in the sample root from cultivated *E. angustifolia,* which had been fertilized with biodynamic compost. Biodynamics is an organic, holistic, spiritual system of production developed in Europe by Rudolf Steiner in the 1920s. 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 (Fig. 1). In other analysis, El-Gengaihi et al. (1998) found that increasing nitrogen and potassium via fertilization can increase alkylamides.

Disease, Insect, and Weed Problems

Compared to wild stands, bringing *Echinacea* into production has resulted in increased disease and plant problems. 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

Fig. 1 Field of cultivated *Echinacea angustifolia* with little management or production cost near Stockton, Kansas (*Source*: Kelly Kindscher)

were used as mulch, and 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 (Cech 2002).

Although we have observed it on other *Echinacea* species, *E. purpurea* appears to be the most susceptible of all *Echinacea* species to aster yellows, which causes the stem to become yellow to red in color. As the disease progresses, the flowers stop producing seeds and become leafy. The overall look of the plant will be stunted and is easy to notice compared to healthy plants. This disease is spread by leafhoppers and appears to develop over a year or two. Where some growers have controlled the spread of the disease by removing infected plants as soon as they are identified, other growers have reported near complete losses in areas of heavy infestation. Resistant cultivars are not available, and control of the disease 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 one cuts through the stems or roots near their base, you will see that the tissues contain dark blotches in and around the vascular system. This has been observed only in wetter soils or during wet years.

Weeds can be controlled by mulching, hand pulling, hoeing and cultivation. Mechanical cultivation will be useful for larger growers. Attempts to cultivate mature plants of *E. purpurea* with a tractor and row-crop cultivator can be unsuccessful because stems easily break off at the base. Herbicides are not labeled for use on *E. angustifolia*, nor do organic certifiers approve them. For crops of *E. purpurea* herb (the above-ground portions of the plant), weeds are an issue for harvest as they could contaminate the crop and affect the chemistry. But for growers of roots, some weed growth can be tolerated.

Harvesting Roots and Tops

When *E. angustifolia* 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.

Fall is the best time to harvest roots as the moisture content is lower and it is believed that the roots have higher medicinal content then. A sturdy spade, adze, or other hand-digging tool, or tractor-pulled modified potato digger or plow are the most common tools used to lift the roots. Afterwards, stiff brushes can be used to remove attached dirt.

Harvested roots can be dried in the shade or a shed with good air circulation, especially with the use of fans. An herb dryer set at 110 °F is also effective, and faster (Cech 2002). Taproots are usually dried whole, but the fibrous roots of *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.

Semi-Wild Cultivation of *Echinacea*

Where soils in agricultural fields are thin due to rock outcroppings or no longer productive for agriculture use, there is an opportunity for interspersing *E. angustifolia* with native grasses, broadcasting seeds of both into these areas with the hopes of harvesting years later. In the case of Conservation Reserve Program land (often just known by its acronym—CRP land), *E. angustifolia* seeds could be broadcast into the area of the grass planting and after the CRP contract expires, or sooner if it is a native grass planting not in the program, these *Echinacea* stands could be harvested by “diggers.” Harvesting wild stands of *Echinacea* or plantings in marginal lands requires an adze, a long handled tool with a flattened blade on a pick-axe, such as *Echinacea* root diggers use in western Kansas (see Chapter “One Hundred Twenty Years of *Echinacea angustifolia* harvest in the Smoky Hills of Kansas”).

Harvesting Tops

There is a growing demand for the tops of flowering *E. purpurea* which have good concentrations of many compounds. Tops of flowering *E. purpurea* can be harvested the first year after planting, and larger yields occur after the second year. *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 (Fig. 2) (Cech 2002).

Fig. 2 Highly productive field of cultivated *Echinacea purpurea* at Trout Lake Farm, Trout Lake, Washington (*Source*: Steven Foster)

Effects of Harvest Time

It is known that time of harvest (season) affects levels of alkamides, an important active secondary compounds. Samples collected in June will differ from samples collected in October or November. Fall harvest produced both greater quantity and quality of essential oil (Smith-Jochum and Davis 1991). Again, there can be much variation in content due to timing and cultural practices. 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 now than 10 or 20 years 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 and drying procedures. It is also a good idea to become certified organic before planting in order to assure that the harvested *E. angustifolia* roots are suitable for the market that pays a higher price.

Both *E. angustifolia* and *E. purpurea* have well-documented histories of use for a variety of medicinal protocols, but there is no consensus on which active constituents are responsible for their efficacy. Some secondary compounds can be increased by certain agricultural practices (El-Gengaihi et al. 1998; Berbec et al. 1998), yet the medical community does not know which compound or group of compounds is preferred or should be selected for increasing.

For those who want to grow *E. angustifolia*, begin slowly, 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*.

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Part II
Botany

The Naming and Classification of *Echinacea* Species

Kelly Kindscher and Rebecca Wittenberg

Taxonomy is the science of classifying and naming organisms to reflect their shared characteristics and evolutionary relationships. It enables us to identify a species no matter what language we speak or common name we use by assigning a unique Latin binomial name (*genus* and *species*) to an organism. Latin names of plants can be revised or changed by the International Botanical Congress to reflect new knowledge about their relationships. However, occasionally names are conserved for ease of communication. *Echinacea* is a particularly confusing genus, as it hybridizes readily in the wild, and has conserved species names due to its long-term, widespread use in the herbal product trade.

Common names, although useful in the field, are sometimes confusing and of limited use across linguistic boundaries, even between nearby towns or similar dialects. For example, all nine species of *Echinacea* (and of several other genera as well) have been called "snakeroot." The common names for *Echinacea* include "purple coneflower" and "*Echinacea*." We believe that due to its use in the herbal product trade, and subsequently on the shelves of health food stores and pharmacies everywhere, *Echinacea* is now also its preferred common name, and so we have used it throughout this book.

Identifying species by their Latin binomial name is important when working with a medicinal species (McGuffin et al. 2000). Latin names can change, and with recent genetic data, there have been considerable changes in scientific names over the last few years as new relationships and orderings in species have been ascertained. 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

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the possible names used for a particular plant. A proposed revision (Binns et al. 2002, 2004) to the names of species in the genus *Echinacea* in the early 2000s created confusion between the newly named *E. pallida* var. *angustifolia* and its former name, *E. angustifolia*. Fortunately, and due to the best available data, the *Flora of North America* editors (Urbatsch et al. 2000, 2005) decided not to adopt these proposed changes and maintain the common taxonomy of the *Echinacea* genus. We will discuss the proposed Binns' revision below so as to be aware of the difficulties discerning the evolutionary relationships.

Because of high morphological variability within the genus, *Echinacea*'s taxonomy has changed often 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 accurately fit the descriptions provided below, and, beyond that, hybridization in the wild which mixes characters of the plants, occurs where *Echinacea* species ranges overlap (Flagel et al. 2008).

Taxonomic History of the Genus *Echinacea*

The genus *Echinacea* is in the daisy, aster or sunflower family, Asteraceae, with the preserved name Compositae. Species belonging in the genus *Echinacea* have historically 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 when discussing what we now call *Echinacea*. For example, both the Lloyd Brothers Pharmacy and ethnobotanist Gilmore (1913) used the name *Brauneria* for their early products and writings. Let's follow the path from *Rudbeckia* to *Brauneria* all the way through to *Echinacea*.

In 1753, Linnaeus described a species we now place 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). In 1790, Noel Joseph de Necker renamed the *Rudbeckia* genus to *Brauneria* (after the botanist Jakob Brauner), but *Brauneria* was later invalidated by the organization responsible for regulating botanical names, the International Botanical Congress.

Finally, in 1794, Conrad Moench renamed the species *Echinacea purpurea*. The genus name comes from the Greek word "echinos," meaning hedgehog, because of the spiny projections on its cone in the seed stage (Flannery 1999; Hobbs 1995). This is all slightly irregular, as when it was realized that Linnaeus's *Rudbeckia purpurea* did not belong in the genus *Rudbeckia*, the rules of the International Botanical Congress, known as the International Code of Botanical Nomenclature, dictated that the genus name should have been the oldest valid published name. But no name

Fig. 1 *Echinacea purpurea*, know at that time as *Rudbeckia purpurea*, illustration from William Curtis, 1787 (*Source*: Steven Foster)

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* (Fig. 1).

More Recent Taxonomic Treatments and Issues

Ronald McGregor was a botanist and director of the University of Kansas Herbarium, now named after him. He conducted a 15-year morphological analysis of the *Echinacea* genus (McGregor 1968), utilizing field, transplant, greenhouse, and garden studies of all possible crosses and backcrosses of species and their varieties. And led by his field activities and collections, the University of Kansas now houses the largest collection of *Echinacea* botanical specimen. This taxonomic treatment resulted in the species recognized today by botanists. Binns et al. (2002) published a systematic analysis of *Echinacea*, using phytochemical data, new molecular techniques, and morphological features for classification purposes. Their analysis did

Table 1 *Echinacea* species names according to McGregor (1968) and Binns et al. (2002)

McGregor (1968)	Binns et al. (2002)
E. angustifolia var. *angustifolia*	*E. pallida* var. *angustifolia*
E. angustifolia var. *strigosa*	*E. pallida* var. *angustifolia*
E. atrorubens	*E. atrorubens* var. *atrorubens*
E. laevigata	*E. laevigata*
E. pallida	*E. pallida* var. *pallida*
E. paradoxa var. *neglecta*	*E. atrorubens* var. *neglecta*
E. paradoxa var. *paradoxa*	*E. atrorubens* var. *paradoxa*
E. purpurea	*E. purpurea*
E. sanguinea	*E. pallida* var. *sanguinea*
E. simulata	*E. pallida* var. *simulata*
E. tennesseensis	*E. pallida* var. *tennesseensis*

not support McGregor's classification at the species level as they collapsed McGregor's nine *Echinacea* species into four species with varieties (see Table 1). So *E. angustifolia* was no longer a distinct species and it was moved to *E. pallida*, variety *angustifolia*.

This is not a new occurrence. For example, Gleason and Cronquist (1963) had previously 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, *E. angustifolia* and *E. pallida* are both medicinally important, so differences in classification have had a confusing effect, especially in the medicinal plant trade. For instance, in 1830, Constantine Rafinesque (1830) wrote about the medicinal properties of plants he placed in the genus *Helichroa* (Flannery 1999). No one realized that he was referring to the genus now called *Echinacea*, and much of his work went unnoticed.

There has also been considerable confusion in the prairie ecology literature. One of the most important researchers, John Ernst Weaver, noted for his work on grasslands through the Dust Bowl era at the University of Nebraska, also confused *E. angustifolia*, calling it *E. pallida* in his extensive writings (Baskin et al. 1994).

Because of all this past and present confusion in the genus *Echinacea*, Binns et al. suggested conserving the name *Echinacea purpurea*, meaning 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 agreed to conserve the name (Binns et al. 2004).

In work leading to his taxonomic treatment by Urbatsch et al. (2005) on *Echinacea* for the Flora of North America, they determined that the taxonomic differences did not require major changes to McGregor's classification of the species and justified this based on molecular data, a conservative view of taxonomy (Blumenthal and Urbatsch 2006). For ease of use and to avoid confusion, McGregor's (1968) taxonomy, now essentially adopted by the *Flora of North America*, is used throughout this chapter and book. Table 1 compares McGregor's and Binns et al.'s treatments. We provide this because these genetic differences are real and offer insights into the grouping of the species.

Factors Contributing to Confusion: Refugia, Hybridization, and Range Movement

Processes that drive the genetic divergence of species can lag behind the physical characteristics that botanists use to distinguish species in the field. We see this happen with *Echinacea* species. There is evidence of hybridization between *Echinacea* species, incomplete lineage sorting, and backcrossing following secondary contact of species after glacial events, all of which confuse interpretations of the molecular data (Flagel et al. 2008). Much of *Echinacea's* range was under ice during the last glacial epoch, resulting in *Echinacea* species surviving in southern refugia. The group of species moved north during the last 10,000 years, genetic barriers were incompletely formed, and hybrid swarms, with mixed characters, were noted during McGregor's (1968) work and have been further indicated by more recent molecular work (Mechanda et al. 2004; Flagel et al. 2008).

Research on *Echinacea* species chemistry at the NIH-supported botanical center at Iowa State University indicated that patterns of biochemical diversity correspond well to McGregor's taxonomy (unpublished but reported in Flagel et al. 2008), even though the molecular data is confusing. Adding to the confusion today is the fact that *Echinacea* species habitat has been destroyed (in areas that are now cropland) or fragmented and reduced (in areas where forest openings have closed or were significantly impacted by decades of livestock grazing and/or fire suppression).

DNA Barcoding and Other Techniques to Differentiate *Echinacea* Species

There is great concern about the identity and quality of any botanical materials used as an herbal supplement and for research. In addition to contamination by foreign substances, research indicates that herbal remedies are also contaminated by plant species not listed on the product's label. In their novel application of DNA barcode analysis of 44 herbal remedies purchased online, Newmaster et al. (2013) found that 59 % of the products analyzed contained DNA barcodes for species not listed on the product's label; 32 % of the products substituted another plant for the main herbal ingredient listed on the label; and 21 % of the products contained filler plant material, such as from rice, soybeans, and wheat.

Supplements that are expected to contain pure botanical product purchased from commercial suppliers have the potential to contain taxonomically related or unrelated plant species in addition to or in lieu of the claimed product (Newmaster et al. 2013). Also, in a review on the contamination of Indian herbal remedies, (Posadzki et al. 2013) discovered that prescription drugs were the most prevalent contaminant, followed by contamination from other sources, including dust, pollens, parasites, microbes (e.g., bacteria and fungi), and heavy metals. The use of DNA barcoding could help identify many of the identification and contamination problems, and especially as India, China, and other countries are becoming suppliers of *Echinacea* and other herbal products.

There has been considerable debate over which molecular marker(s) are ideal for plant DNA barcoding (Chase et al. 2007; Pennisi 2007; Kress and Erickson 2008; Ledford 2008). It is important to verify that any botanical product containing *Echinacea* is unadulterated, and if not, to identify the adulterant. Accomplishing these goals will require the use of molecular markers sufficiently variable to discriminate among closely related species, as well as markers that can "place" the putative adulterant within the larger phylogeny of flowering plants. Thus, it will be necessary to use a multi-locus barcoding approach, as described by Chase et al. (2007).

Native American Species Classification

It's possible that, even as recently as the past 100 years, Native Americans had a more finely scaled taxonomy than we do today. Within the species we call *Echinacea angustifolia*, and among other species, too, there was recognition of what I would see as two groups—male, "nuga"; and female, "miga."

The Omaha, Ponca, Lakota, and all the Sioux people made this division; there was a set of characteristics for each plant group. The "male" plants typically were stronger, bigger. The "females" were smaller, and perhaps they were considered more beautiful. I first learned about this division from elders I was working with at the Rosebud reservation when I was in my 20s.

We think of taxonomy in the terms used by Western culture; we think of the number of species and how we divide things today. But that's not the only system—just think how much more we would notice if we spent more time outside daily, as these tribal cultures did. Native Americans, for the most part, would recognize most of the different species we see today, but they also had some other divisions based on definite characteristics. Growing environment may have been a factor; one may have found the "male" plants in rocky outcrops or some other habitat. It's not at all surprising to me that some of those bigger, stronger, older, gnarlier plants, the ones with "male" characteristics, might have different chemistry than something that is viewed as more feminine.

Cultures vary in how they choose to divide and categorize things. Different cultures have different systems, and they work.

DNA barcodes have been published for six *Echinacea* species in the Barcode of Life Data (BOLD) Systems (Ratnasingham and Hebert 2007). These DNA barcodes will allow future businesses and companies who use *Echinacea* species to verify the species identity of the material they are using. Although this does not substitute for good botanical practices, such as always collecting botanical vouchers for materials used (see Eisenman et al. 2012), DNA barcoding is an additional, new technique that can serve a very useful function in ensuring quality.

There are differences between *Echinacea* species and they can be used to separate the species, but this is a rather expensive process, and may not always help with hybrids and mixture of species. They also relate to standards of analysis and the chemistry to do this, and to help with species identification, is found in the American Herbal Pharmacopoeia (2010a, 2010b) volumes on *Echinacea angustifolia* and *E. pallida*. These techniques are also discussed in "The Medicinal Chemistry of Echinacea Species" chapter of this volume.

And one other technique for identifying *Echinacea* species has recently been published, based on some 1960s research. *Echinacea* species have unique and distinctive micromorphology of adaxial epidermal cells in the ray flowers (the petals). These pyramid-shaped tiered cells are not found in other plants and also differ between *Echinacea* species. This interesting work was conducted by botanist Harold Keller (2014) as he was working on his Master's degree under Ronald McGregor at the University of Kansas, and he never published this data until he retired as a faculty member of Central Missouri State University, and had time as a research associate at Botanical Research Institute of Texas.

Echinacea Cultivars Used in Horticulture

One other aspect of *Echinacea* taxonomy needs to be discussed. *Echinacea* species are beautiful and important in the floriculture trade, and they are one of the finest ornamental perennials in gardens. 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. Until recently, only *E. purpurea* has been developed as a cultivar (Starman et al. 1995), although new hybrids have recently been introduced that are crosses between *E. purpurea* and the yellow-flowered *E. paradoxa*, and there are amazing new varieties of different colors, flower forms and even scents.

Numerous cultivars now exist, such as "Magnus," a single-flowered, full-sized, 6 in. lavender coneflower, and "White Swan," an all-white option (both offered by commercial seed companies). Since 2003, there have been five or more cultivars released every year, and by 2009 there were over 60 cultivars on the market. The array of colors includes yellow, green, orange, pink, purple, mango, coral, orange, salmon, and colors in between; some of these are from the newly developed orange-petaled and other colored varieties of the "Big Sky series" (Hawks 2004; Cohen 2006). The wonderful cultivar names give good indication of the color and varieties, with names like Solar Flare, Tangerine Dream, Sunrise, Razzmatazz, Harvest Moon, and Sundown.

Until recently, all varieties existed in wild populations (McGregor 1968). Newly introduced strains bring doubled and frilly petaled cultivars including the "painfully deformed" *Echinacea* cultivar "Doppelganger" (Carey and Avent 2010) and other cultivars that we believe most *Echinacea* enthusiasts would find to be strange, diseased-looking, or even just ugly. There is some concern that cultivars could inadvertently mix with native wild species, and this has been demonstrated to be possible as gene flow does occur between the variety "White Swan" and wild *E. purpurea* plants (Van et al. 1998).

Extensive germplasm collections by McKeown (1999) and others have now been archived in the USDA National Germplasm System at Iowa State University and made available and used for both medicinal plant and horticultural breeding programs.

The names and naming of *Echinacea* species are very important. Which *Echinacea* species must be properly identified for use as natural products and as cultivars for gardeners, the boundaries of species and varieties has been, and will continue to be, confusing to both the gardener and the scientist.

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The Biology and Ecology of *Echinacea* Species

Kelly Kindscher

The species in the genus *Echinacea* form a 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.

The genus *Echinacea* has a wide distribution, extending from the foothills of the Rocky Mountains to the Atlantic Coast and from Texas and Florida up into southern Saskatchewan, North Dakota (Fig. 1) and Manitoba. The densest populations exist throughout the short- and mixed-grass prairies, extending to the edge of the tall-grass prairie. Range maps of all Echinacea species are provided in the chapter titled "A Species-by-Species Overview of *Echinacea*."

Although *Echinacea* has a cool-season plant physiology, including using the C3 photosynthetic pathway, 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, green leaves emerge from its root crown and begin to form a basal rosette when most danger of frost is past. For most of its range, that growth begins in April.

Echinacea angustifolia roots are anchored in the soil by a deep and large taproot (up to 1 in. in diameter) that is almost woody and can grow 5.5–8 ft 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 if the top part of the root is damaged by borers or animals or from the heat of fire. In Kansas where diggers harvested the top 6 in. 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

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Fig. 1 *Echinacea angustifolia* stand in the Little Missouri National Grasslands, in western North Dakota, with flower plants being counted by Maggie Riggs as part of our population monitoring project (*Source*: Kelly Kindscher)

(Hurlburt 1999). And upon further research we documented 50 % of harvested roots resprouted in both Kansas and Montana (Kindscher et al. 2008).

Other *Echinacea* species have taproots with the exceptions being *Echinacea purpurea* and *E. laevigata* which have spreading, fibrous roots that are not as deep or as large in diameter. These two species, which grow in moister, woodland habitats, benefit from additional soil moisture and are easier to transplant, which may explain why *E. purpurea* is a favorite for gardens and cultivation.

The *Echinacea* Yearly Cycle

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, germination occurs early in the spring as the ground warms up. Rates of germination may be less than 10 % and it is rare for seedlings to survive due to climate and competition. In a remarkable study from Wisconsin, five *Echinacea* species were shown to have their germination rates increased significantly if they were exposed to the smoke of native prairie plants. This indicates that seed germination and therefore establishment rates may very well increase after a prairie fire (Jefferson et al. 2008). Regardless of how they get established, seedlings grow slowly, sometimes requiring 3 years for the small rosette of basal leaves to put forth a flower stalk (Weaver and Fitzpatrick 1934).

For established plants, the green basal leaves emerge and start to grow as soon as the temperatures generally stay above freezing in the spring, with growth beginning earlier in southern states. By May, plants begin to bloom in Texas, and by the middle of June, plants throughout Kansas and the latitudinal midrange of where *Echinacea* is found 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 largest plants will bloom during most good years.

Flowering lasts about a month as some plants may have extended flowering due to multiple crowns and flowers as we have observed over ten flowers per plant on wild plants. *Echinacea* pollinators include a diverse mix of flying insects, including native bees, wasps, and butterflies. Some rare butterflies, such as Dakota skippers, now federally protected as threatened due to native prairie habitat loss (U.S. Fish and Wildlife Service 2014), pollinate *Echinacea* species in the Northern Plains; while regal fritillaries pollinate them in the upper Midwest and Central Plains. *Echinacea* species cross pollinate, 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) and our research crews.

The sterile strap-shaped ray flowers (most people think of them as petals) have attractive colors ranging from light pink (rarely white) to purple. The exception is *E. paradoxa* var. *paradoxa*, which is a yellow-flowered purple coneflower. The brownish-purple to maroon disk flowers of *Echinacea* are fertile, and the corolla expands into a fleshy, bulb-like base, while the tube is cylindrical and has a five-lobed erect limb (Urbatsch et al. 2005). 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. Most *E. angustifolia* plants that are flowering will have one flower. While other species, such as *E. purpurea*, makes several flowers each season.

Overharvest and Recovery on the Fort Peck Reservation

The Fort Peck Indian Reservation in northeastern Montana borders Canada on the north. This is a Sioux reservation, out on the prairie, beautiful northern plains country. In the late 1990s, there were serious problems with overharvest— I heard many accounts of it. Robyn Klein, a colleague in Bozeman, Montana, put me in touch with a University of Montana graduate student, Monique Kolster, who had done her master's thesis on overharvest on the Fort Peck, invited her down to Kansas for an *Echinacea* meeting and to discuss her documentation of *Echinacea* overharvest.

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The situation had gone far beyond traditional harvest, with several brokers putting up signs for *Echinacea* root, the price going very high, contests created for finding the largest roots, and people digging all over the reservation and on private property because they needed the money. Tribal leaders were concerned. The harvest became so intense that people eventually had trouble finding the plants, and there was an account of some people going out at night with their pickup trucks because it was easier to see the cone heads in the headlights than during the day.

Robyn also gave me the name of Curly Youpee, the cultural liaison for the tribe. I called him and asked to see some of the sites that were severely damaged or thought to be wiped out. I went up the next month, and he took me on a field trip of the Ft. Peck. He spoke of how he wanted to encourage the traditional root harvest, which had great cultural significance, but he also recognized that the situation had changed because of the demands of the commercial market. The big push had been in 1998, and I visited 3 years later. Just as at other sites I'd visited, I could see the shovel divots; I could even see where the soil had been tossed over. And, also as at all sites, there were *Echinacea* sprouts from the shovel holes and flowering plants all around.

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 from the outside bottom on 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 in sparsely vegetated habitats can blow seeds considerable distances across rocky or crusty frozen surfaces. This can occur with the strong dry winds that follow a snowstorm as it crosses the plains. The snows and rains of winter and spring leach germination-inhibiting compounds from the seed, and the oscillating temperatures of winter and spring help break the dormancy (Cech 2002).

Echinacea's underground plant parts store food during the long period of winter dormancy which bring about the rapid growth of the plants after their early awakening in the spring. Plants 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, and sets the stage for which plants store enough energy to bloom the following year.

Additional *Echinacea* Ecology

Echinacea angustifolia is exceptionally 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 2 years, then germinate and grow (Cech 2002). In all of these ways, populations of *Echinacea* survived the great droughts, including the Dust Bowl of the 1930s. 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 shoots and leaves reemerge, even after a hot fire, and continue to grow. Seeds, especially if covered by some soil or if they fall in rocky areas, survive prairie fires racing across the landscape, and then when there is soil moisture again, the seedlings can emerge.

Echinacea is a tough prairie plant adapted 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 crown that branches over time, and the leaves push back the grasses and lay on top of them to photosynthesize, making room for the tall *Echinacea* stalks (Cech 2002). These stalks hold the flower and the seed out of direct competition with the grasses and make them available for pollinators (Fig. 2).

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

Fig. 2 Rocky Greenhorn Limestone outcrops in the Smoky Hills of Kansas, north of Hays, Kansas are excellent habitat for *Echinacea angustifolia*. Here in the photo it is competitive with big bluestem, *Andropogon gerardii*, and side-oats grama, *Bouteloua curtipendula*, along with the yellow-flowered broom snakeweed, *Gutierrezia sarothrae* (*Source*: Kelly Kindscher)

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 seen root damage caused by root borer predation (also in both Kansas and Montana; 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 gardens and especially cultivated *E. purpurea*.

Basing her findings from 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 individual wild *E. angustifolia* plants 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, despite producing few, if any, seedlings in a given year.

Habitat

Echinacea species typically prefer full sun and well-drained soils. They are often found in thick patches on rocky sloping limestone, sandstone, or baked clay (locally call scoria in North Dakota) outcroppings in native prairie habitats, although they also can occur in glades, barrens, and openings in forests (McGregor 1968). In all of these conditions, they are usually found within a grass-dominated plant community. It appears that the overall preferred habitats are sunny, rocky, or disturbed locations where there is less competition with grasses and other broad-leaved plants. *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.

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 (*Schizachyrium scoparium*), bluegrass (*Poa pratensis*, a nonnative species), and side-oats grama (*Bouteloua curtipendula*); see the tables in the Baseline Monitoring appendix for the specific summarized data. *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 grasses little bluestem (*Schizachyrium scoparium*), big bluestem (*A. gerardii*), and side-oats grama (*Bouteloua curtipendula*) (Fig. 3). Although grasses dominate these plant communities, niche spaces exist for deep-rooted forbs such as *Echinacea*. Important forbs in the Kansas sites were, in descending order according to amount of cover, *E. angustifolia*, resinous skullcap (*Scutellaria resinosa*), and white aster (*Leucelene ericoides*); see the tables in the Baseline Monitoring appendix for the specific summarized data.

Fig. 3 Dense stands of *Echinacea angustifolia* are not always easy to observe. The *aluminum tags* mark young *Echinacea* plants within 1 m^2 plots that we sampled in this grazed mixed grass pasture north of Hays, Kansas (*Source*: Kelly Kindscher)

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 by shading them and starving them of light.

Echinacea's distribution is very large, though patchy, and covers a range of moisture and temperature regimes, from central Texas, Georgia, and Alabama to frigid winters in Montana (Fig. 4), 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 we have observed extensive stands of *Echinacea* on tribal lands, 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*. A major reason why a conservation status report (Kindscher 2006) was previously written was due to the interests and funding from the US Forest Service who was interested in the conservation status of *Echinacea* stands on the lands that they managed. 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, Cimarron, Comanche, Lyndon Baines Johnson, Rita Blanca, Black Kettle, and Kiowa National Grasslands. US Forest Service lands also contain several *Echinacea* species, notably

Fig. 4 This root would be called a "big carrot" by diggers. This portion of a decades-old *Echinacea angustifolia* root dug in eastern Montana is approximately 15 in. long and also 1 in. in diameter. The full extent of this root might snake its way into the ground 6–8 ft. (*Source*: Kelly Kindscher)

*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.

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A Species by Species Overview of *Echinacea*

Kelly Kindscher

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 3–5 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 3–4 whorls of bracts. Ray flowers are usually rose-colored to purple, white, pink, or yellow in *Echinacea paradoxa* (McGregor 1968). Below are short descriptions of each species along with the specific habitat and range maps. The three species used in commerce—*E. angustifolia*, *E. pallida*, and *E purpurea*—are discussed first, followed by the rest in alphabetical order.

Distinguishing Characteristics of *Echinacea* Species

Echinacea is known for having confusing species. This species by species treatment should help, but will likely not be sufficient for distinguishing between species that are hybrids, off-season, or unusual. The very accurate range maps can help and can tell you which species are found in a specific area, thus narrowing down the choices. The best technical keys are in the Flora of North America, vol. 21 (Urbatsch et al. 2005), but are available online at: http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=111203.

The most important key characteristics are the shape and size of basal leaves, hairs on stems and foliage, color, length and shape of ray flowers, shape of the cone-head structure, pollen color, and the geographic location. In addition, university and

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other large herbaria have specimen, and trained staff, that can help you with difficult identifications. Some keen observations of floral stem and petiole morphology that can also be used to distinguish *Echinacea* species have recently been published by Harold Keller (2014), who as a graduate student worked under Ronald McGregor at the University of Kansas.

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. Determining precisely where each *Echinacea* species grows is important to understanding the ecology and ethnobotany of these species. These maps reflect only locations from species in herbarium 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. We only included locations during the last few decades (there were previously fewer collections and they typically have only general location data). Our research team at the University of Kansas has looked at the majority of specimen listed and has been especially diligent with specimen outside their core range. We did not include herbarium specimens for cultivated vouchers (from the state of Washington, for example) or escapees (such as *E. angustifolia* along railroad tracks in downtown St. Louis, or the likely planted location of an interstate interchange near Santa Fe, New Mexico). We are continuing to improve our maps, and you are welcome to help us. We have directions on how you can provide updates to the maps, and we will also update the maps online. For helping us with this ongoing project, please follow the directions at: http://web.ku.edu/~kindscher/research/ethnobotany/*Echinacea*-mapping-project-3.

The Species

Echinacea angustifolia *Description*

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, lance-shaped, and entire, with entire (never serrated) leaf margins; dark green, with veins slightly more rounded than parallel. The head is conical and the 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 (Fig. 1). It is found on barren, dry prairies, thin soils, and limestone, sandstone, and scoria rock outcrops in the Great Plains. McGregor (1968) recognized two varieties (var. *strigosa* and var. *angustifolia*), but these are not

Fig. 1 *Echinacea angustifolia* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

supported by the work of Binns et al. (2002) or Flagel et al. (2008). The removal of these subspecies is the only significant change from McGregor's taxonomy that appear in the *Flora of North America* (Urbatsch et al. 2005).

Echinacea angustifolia *Range*

This species has the most northerly range of the *Echinacea* species, and the only one reaching Canada. The range stretches from central Texas to the Dakotas and southern Saskatchewan and Manitoba. It also occurs furthest west, being the only species

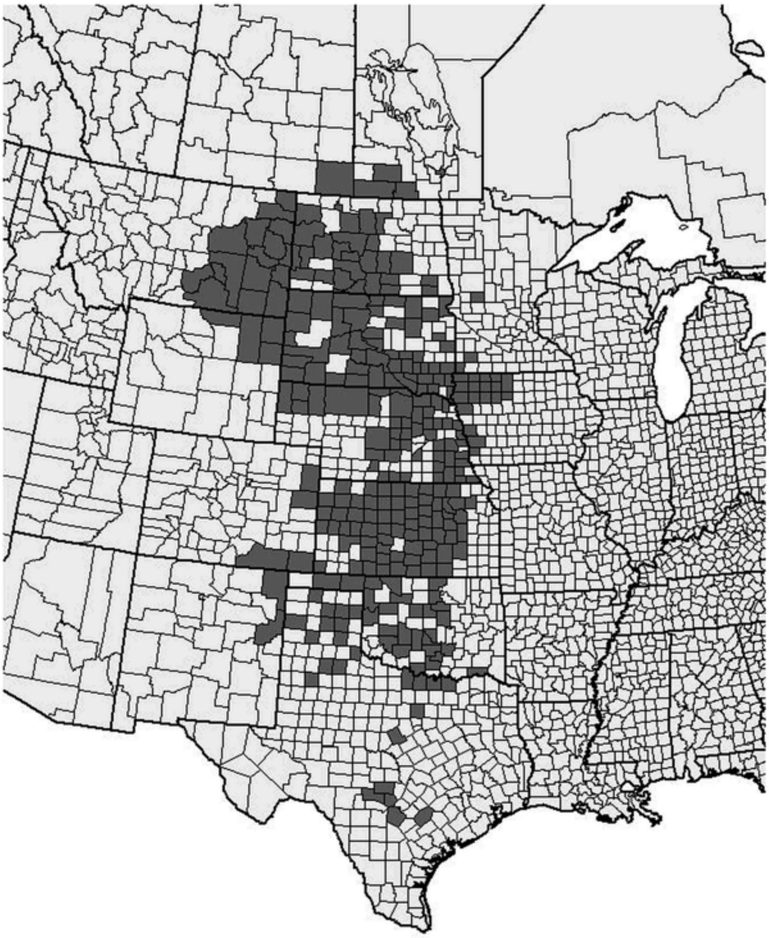

Fig. 2 *Echinacea angustifolia* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

found west of the hundredth meridian (including New Mexico, Colorado, Wyoming, and Montana). 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 (Figs. 2 and 3).

Fig. 3 *Echinacea angustifolia* flower (*Source*: Steven Foster)

Echinacea pallida *Description*

Stems are 40–90 cm tall. The leaves are lance-shaped, with entire margins. The head is conical, and the receptacle spines are rigid at the tips. This is the only *Echinacea* with white pollen. The ray flowers or petals are very attractive, narrow and gracefully droop and curve toward the stem and are 4–9 cm long. The ray flowers are usually white to pink but can very occasionally be deep purple (Fig. 4).

Fig. 4 *Echinacea pallida* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea pallida *Range*

This species 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. It can be abundant and is harvested in the wild (Figs. 5 and 6).

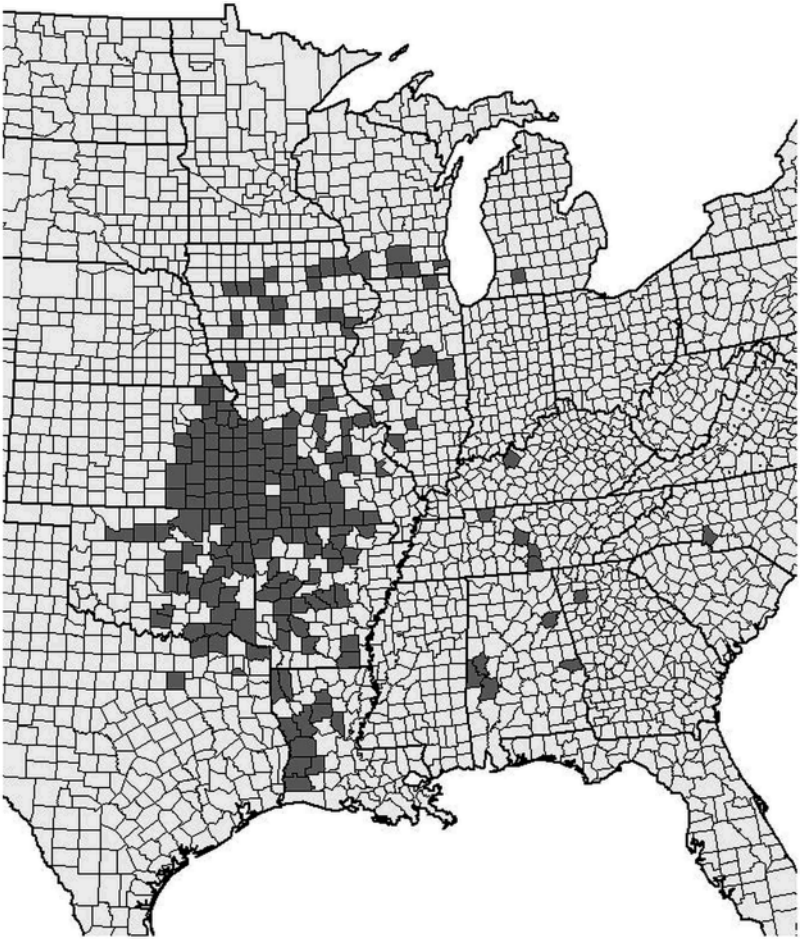

Fig. 5 *Echinacea pallida* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

Fig. 6 *Echinacea pallida* flower (*Source*: Steven Foster)

Echinacea purpurea *Description*

Stems are 60–180 cm tall, often branching near the top with soft short hairs. The lowermost leaves are oval to broadly lance-shaped 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). The receptacle spines 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 (Fig. 7).

Fig. 7 *Echinacea purpurea* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea purpurea *Range*

This species is not common in the wild. It 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, it does well in home gardens and landscaping. In the wild, the plants show much more diversity in ray flower color and shape, in contrast to the typical wide purple ray flowers of the typical garden cultivar (Figs. 8 and 9).

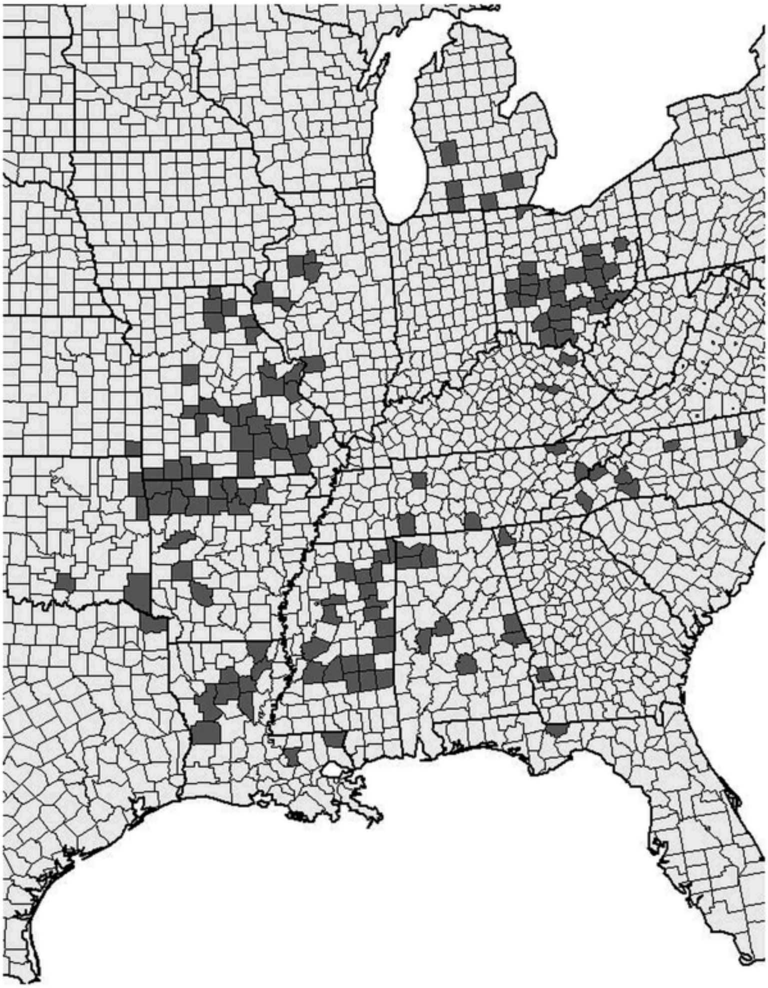

Fig. 8 *Echinacea purpurea* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

Fig. 9 *Echinacea purpurea* flower (*Source*: Steven Foster)

Finding the Jingle Bell Plant

After deciding to go to graduate school, I knew I wanted to learn about medicinal plants, like *Echinacea*. I also knew I should work with Native people who had their tradition intact. There wasn't a Native American tribe in Kansas still living on its historical homeland with the plants and its members traditionally used for medicine right there. I wanted to work with Siouan people and made connections through friends and colleagues at what is now Haskell Indian Nations University, here in Lawrence, and went up to the Rosebud Reservation, home of the Sicangu Sioux, a Lakota tribe, in South Dakota to see if there was a working relationship for me to learn about medicinal plants.

Eventually I met alex Little Soldier, Alex Lunderman, a tribal elder, and at the time was tribal chairman. I gained so much insight, working with him and others, about the healing process, and, along the way, about cultural interaction—including storytelling and humor. Healing is as much about spiritual practice as it is about medicinal plant compounds. That said, there were specific plants people used, and one was called jingle bell plant, *Mirabilis albida*, a wild 4 o-clock. It was used for kidney medicine. The plant's traditional name was *pejuta-ska*—*pejuta* is medicine.

Alex knew the plant, and we took the pickup and went out to look for some at a place on the reservation where he had harvested it before. We walked this big, long loop, and it was nice just walking on native prairie. Finally we got back to the pickup truck and were about ready to give up, and there was the plant. He saw it and pointed—"It's right here! It's right here!" He teased me, the academic botanist, about not seeing it.

Alex was a master storyteller, and for him, this became the story, which he told repeatedly: "Oh, we went out to look for *pejuta-ska*, and, you know, Kelly was looking and looking …," and he would put his hand up to his brow looking out and just start laughing and pointing down at his feet: "It's right here, right here." Of course, the way Alex told stories, everybody laughed. When he started telling a story, people would stop what they were doing and listen. I've realized that stories like that were, in a way, honoring me. He was making fun of me, but there was respect underneath. A lot of the humor up there would be self-deprecating, not stories that elevated the teller, but stories that showed you were very human.

Echinacea atrorubens *Description*

Stems are 30–90 cm tall, light green, hairy and simple or rarely branched. Leaves are often smooth, lance-shaped and have entire margins. The receptacle tips are rigid. The ray flowers are uniquely short (2–4 cm long) and curve down to touch the stalk. The petals are dark purple, occasionally pink, or white (Fig. 10).

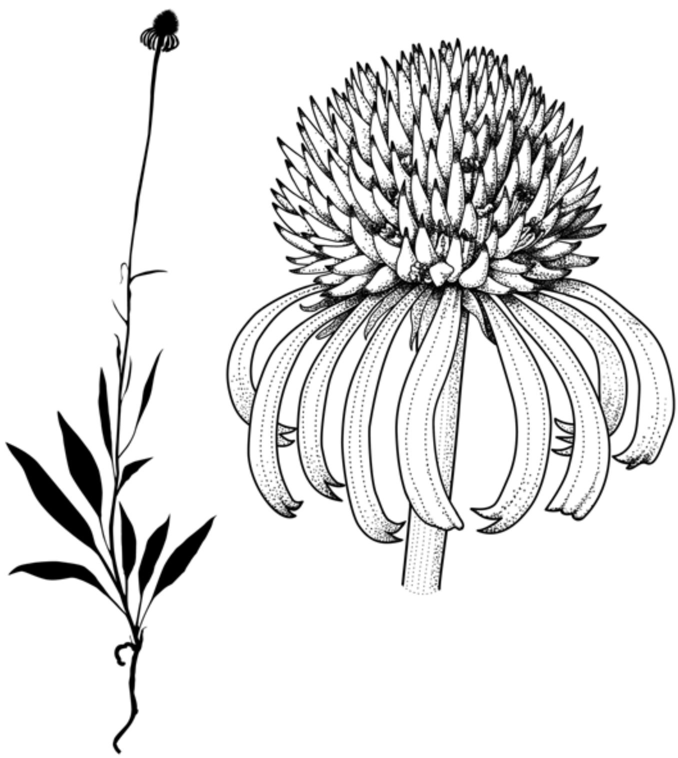

Fig. 10 *Echinacea atrorubens* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea atrorubens *Range*

This species occurs in prairies and open woodlands in both deep soils and rocky habitats in a very narrow range from Texas to Kansas. It is relatively uncommon; few people know it or recognize it, and it overlaps in range with other species. Hybrids with other species can be found; we have found them in south-central Oklahoma (Figs. 11 and 12).

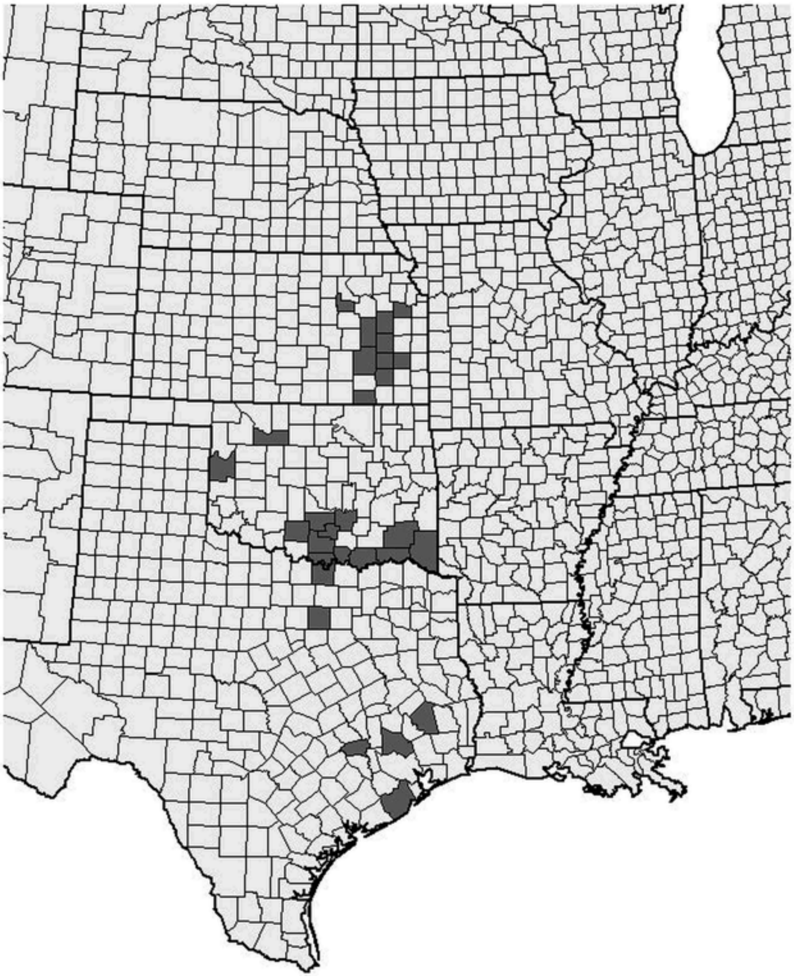

Fig. 11 *Echinacea atrorubens* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

Fig. 12 *Echinacea atrorubens* flower (*Source*: Steven Foster)

Echinacea laevigata *Description*

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 3–10 times longer than wide (Fig. 13).

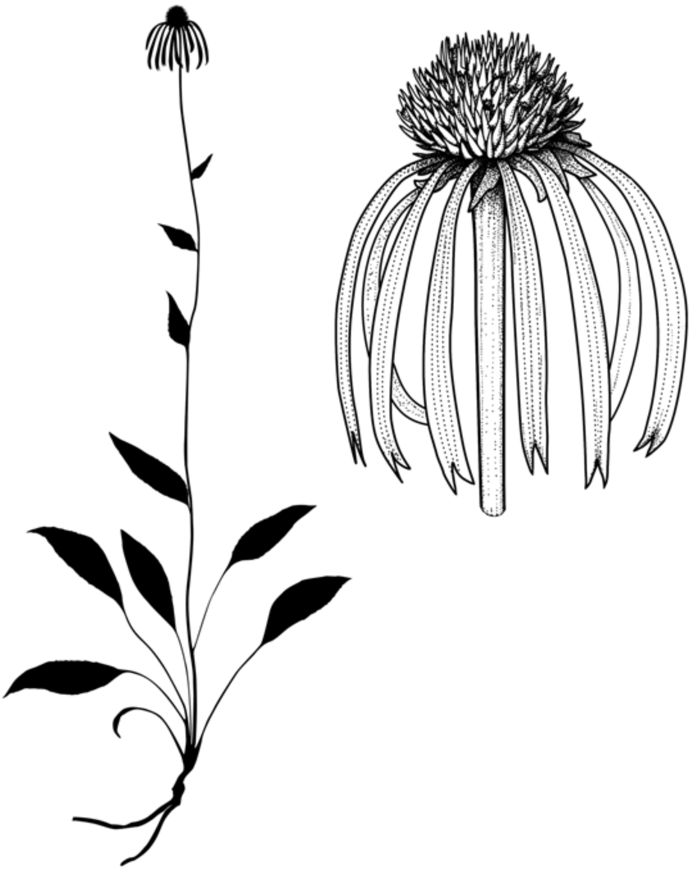

Fig. 13 *Echinacea laevigata* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea laevigata *Range*

This species 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 (Figs. 14 and 15) (U.S. Fish and Wildlife Service 1995).

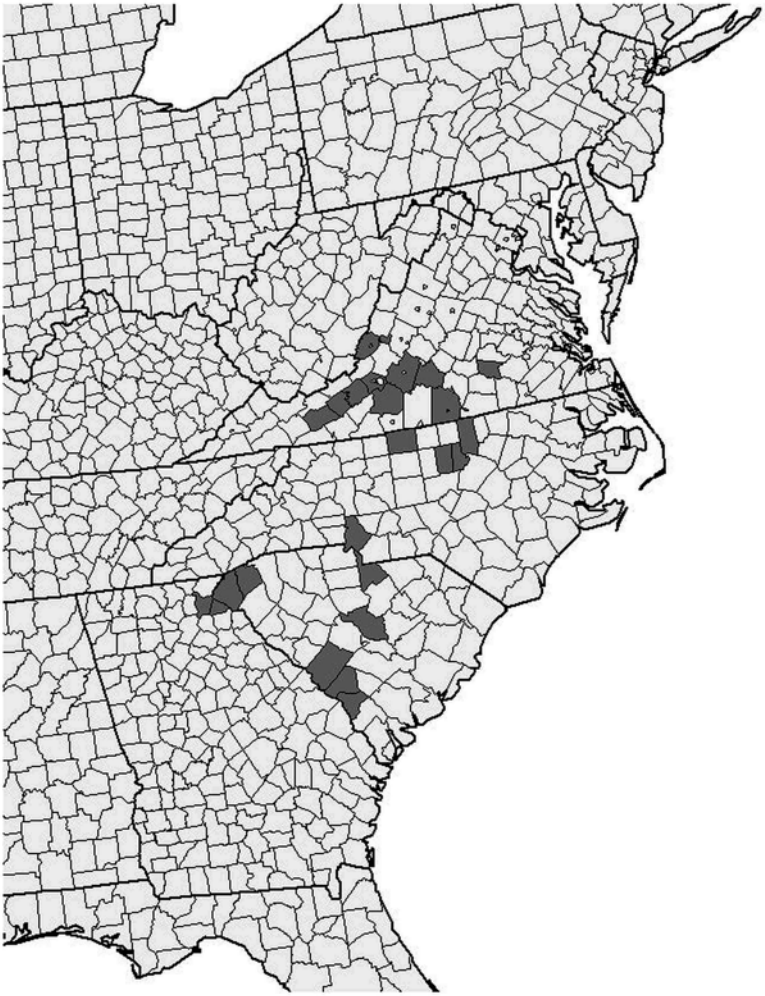

Fig. 14 *Echinacea laevigata* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

Fig. 15 *Echinacea laevigata* flower (*Source*: Steven Foster)

Echinacea paradoxa *Description*

Stems are 30–80 cm tall, light green, and otherwise smooth. Leaves are lance-shaped (never serrated). The central disk is dark brown and conical. The receptacle tips are rigid. 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). The yellow variety is indeed a paradox as we all know that a purple coneflower cannot be yellow (Fig. 16).

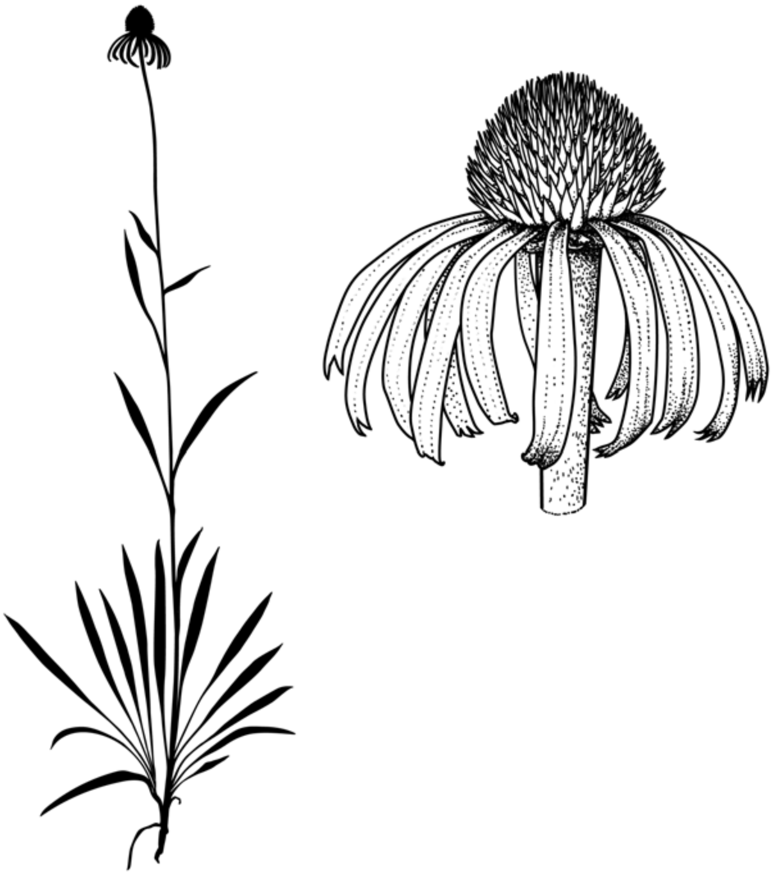

Fig. 16 *Echinacea paradoxa* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea paradoxa *Range*

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 (Figs. 17 and 18).

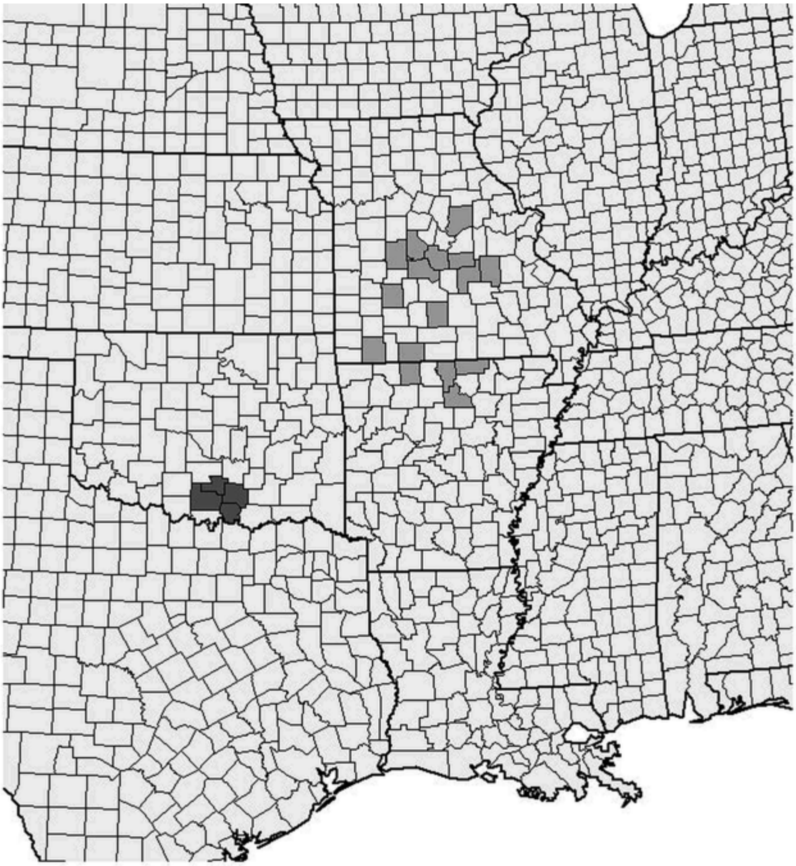

Fig. 17 *Echinacea paradoxa* range map showing counties where it is documented to grow in the wild. *Light gray* counties indicate the yellow variety, *Echinacea paradoxa* variety *paradoxa*, and *dark gray* counties indicate the light purple "petaled" variety, *Echinacea paradoxa* variety *neglecta* (*Source*: Jennifer Delisle, Kansas Biological Survey)

Fig. 18 *Echinacea paradoxa* variety *paradoxa* flower (*Source*: Steven Foster)

Echinacea sanguinea *Description*

Stems are 40–90 cm tall. Leaves are lance-shaped and entire. The basal leaves are elliptical. Flower head is a half sphere; it has thin stems and dark red, rarely white, flowers. The receptacle spines have rigid tips (Fig. 19).

Fig. 19 *Echinacea sanguinea* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea sanguinea *Range*

This species has the most southern range of all *Echinacea* species and is found in open sandy fields and pine woods (Figs. 20 and 21).

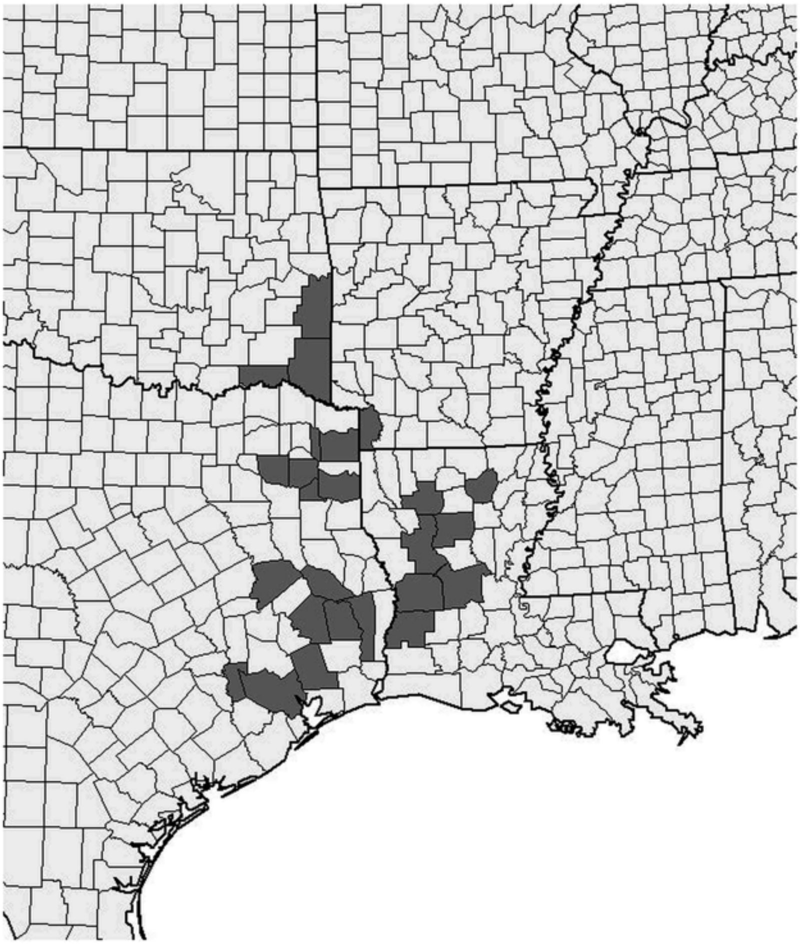

Fig. 20 *Echinacea sanguinea* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

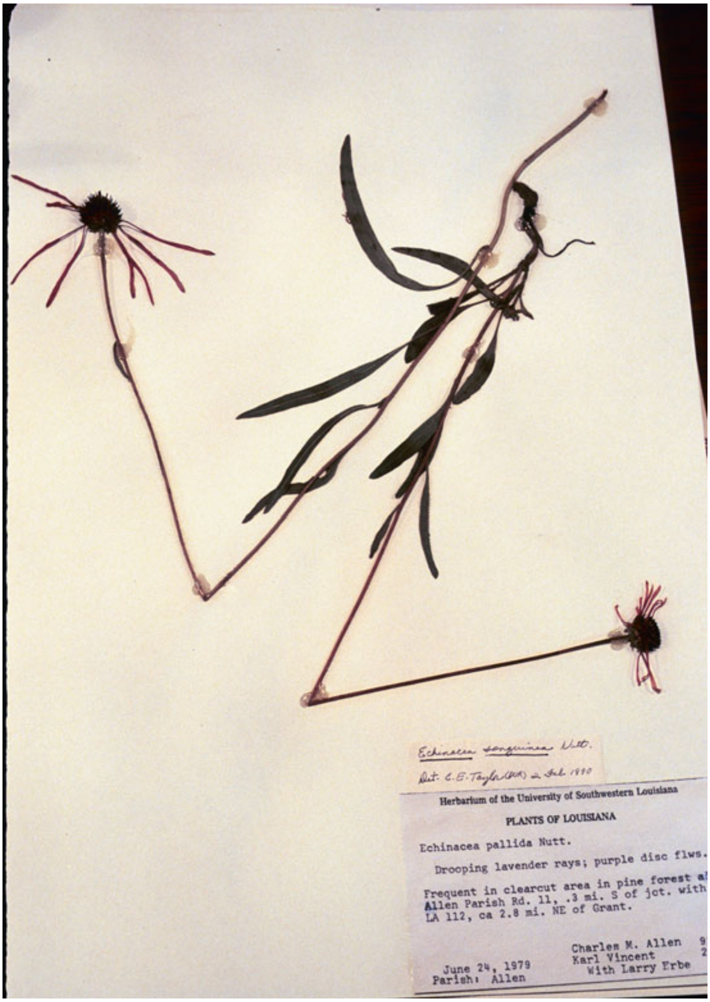

Fig. 21 *Echinacea sanguinea* herbarium specimen showing flower shape (*Source*: Steven Foster)

Echinacea simulata *Description*

Stems are 40–90 cm tall. Leaves are lance-shaped and entire. The head is conical, and the tips of the receptacle spines 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* (Fig. 22).

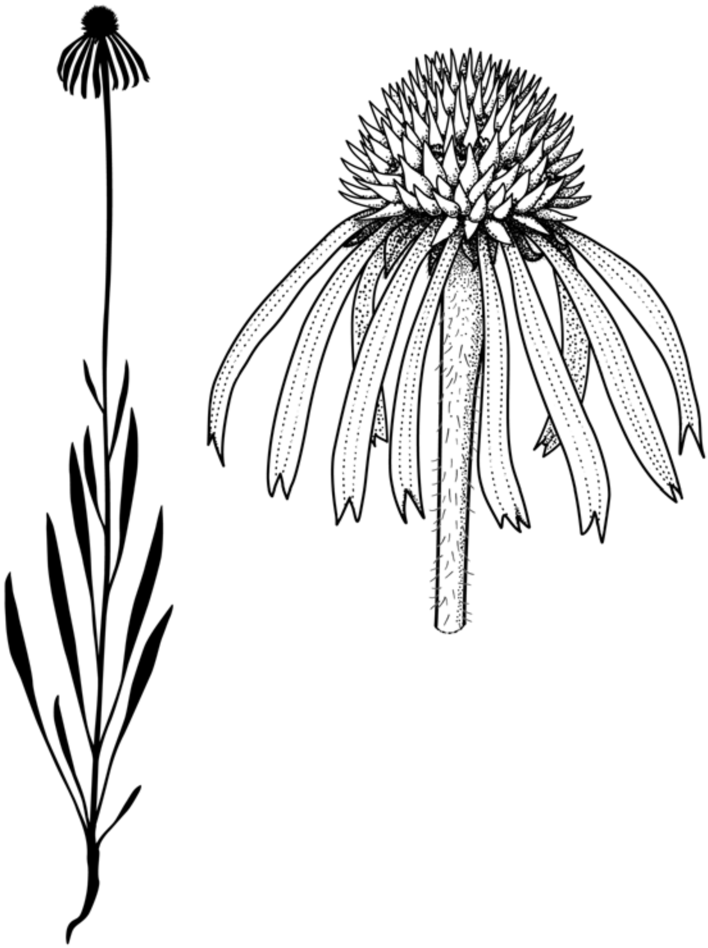

Fig. 22 *Echinacea simulata* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea simulata *Range*

This species occurs in prairies and rocky open woods (Figs. 23 and 24).

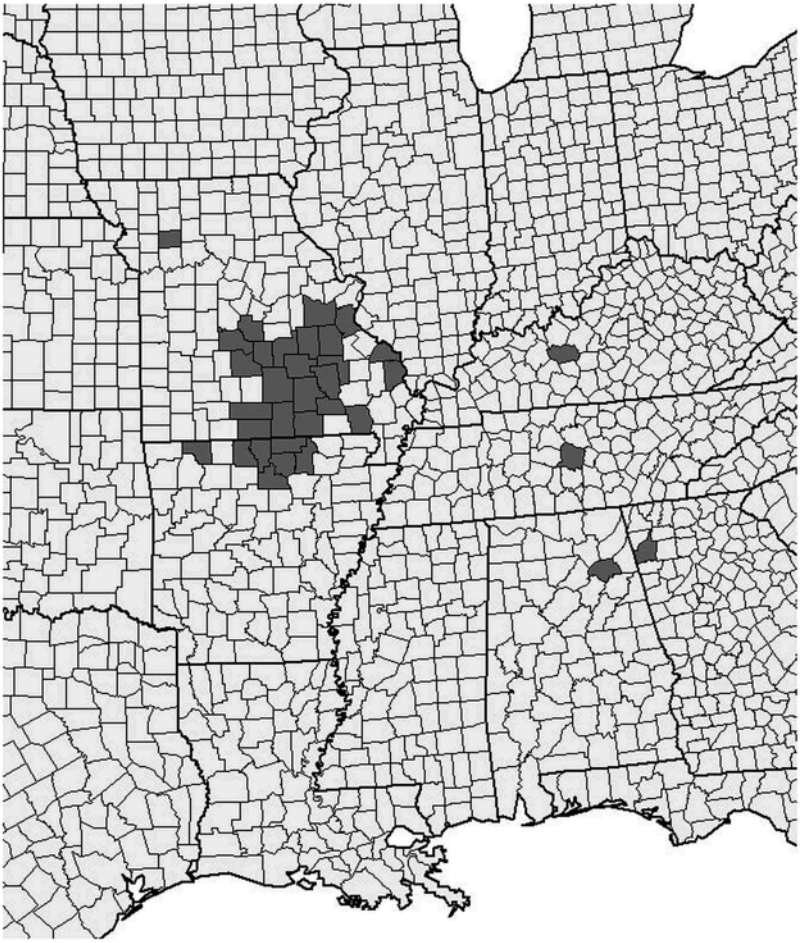

Fig. 23 *Echinacea simulata* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

Fig. 24 *Echinacea simulata* flower (*Source*: Steven Foster)

Echinacea tennesseensis *Range*

This species is known from only five native 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 as only five populations were known. After listing, lands were protected by purchase by the Nature Conservancy and the State of Tennessee. In addition, monitoring was established, work on propagation was conducted, the number of plants in populations was increased through restoration efforts, including fire, and threats were greatly reduced. For these reasons in 2011, the U.S. Fish and Wildlife Service (2011) declared that the species was successfully recovered and removed it from the endangered species list, while assuring that there is a continued monitoring plan (Fig. 25).

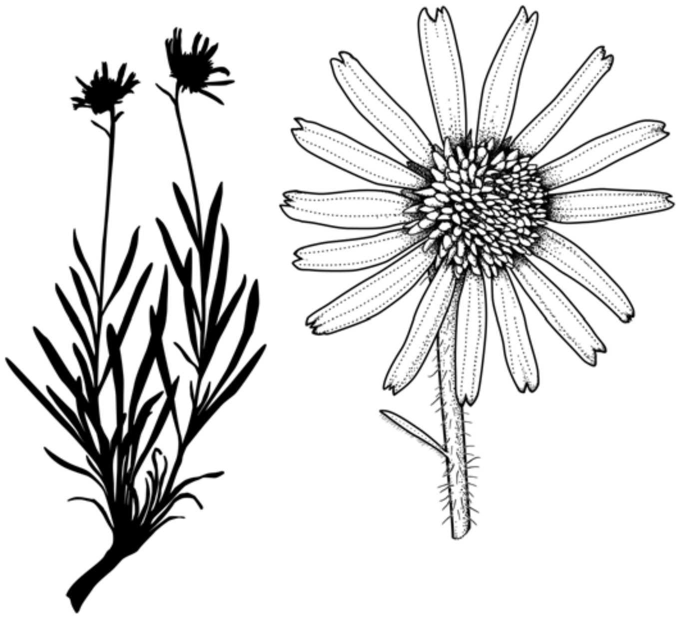

Fig. 25 *Echinacea tennesseensis* drawing showing distinctive botanical features (*Source*: Sarah Taliaferro)

Echinacea tennesseensis *Description*

Stems are 10–40 cm tall and are leafy with soft hairs. The leaves are lance-shaped and entire. The head is conical. The pollen is yellow and small. The tips of the receptacle spines are rigid. Ligules are 2–4 cm long and spreading. The flower petals turn up as though to touch the sun (Figs. 26 and 27).

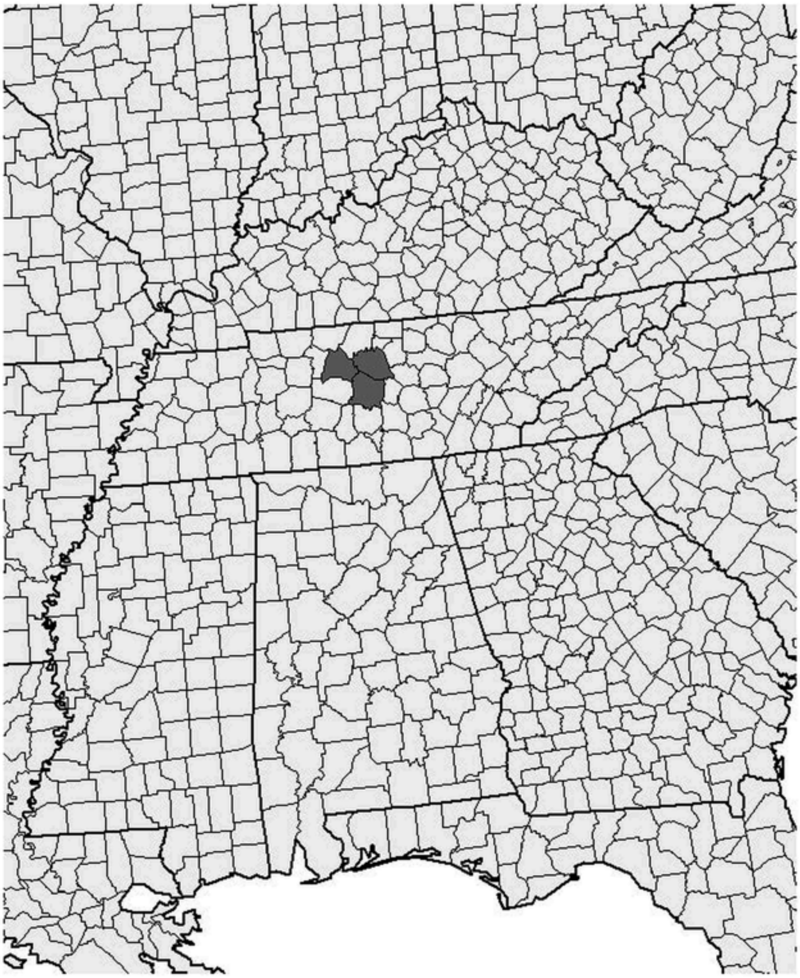

Fig. 26 *Echinacea tennesseensis* range map showing counties where it is documented to grow in the wild (*Source*: Jennifer Delisle, Kansas Biological Survey)

Fig. 27 *Echinacea tennesseensis* flower (*Source*: Steven Foster)

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Part III
Wild Populations

One Hundred Twenty Years of *Echinacea angustifolia* Market Harvest in the Smoky Hills of Kansas

Dana M. Price and Kelly Kindscher

As a popular medicinal herb, *Echinacea* led a dramatic expansion of the US 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 more than doubled:

- US $360 million per year in 1981 (Tyler 1986)
- $1.6 billion in 1994 (Brevoort 1996)
- $3.87 billion in 1998 (Brevoort 1998)

And it was at this time that the wild harvest of *Echinacea angustifolia* reached its pinnacle of harvest in the wild, an amount not seen since. Despite a downturn from 1999 to 2000, herbal products sales were $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).

Three of the nine *Echinacea* species are important in commerce: *E. purpurea*, *E. pallida*, and *E. angustifolia*. Because it is easy to grow, the *Echinacea purpurea* supply is predominantly from cultivated sources (McGuffin 2001; American Herbal Products Association 2012). *E. pallida* and *E. angustifolia*, as well as 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), although most recently, a considerable amount of *E. angustifolia* is being

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cultivated. For these and other wild-harvested medicinal species in commerce, the sustainability of supply has been a matter of increasing concern.

Trade in wild-harvested ("wild crafted") medicinal herbs is culturally and economically important, yet its effects on wild populations are not well understood. There are several reasons for this:

- There has been little study of the long-term economic or ecological sustainability of commercial harvest of even well-known wild-harvested plant products (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 US federal or state agencies.
- The tonnage of plants harvested and the value of this trade have been very difficult to quantify. The best effort to quantify tonnage of wild plant harvest has been made by the American Herbal Products Association (2007, 2012). The market value of herbal products is frequently reported in the publication HerbalGram (Blumenthal 2000; Brevoort 1996, 1998; Blumenthal et al. 2012; Lindstrom et al. 2014).

The vast majority of sustainable-use studies have concerned forest products, especially in the tropics (Stanley et al. 2012). 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 more than 120 years. The threat of overharvesting has been a concern throughout its 120-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" (Fig. 1).

Echinacea's 120-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) and Constantine Rafinesque was discussing it in his *Medical Botany* in 1830. *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).

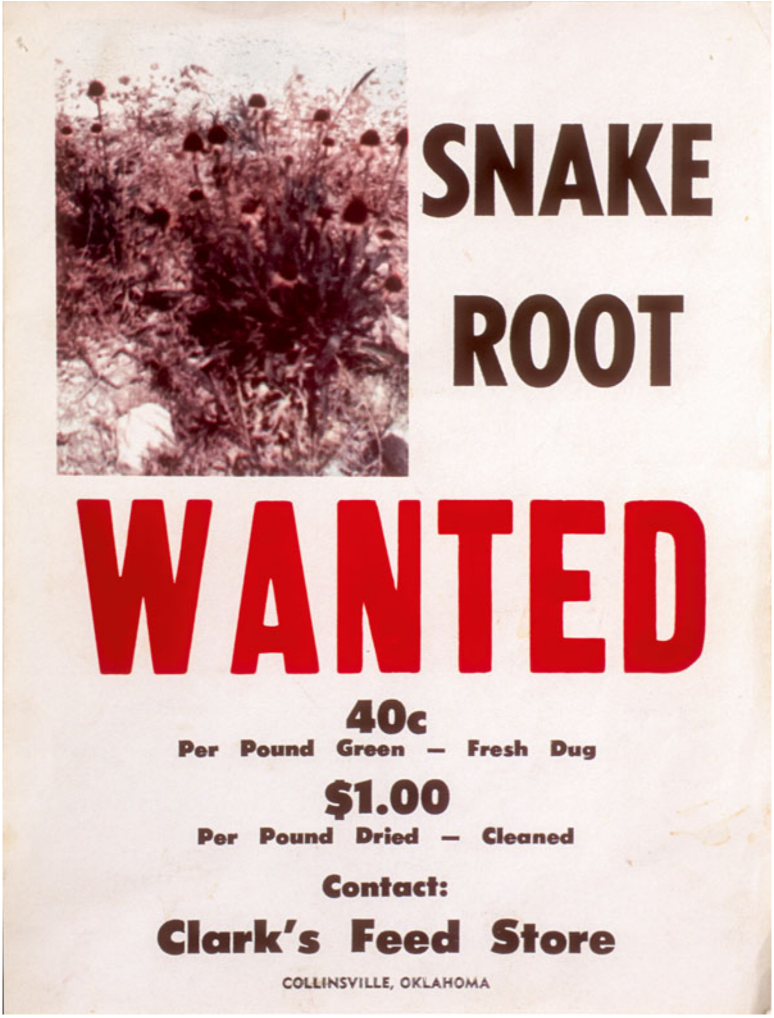

Fig. 1 Snakeroot Wanted poster. When *Echinacea* prices are high, posters like this one appear at cafes, sale barns, and grocery stores in Great Plains towns near where regional brokers are wanting to buy *Echinacea* roots. This one was posted, probably in the 1950s or 1960s, to buy the *Echinacea angustifolia* in the picture. Collinsville, Oklahoma, and the surrounding counties only have *Echinacea pallida*, but within 100 miles at least four *Echinacea* species can be found. This situation has led to the confusion of which *Echinacea* species is the snakeroot that companies have been buying (*Source*: Steven Foster)

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 (Fig. 2) (Foster 1991; Flannery 1999).

Fig. 2 The Lloyd Brothers Pharmacy was a major producer of herbal products for doctors from the 1890s to the 1930s and was well-known for their *Echinacea* products (*Source*: Steven Foster)

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 also was in the top-selling 3–5 herbs in the mass market during this time (Johnston 1998b; Blumenthal 2000). And it is still ranked in the top ten of medicinal herbs sold in stores (Blumenthal et al. 2012).

Conservation Concerns and Harvest Practices: Gaps in Understanding

Along with *Echinacea's* increased popularity, serious conservation concerns have arisen. Warnings have come from the botanical and conservation community that commercial exploitation of *Echinacea* is unsustainable. Only a few years after its introduction to the medical profession, concern was expressed by Lucius Sayre, the first Dean of Pharmacy at the University of Kansas that the quantity harvested exceeded the plant's ability to regenerate (Sayre 1903). Decades later, Ronald McGregor (1968), Professor of Botany at the University of Kansas noted declines in *E. pallida* populations in Eastern Kansas. Steven Foster noted herbal products writer, researcher, and photographer, documented large harvests of uncommon *Echinacea* species, *E. paradoxa* and *E. simulata*, in the Ozarks (Foster 1991). Poaching in protected stands and over-collecting have been reported in Missouri (Missouri Department of Conservation 1998; Trager 1998) and Oklahoma (Boyd 1997; Lantz 1997). And a "gold rush" of unethical harvesting affected North Dakota and Montana in the 1990s (Crawford 1998, 1999) and Montana (Kolster 1998; Kolster and Youpee 1998; Klein 1999).

Lucius Sayre: KU Dean and *Echinacea* Researcher

As a researcher, I have found that there are certain people who you keep running across in life, in person or in print. One of them for me is Lucius Sayre, who from 1885 to 1925 conducted research on medicinal plants and became the first Dean of Pharmacy at the University of Kansas. He published some of the first research on *Echinacea* that had references to its harvest in the field, including the fact that graduate students at KU could make good money during the summer (in the 1890s) harvesting local *Echinacea* roots. He also expressed concern in 1903 about its potential overharvest not just locally by grad students, but also across its range. We have continued to be concerned about its potential overharvest for the past 120 years. When the new School of Pharmacy at KU was being built a few years ago, I was asked to be involved with the landscaping plan and we decided to create medicinal plant garden beds that included one honoring Lucius Sayre. So we grew all the *Echinacea* species for the garden and also plants that Sayre had encouraged to be grown in the KU Drug garden that was planted soon after his death. Based on photographs and articles from that time, we planted species that were planted in the original Drug garden, including—foxglove, marshmallow, rue, cotton, job's tears, wormwood, and lambsquarters. But we decided not to plant the poppies and marijuana, because times have changed and as a gardener, I was concerned that they might disappear in the wee hours of the night.

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 2015). Specific conservation status for individual states can be found in the "Biology and Ecology of *Echinacea*" chapter.

In a study we conducted in the late 1990s to further understand more about wild harvest of *E. angustifolia* in Kansas, we had three main objectives: (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. Here are details of that work:

Methods

Study Area

The study was conducted from 1996 to 1998, with a follow-up visit in 2002. Our study area was in north-central Kansas, in Rooks County and adjoining counties (39°05′–39°34′N, 99°00′–99°30′W). This area was chosen for its 120-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 Dana Price Hurlburt's dissertation (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. We also interviewed 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 from 1997 to 1998 and in 2002.

Market Information

To obtain quantitative information on the market in *E. angustifolia* roots, we first searched the historical literature and unpublished correspondence, as noted 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 20 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 was 120 years ago, noted in 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 Lucius 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), which includes the Smoky Hills region.

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 Fig. 1. The family's history in the trade was confirmed by other local 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' extensive area of soft, broken 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. 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 the 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 the amount previously stockpiled (Fig. 3).

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). That year the price rose to \$0.55/kg (\$0.25/lb). Sayre (1903) reported that *Echinacea* "in 1 year has brought to the state over \$100,000, as over 200,000 lb have been collected, and it has brought at times as much as 50 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. 3). 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,

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. 1485.5 kg (3275 lbs) of *Echinacea* roots at $0.67/kg ($0.30/lb) in February–March. In April, Lloyd Bros. receives "an offer of 5000 lbs [2268 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 1922–1924).
1925–1930	Wholesale prices decline slowly to $0.53–$0.58/kg ($0.24–$0.26/lb; OPDR 1925–1930).
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 Company 1952).
1965	11,340 kg (25,000 lbs) of *E. pallida* is harvested (McGregor 1968).

(continued)

Table 1 (continued)

Year	Market and Price Information and Reference
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); 4500–18,600 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 (1000 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)
2012	During the last 10 years, markets have been down, Pat Thrasher passed away; fewer locals are now harvesting roots

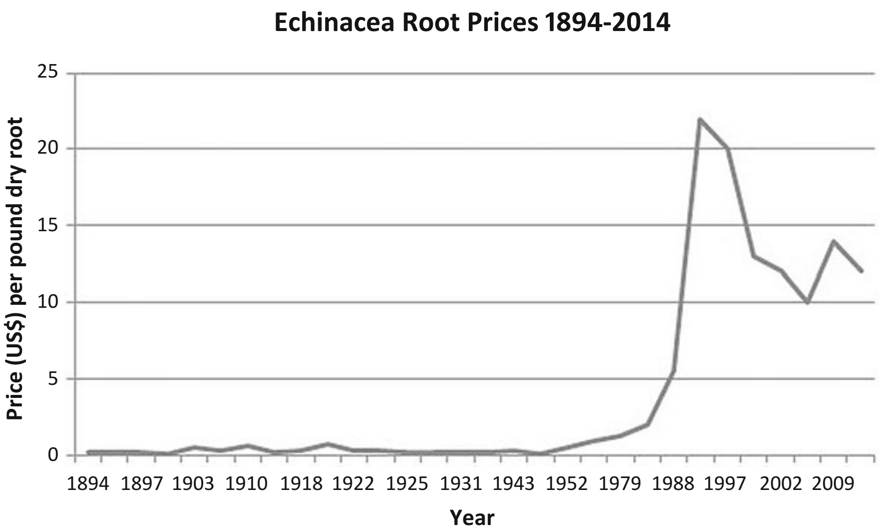

Fig. 3 Dried *Echinacea angustifolia* root prices paid by local brokers to wild harvesters in the Smoky Hills near Hays, Plainville, and Stockton, Kansas (*Source*: Rachel Craft, Kansas Biological Survey)

cycles in the market that occurred during 1996–1998 probably occurred in other years as well.

In the late 1990s, 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 purchased 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 one 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/h) (Fig. 4).

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). In related work, with diggers harvested north of Hays, Kansas, we determined that it would take 112 harvested roots to get one pound of dried *Echinacea* root (see Fig. 2). 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. Individual 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.

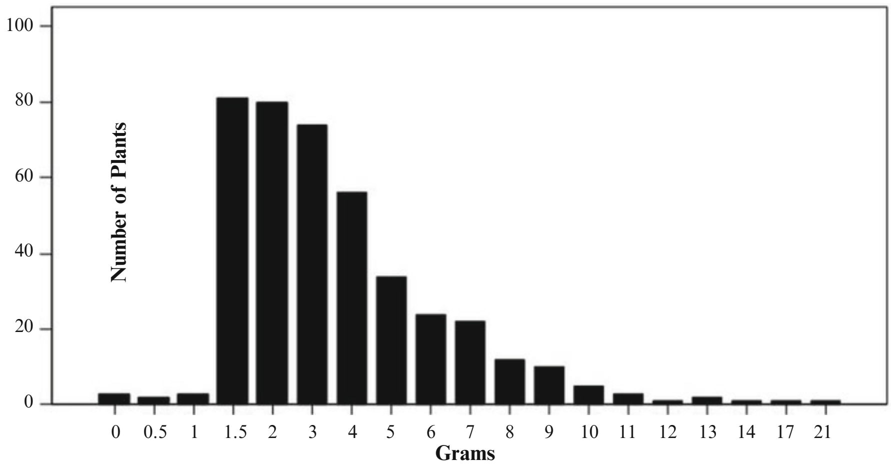

Fig. 4 Data from 415 wild-harvested *Echinacea angustifolia* roots illustrate the wide variation in individual root weights. Height of bars represents the number of roots in each weight class that are harvested by commercial "diggers" who we worked with near Hays, Kansas, in September 2001. For these 415 roots, the mean weight = 3.65 g. In other words, 112 roots were harvested per pound. Note that the majority of harvested roots are in the smaller weight categories (*Source*: Rachel Craft, Kansas Biological Survey)

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 in Kansas, 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

Fig. 5 Root resprouting by *Echinacea* plants is a remarkable trait. This root of this plant was dug from rangeland east of Miles City, Montana and the picture is from 2 years later when it was re-dug below where it was previously harvested. The large root, above the metal tag that curves about the root at the bottom of the picture, is the original root. In year one, two sprouts emerged from the root and are now brown colored and held by one hand, and in year two, two more sprouts emerged and are smaller, held by the other hand, and are lighter brown (*Source*: Kelly Kindscher)

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 (Fig. 5).

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/h) in a 10 h 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 overharvesting had caused the declines, they also 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, ideally 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. 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 regrown 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, five of 14 roots had resprouted within 2 years of digging. Our observations thus support the harvesters' assertions that harvest is incomplete and that some plants grow back after harvest. And these observations led us to realize that traditional knowledge is valuable and helped us embark on another study where we demonstrated that at research sites in both the Smoky Hills of Kansas and in eastern Montana, that about 50 % of harvested roots do resprout and grow again (Kindscher et al. 2008).

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–\$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 and Soldati and de Albuquerque (2011) for medicinal plants. 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; Trager 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

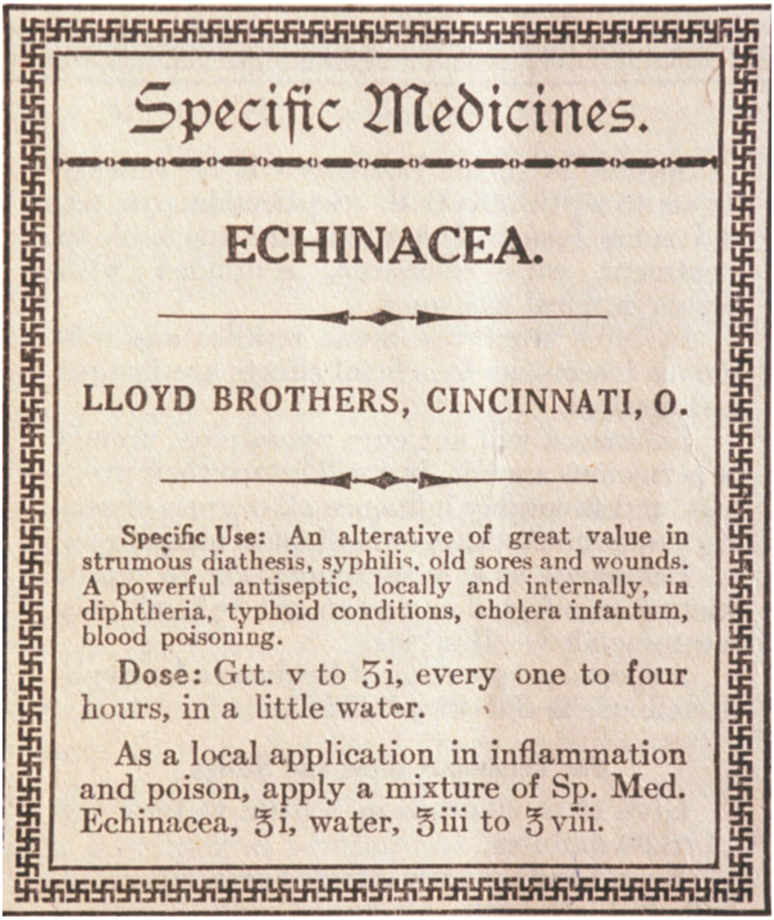

Fig. 6 The label from the Lloyd Brothers Echinacea Specific Medicine (*Source*: Steven Foster)

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 cultural and environmental variability (Fig. 6).

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 et al. 1935; Baskauf and Eickmeier 1994; Chapman and Auge 1994).

Regrowth of harvested *E. angustifolia* plants, as we observed during this study, also was 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. In the Smoky Hills, where rangelands are almost entirely privately owned, this will happen only with the support of landowners and ranchers. Suggestions include:

- 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 revegetating degraded areas and Conservation Reserve Program (CRP) lands with *E. angustifolia* and other native forbs (in addition to grasses) would be beneficial, which is allowed under some of the newer CRP sign-ups.
- 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.

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; AHPA 2012).

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 herbal product business downturn in the early 2000s meant that many growers lost money and even plowed up medicinal crops or went out of business (*Nutrition Business Journal* 2001). Since then, the demand has been up and down. 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 we have met enjoy work that allows them to be outdoors in the native prairie landscape, preserving the connection between people and land. We have observed that long-term diggers have a strong conservation ethic and appreciation for the native prairie.

Also, 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. 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 120-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 only after populations have recovered. 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 a substantial number of plants resprout within a year or two 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.

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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 overharvest of *Echinacea* occurred more than 100 years ago, when questions were raised. Lucius Sayre, the first Dean of Pharmacy at the University of Kansas expressed concern in 1903 about overharvesting *E. angustifolia* in Kansas (Sayre 1903; Kindscher 1989). These worries passed, but the recent cycles of popularity have caused concern for the sustainability of wild stands, which are threatened by consumer preference for wild over cultivated *E. angustifolia*. The resulting price spikes are 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 rural areas, especially on Great Plains Indian reservations that are close to some of the best stands of *E. angustifolia* (Kolster 1998; Kolster and Youpee 1998).

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Habitat Loss

The biggest causes of habitat loss for *Echinacea* stands of all species over the last few decades are conversion of land to other uses (farmland, housing, industry, roads) and degradation caused by overgrazing. This loss is substantially greater than the loss due to overharvest, which has never been observed to be 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 that less than one-tenth of 1 % of the historic area of native prairie 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, with 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 "Biology and ecology of *Echinacea*" chapter) 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, especially in the northern part of the range.

Fragmentation of the landscape 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. *Echinacea 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 it results in flowering shoots becoming damaged and overall seed production being 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 eastern and central Kansas pastures where there has been continuous heavy grazing, especially spring grazing over many years, *E. angustifolia*, *E. pallida*, and *E. atrorubens* are not found, though they are found locally in similar habitats. Under these heavy grazing conditions, the species mix will shift, and *Echinacea* will lose 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.

Overharvest and Recovery in the Custer

In the late 1990s, I worked with Dana Price, a doctoral student, on the subject of *Echinacea* overharvest and resprouting of plants from the root. As we delved into the subject, I became intrigued with the idea of finding sites thought to be completely wiped out. And she helped me.

How do you find such sites? You go through the network. Eventually, someone sent me an article from the Billings, Montana paper. Another contact already had told me about the incident the article covered and had given me a contact, Scott Studiner, from the Custer National Forest. As the story went, some guys went up from Texas wanting to harvest in the Custer for commercial purposes, and they asked permission. After some hesitation, the staff told

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them no. The reason was that offering commercial permits would require more study, maybe an environmental impact assessment on *Echinacea* harvest, so it was easier to say no than to open the whole process. But the next day, the Texans were caught digging and arrested. They were taken to court and fined, and the Custer authorities were glad for the publicity and believed it discouraged other diggers.

The newspaper article talked about how the diggers had wiped out the *Echinacea* population. I wanted to see the site for myself, so I got in touch with Scott Studiner. By then, I already knew from my previous research that *Echinacea* resprouted from the root, so I wondered what I'd see.

When I visited, it was two years after the arrests, but you could still see the shovel divots. Scott took me right to them. And to my great interest were two things: there were flowering plants at the site, and in the bottom of the shovel holes, in some cases, were what looked like sprouts. Scott was a little surprised, but relieved. The population was thought to be lost but in fact had come back.

The *Echinacea* Market as a Threat to Wild Populations

Increased domestic and international demand for *Echinacea* (see "The *Echinacea* Market" chapter, in this volume) has put pressure on native stands over the last two decades. With such large national and international demands, the question needs to be asked who will continue to supply the global market? While cultivation fills some of the heavy demand, most commercial supply of *E. angustifolia* over the years has come from the wild (American Herbal Products Association 2000, 2003, 2007, 2012). Despite cultivation efforts, wild populations throughout the Great Plains constitute the majority of commercial supply of this species and have been threatened by overharvest (Fig. 1) (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); the same is true of *E. pallida* and other species in Missouri, Oklahoma, and Arkansas (Foster 1991; Kindscher personal observation). Fortunately for the survival of *E. angustifolia* (and possibly the other tap-rooted *Echinacea* species), we have observed root resprouting after commercial harvest (Kindscher, personal observation in Montana and Kansas; Hurlburt 1999). Data we published on field experiments demonstrated a 50 % rate of resprouting for harvested populations in both eastern Montana and north-central Kansas (Kindscher et al. 2008).

Although research on *Echinacea* medicinal effects has not been sufficient to drive the market for *Echinacea*, it someday might be. Imagine how the market

Fig. 1 This hay meadow in eastern Kansas (Miami Co.) has a nice population of *Echinacea pallida* that can be seen in the photo. The landowner did not want someone who was driving by to stop and dig it, off his land (*Source*: Hillary Loring, Kansas Biological Survey)

would change if *E. angustifolia* was proven efficacious for whooping cough, tuberculosis, leukemia, tumors, type II diabetes, or infectious diseases. Already, initial results look promising (see "The Medicinal Chemistry of *Echinacea* Species" chapter). Some specific results will clarify this.

In a study involving 500 children treated for tuberculosis, the *Echinacea* treatment demonstrated positive benefits including acute signs of immunostimulation, and a 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. There was an opportunity for significant, insightful research with the establishment of a NIH funded Botanical Center at Iowa State University, but although the center did publish significant works in the scientific literature, they were not able to answer fundamental questions about the efficacy of *Echinacea* for human health. Subsequently, due the perceived lack of progress the NIH declined to continue its funding. But if funding does become available again 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 continues to be 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 (roots rot and diseases are problems). There continued to be a large cult-like following for *E. angustifolia*, even though there is still no conclusive evidence that it is better than *E. purpurea* (Foster 1991).

The suitability of cultivated *E. angustifolia* to replace wild-harvested roots of the same species has not been established. The belief 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 lb of cultivated *E. angustifolia* (irrigated under a center-pivot in southwest Kansas), asserting that it takes 5 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 of biomass but lower content of secondary compounds. We discuss this concept further related to work we conducted on the anticancer compounds of wild tomatillos (*Physalis longifolia*) (Kindscher et al. 2014). The above 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 wild *E. angustifolia* is the price harvesters are paid for the roots. When the price is high (see the graph in the chapter "One Hundred Twenty Years of *Echinacea angustifolia* Harvest in the Smoky Hills of Kansas"), or when economic conditions are poor, harvesters can decimate a stand in a relatively short time. *Echinacea* digging has been likened to a "Gold Rush" (Crawford 1999) that

Fig. 2 *Echinacea angustifolia* stand in eastern Montana rangeland (*Source*: Kelly Kindscher)

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 Indian 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 about this *Echinacea* harvest after Turtle Mountain and Fort Berthold Reservations (Fig. 2) (Kolster 1998).

Local root buyers around the Fort 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 in. *Echinacea* root that was part of the contest (Kolster 1998; Stewart 1999).

It was estimated that 350–400 people were harvesting *E. angustifolia* on native prairie lands in the Fort Peck Reservation area in spring 1998 (Kolster 1998). They would harvest anywhere from a couple of hours to more than 40 h 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. When I visited the reservation, I was told by an elder that at the height of the harvest, the pickup trucks' lights were sometimes used at night to illuminate the last remaining flowering cones so the roots could be harvested. One local resident predicted that *Echinacea* would be gone from the reservation in another 2 or 3 years (Kolster 1998).

Digging was not just a Native American or Indian Reservation phenomenon. 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 lb—at least 700,000 plants—were harvested during this period (Crawford 1998). One company with a Fort Peck, Montana, address bought as much as 1200 lb of root a day and paid more than $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 lb of roots in gunny sacks that they said were for "personal use." They had dug an estimated 6000 roots and left shovel holes 6–8 in. deep throughout the area they harvested (Stewart 1999; Scott Studiner, Custer National Forest Service ranger, pers. comm., 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 sites still had flowering *Echinacea* because small plants had not been harvested and were present, and a few harvested roots had resprouted 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 by conservationists and U.S. Forest Service personnel in other areas, harvesting other *Echinacea* species. During a previous upswing in the *Echinacea* market in 1987, about 7000 yellow coneflower plants (*E. paradoxa* var. *paradoxa*) were poached from Ha Ha Tonka State Park in Missouri. This variety is known only from 13 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). We learned from *Echinacea* brokers that 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 unidentified 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 species specific market for wild-harvested roots.

The initial threats due to wild harvesting were caused by the sheer number of lost plants. Considering that more than 145,000 kg (320,000 lbs) of dried roots of *Echinacea angustifolia* were wild-harvested during the 4 years of harvest from 1998 to 2001 inclusive (American Herbal Products Association 2000, 2003), and that it may take more than 100 plants to make 1 lb (0.45 kg) of dried *Echinacea* root (determined from roots that we have weighed that were wild-harvested in western Kansas), we believe that more than three million *E. angustifolia* plants were harvested.

But more than just the loss of individual plants, a basic 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 mature seed-producing class of plants can be reduced, or in some cases, eliminated, at least for a while. The related loss of *Echinacea* flowers and nectar could also negatively affect the rare Dakota skipper butterfly (*Hesperia dacotae*), which has been listed as threatened by the U.S. Fish and Wildlife Service (2014).

Professional diggers often have specialized digging tools, specially shaped or they use a pick mattock. When the price is high and there is a frenzy of digging activity, such as occurred in the late 1990s in Kansas, Montana, and North Dakota prairies, many new diggers join in, shovels are used to dig. With shovels, 6–8 in. holes are often created and not filled. We could still observe these years after harvest on both the Fort Peck Reservation and in 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 resprouting. And ranches don't like the holes because they believe that cattle can get injured from them. Although this may be true, we have data which indicated that at least in dry years, shovel holes may benefit the resprouting plants by capturing more moisture (Kindscher et al. 2008). Nonetheless, disturbance by vehicle ruts and other human harvesting activity is problematic and 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 drive the application of herbicides to rid pastures of all weeds; this further endangers the health of native *Echinacea* stands because most herbicides used in rangeland (often a mix of 2-4D and diesel fuel) 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 no more than once every 3 years because it then becomes easier and more worthwhile time-wise to harvest. They also know, by looking for the largest basal rosette of leaves for the largest roots they can harvest, and they tend to harvest moderately because they intend to come back. Hurlburt (1999) determined from these stands that there is a sustainable rate of harvest: When 6–7 % 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 benefit plant populations, the market, and individuals involved.

Since 2000, demand for wild-harvested *Echinacea* root has decreased dramatically (American Herbal Products Association 2003, 2007, 2012). Based on 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 overharvested (Kolster 1998). These areas included sites on the 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 and 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 reported to have been “wiped out” or made locally extinct by overharvesting (Kolster 1998; Scott Studiner, Custer National Forest Service ranger, pers. com., July 2002). 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 Fort 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 overharvesting (Fig. 3).

At Risk List

The United Plant Savers, a non-profit organization dedicated to the conservation of medicinal plants created a list of plants that they believed were potentially “at risk” of being overharvested. *Echinacea* was put on this list by the organization, see: http://www.unitedplantsavers.org/content.php/426-Echinacea. About 10 years ago, I was asked to join their board of directors, as they were wanting to broaden their board to have more of a science perspective on it. And one of the things that I took great interest in was their At Risk List. And with the help of then graduate student, Lisa Castle, we began work on a math-based, objective tool to rank medicinal plant species. We have recently refined and published the tool (Castle et al. 2014) which is based on questions that rate each species from being low to high-risk numerically, on five categories of factors: the plant’s life history, the effects of harvest on its populations, the plant’s abundance and range, its habitat, and demand for it from wild populations.

Fig. 3 Root resprouts. These are all *Echinacea angustifolia* resprouts from plants that were marked with aluminum tags, re-harvested and dried. The resprouted material is much thinner than the longer living root from which is emerged 1 or 2 years previously (*Source*: Kelly Kindscher)

In looking specifically at *E. angustifolia*, the life history score is low to moderate because, although it is a long-lived perennial, it tolerates disturbance, produces lots of seeds, and as mentioned above, half of the harvested plants are able to resprout after the top 6–10 in. (15–25 cm) portion of the long root is harvested (Kindscher et al. 2008). The score for "effects of harvest" is high because it is the roots that are harvested in the wild (which can kill the plant), it takes years for plants to be large enough to harvest, harvest is conducted nearly year-round, and it takes several years for the roots to be large enough for harvest again. The abundance and range score is very low because many scattered populations exist over a large range of Great Plains states and *E. angustifolia* can grow in many broad habitats, although some populations have been decreasing due to grazing, herbicide use, and other land management practices. The habitat vulnerability score is moderately low as the rocky prairie habitat is widespread and not particularly threatened on the landscape scale, although it is fragmented. The demand score is moderately high as market demand is high, but yield per acre is moderate, and cultivated sources are known and available. Overall, *E. angustifolia,* with a score of 44, has only a moderate risk of being overharvested (Castle et al. 2014). So for now is being kept on the At-Risk List, but the score should be reevaluated in the future due to changing factors including demand, habitat, and climate change.

Conservation Status and Rankings

One good way to ascertain threats to species is to look at the conservation status rankings by Natural Heritage Programs, which are the state by state rankings by staff in each state of the rarity of species of concern. 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.

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 due to high prices for ethanol-producing commodity crops, oil and gas development, home building, and other development, but is not an eminent threat for most remaining stands, most of which are 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 for *E. angustifolia* (Fig. 4) and, to a much lesser degree, for *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,* have been protected by the Endangered Species Act and more recently *E. tennesseensis* has been delisted because active management of it habitats have increased populations sizes (U.S. Fish and Wildlife Service 2011). It is the other somewhat uncommon

Table 1 Conservation status of wild *Echinacea* populations in the United States and Canadian provinces

Species	State/province	Status
Echinacea angustifolia	Iowa	S3
	Montana	S4
	Wyoming	S3
	Manitoba	S3
	Saskatchewan	S3
Echinacea laevigata	Federally endangered	
	Pennsylvania	SX
	North Carolina	S1
	South Carolina	S3
	Georgia	S2
	Virginia	S2
Echinacea pallida	Ontario	S1
	Georgia	S1?
	Nebraska	S1
	North Carolina	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	S2?
	Mississippi	S3
	Kentucky	S4
Echinacea sanguinea	Arkansas	S2S3
Echinacea simulata	Georgia	S2S3
	Tennessee	S2
	Kentucky	S3S4
Echinacea tennesseensis	Tennessee	S2

Source: NatureServe Explorer at www.natureserve.org/explorer/index.htm (accessed January 25, 2015). 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

Fig. 4 *Echinacea* angustifolia is abundant in eastern Montana, here associated with ponderosa pine habitat, in the Powder River breaks east of Miles City, Montana (*Source*: Kelly Kindscher)

species, *E. atrorubens*, *E. simulata*, *E. paradoxa*, and *E. sanguinea*, 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 (Fig. 4).

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. And the herbal product industry could be encouraged to use wild harvested tops, and fewer roots. 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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Part IV
The Medicine and the Market

The Medicinal Chemistry of *Echinacea* Species

Congmei Cao and Kelly Kindscher

Introduction

The nine recognized *Echinacea* species have been a subject of significant scientific interest and have resulted in 1652 journal publications related to any topic of *Echinacea* and science cited in SciFinder, 1363 approved patents, and 84 recorded clinical trials, when consulted in January 2015. More than a third of these records are from work conducted between the years of 2012–2014, which indicates the continued interest in these medicinal plants. Among these records, half of them are about *E. purpurea*, including 854 journal publications, 533 patents, and 39 clinical trials.

Echinacea species were traditionally used by Native American tribes for a variety of ailments, as discussed by Kindscher (1989; and in this volume) which included the treatment of mouth sores, colds, and cough (Borchers et al. 2000). In recent years, *Echinacea*-based medicinal products became widely available and utilized throughout the world as herbal dietary supplements in the United States, as natural health products in Canada, and as phytomedicines in Europe. *Echinacea* is mainly marketed and used as an immunostimulant (they stimulate the body's immune system) in the treatment and prevention of the common cold, influenza, and upper respiratory tract infections.

Three species, *E. purpurea*, *E. angustifolia*, and *E. pallida*, are primarily used to make *Echinacea* extracts, tinctures, and capsules for herbal supplement use. Studies of the chemistry of these three species have focused on chemical constituent isolation and identification, chemical analysis of certain structural types between species, quality control of plant materials, bioactive screening, mechanistic studies, and methodology for the separation or enrichment of active components in extracts.

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The chemical constituents contained in each species and plant part can vary greatly, making analysis both difficult and confusing. Like good food, beer, or fine wine, the combination of ingredients and preparation can have great impacts on the marketable products and consumer satisfaction.

There has been considerable debate over the identity of the specific constituents which are responsible for the biological activities of *Echinacea* species. Chemical constituents reported from *Echinacea* include alkamides, caffeic acid derivatives, polysaccharides and glycoproteins, polyacetylenes and polyenes, flavonoids, and terpenoids. Extensive scientific research on these compounds has suggested that alkamides, caffeic acid derivatives, glycoproteins, and polysaccharides are responsible for the immunostimulatory activities of *Echinacea*. These structural types are discussed in greater detail below.

The chemical profile of *Echinacea* products is further complicated by the fact that a variety of plant parts, including roots, flowers, and entire aerial (all aboveground) parts of *E. purpurea*, *E. angustifolia*, and *E. pallida*, are used in herbal product formulations. All of these factors contribute to considerable differences in the chemical composition of *Echinacea* products, which also affect their pharmacological activities. Analysis of chemical constituents in plant material is therefore required for standardization and quality control of any *Echinacea* preparation. Fingerprinting recorded from high performance liquid chromatography (a chemical separation technique) can be used to distinguish the difference in the chemical constituents of plant materials. And some companies are now providing information on their tincture bottles related to standardization. Four percent echinacosides (a caffeic acid derivative) is a common standard, which indicates that at least this *Echinacea* compound is present in the formulation.

Chemical Constituents Isolated from *Echinacea* Species

Alkamides are primarily components of the roots of *E. angustifolia* and *E. purpurea*, as well as the aerial parts *of E. purpurea*. Although the content of alkamides in *E. pallida* is very low, alkamides are still considered by some experts to be the characteristic and bioactive constituents of *Echinacea* (Bauer 1999; Miller 2004; Barnes et al. 2005; Hudson 2012; Gupta et al. 2012).

The most abundant caffeic acid derivatives observed in *Echinacea* species include the caffeic acid glycosides, as well as caffeoyl quinic acid and caffeoyl tartaric acid esters. The distribution of these compounds within the plant material differs greatly depending on the species.

Glycoproteins and polysaccharides are considered to be the primary constituents responsible for the immunostimulatory activities of the genus (Mitscher and Cooper 2004). These compounds were first observed in the aerial parts of *E. purpurea*. Other research on cultured tissues of *E. purpurea* resulted in the identification of additional polysaccharides with different structural patterns that still maintain potent immunostimulatory activity (Wagner et al. 1988).

Alkamides

The name alkamide is derived from the term *alkyl amide*, which represents a group of compounds that contain a carbonyl connected to an alkyl group, and a nitrogen atom. Alkamides are considered to be characteristic structural types of *Echinacea*. The presence of alkamides is responsible for the pungent taste and tongue-tingling feeling associated with chewing *E. angustifolia* root (Kraemer and Sollenberger 1911). Many *E. angustifolia* root buyers associate a strong tongue-tingling effect with roots being of higher quality.

Alkamides are major constituents present in *Echinacea* derived from ethanol–water plant extracts. A total of 29 alkamides (**1**–**29**), which vary significantly in degrees of unsaturation in the aliphatic chains, were identified in *Echinacea* species (Fig. 1). These include several isomeric pairs of alkamides that only differ structurally in their double-bond configuration.

Echinacein (**1**) was the first alkamide observed in *Echinacea*, where it was isolated from the roots of *E. angustifolia* in Maryland (Jacobson 1954) and its structure was elucidated in 1967 (Jacobson 1967). Although **1** (0.01 % weight/weight in plant material) was suggested to be a major component of *E. angustifolia* (Jacobson 1967), it has not been detected in subsequent studies on the species (Bauer and Remiger 1989). This compound exhibits a highly pungent taste and is moderately toxic to houseflies (Jacobson 1954). Over subsequent years, a further 28 alkamides have been identified in the genus, which includes 26 new structures (**1**–**15**, **17**–**22**, **25**–**29**), and these are listed in Fig. 1 following the chronological order in which they were reported in *Echinacea* species.

Echinacea angustifolia: The roots of *E. angustifolia* are commercially used more than any other part of the species due to its original use by Native Americans. Hence the chemistry of the *E. angustifolia* root has been investigated intensively, where a total of 19 alkamides (**1**–**5**, **7**, **8**, **14**, **15**–**24**, and **26**) have been reported to date (Jacobson 1954; Bohlmann and Grenz 1966; Bauer et al. 1989; Chen et al. 2005), primarily from German research.

Alkamides **2**–**5** were isolated by a German group from the roots of *E. angustifolia* and *E. purpurea* (Bohlmann and Grenz 1966). Another German group reported a total of fifteen alkamides (**2**, **4**, **5**, **7**, **8**, **15**–**24**) from the roots of *E. angustifolia*, which include five alkamides (**17**–**21**) that are so far exclusive to the species (Bauer et al. 1989). More recently, compound **26** was purified from *E. angustifolia* roots by Gaia Herbs (Chen et al. 2005).

Echinacea purpurea: Phytochemical investigations on *E. purpurea* isolated five alkamides (**6**–**10**) from the aerial parts (Bohlmann and Hoffmann 1983), while 16 alkamides (**2**, **4**, **5**, **6**, **11**–**16**, **22**, **24**, **25**, **27**–**29**) were purified from the roots (Bauer et al. 1988; Chen et al. 2005; Kotowska et al. 2014).

Echinacea pallida: Compared to the other species within the genus, *E. pallida* contains only trace amounts of alkamides, where only two alkamides (**2** and **27**) were purified from the roots. (Chen et al. 2005).

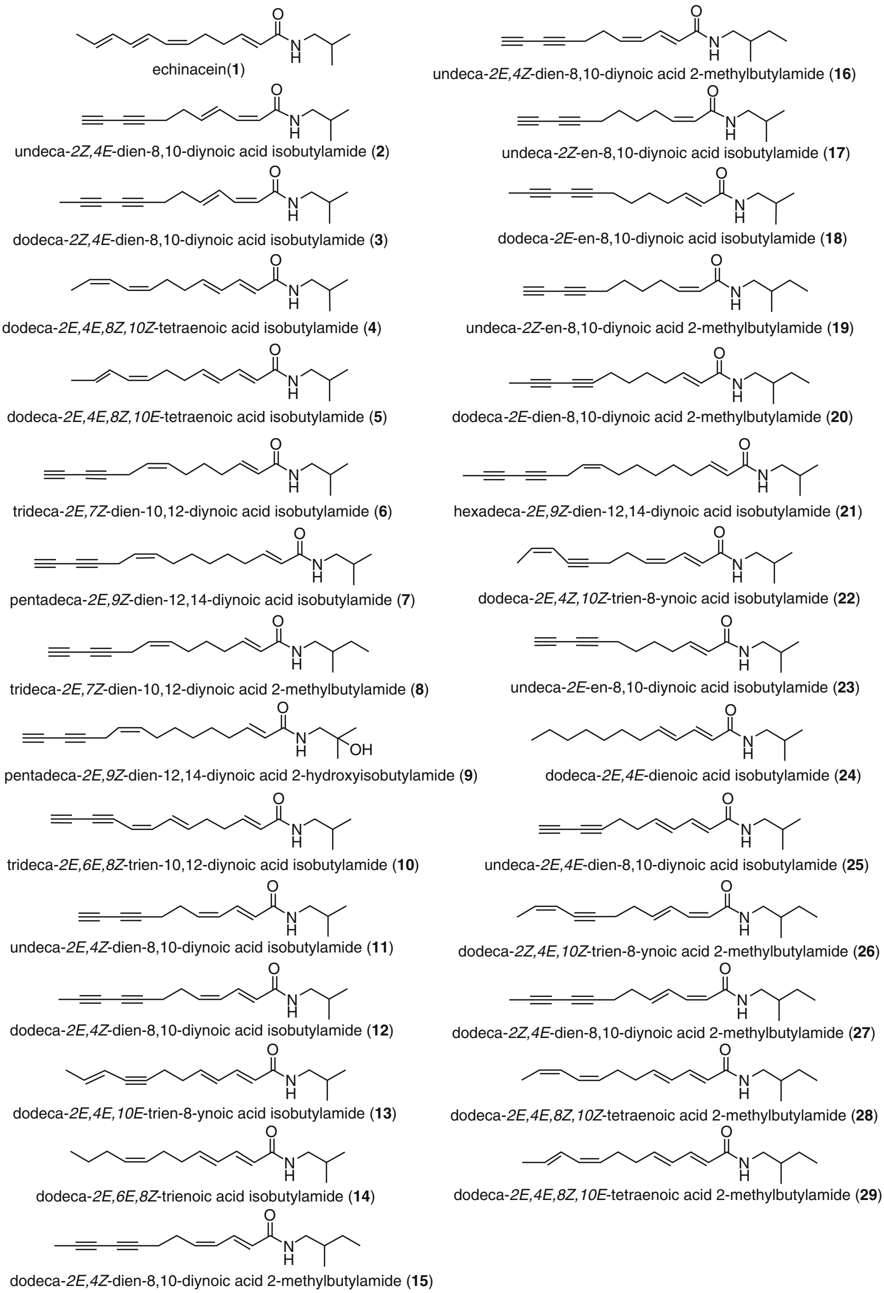

Fig. 1 Alkamides isolated from *Echinacea* species (*Source*: Congmei Cao)

Echinacea atrorubens: Eleven alkamides (**4–6**, **11**, **12**, **14**, **20**, **22–25**) were isolated from the roots of *E. atrorubens* (Dietz and Bauer 2001).

Caffeic Acid Derivatives

Caffeic acid derivatives are chemical constituents distributed in a large number of plant families. Examples are rosmarinic acid in the Lamiaceae and chlorogenic acid in coffee beans, peaches, and plums. These compounds are believed to be responsible for the antioxidant and antiviral activities (Cheminat et al. 1988). Echinacoside was initially isolated from the roots of *E. angustifolia* in 1950, and represents the first caffeic acid glycoside identified in the *Echinacea* genus (Stoll et al. 1950; Becker et al. 1982). More caffeic acid derivatives were isolated and identified in *E. pallida*, *E. purpurea*, and *E. angustifolia* (Cheminat et al. 1988; Bauer et al. 1988b). Three different structural types of caffeic acid derivatives: caffeoyl glycoside (echinacoside, **30**), caffeoyl quinic acids (chlorogenic acid **31**, cynarin **32**, isochlorogenic acid), and caffeoyl tartaric acids (caftaric acid **33**, cichoric acid **34**), were found in *Echinacea* species (Cheminat et al. 1988; Harbonrne and Williams 2004).

Polysaccharides and Glycoproteins

The name "saccharide" comes from the Greek word "σάκχαρον" (*sákkharon*), and is a general synonym for sugars, including starch, and cellulose. According to the number of sugar units, saccharides are divided into four categories: monosaccharides, disaccharides, oligosaccharides, and polysaccharides. Polysaccharides, which have higher molecular weights, are composed of long chains of monosaccharide units bound together by glycosidic linkages, which upon hydrolysis give the constituent monosaccharides or oligosaccharides. They range in structure from linear to highly branched. Examples include storage polysaccharides such as potato starch, and structural polysaccharides such as cellulose and chitin. The polysaccharides isolated in *Echinacea* so far only contain rhamnose, arabinose, xylose, galactose, and glucose sugar units.

Research on the polysaccharides in *Echinacea* originated in Germany and over time resulted in the isolation of several polysaccharides, whose structures were partially identified later. At first, two immunostimulatory polysaccharides, PS1 and PS2, were isolated from the aerial parts of *E. purpurea*. These were identified as the main components from the fractions consisting of arabinose, xylose, and galactose (1:4:1) and rhamnose, arabinose, xylose, and galactose (1:1:0.6:1.2), respectively (Wagner and Proksch 1981). PS1 is a methylated polymer of glucuronic acid and arabinose with a mean molecular weight of 35,000 Da. PS2 was an acidic polymer of galactose, arabinose, and xylose, whose average molecular weight is 50,000 Da. Polysaccharides with large molecular weight are also complex, and these two polysaccharides demonstrated significant activity in vitro and in vivo immunological test systems (Wagner and Proksch 1981; Wagner et al. 1984; Stimpel et al. 1984; Proksch and Wagner 1987). In other words, these compounds positively increase the immune response in both test tube and animal tests.

A third polysaccharide containing xylose and glucose was reported as xyloglucan with molecular weight of about 79,500 Da from the leaves and stems of *E. purpurea*. Also, a pectin-like polysaccharide has been isolated from the juice of *E. purpurea* (Stuppner 1985).

Considering the relative difficulty in the isolation and purification of polysaccharides, tissue culture was used to produce more and repeatable polysaccharides. Homogeneous polysaccharides were isolated in large-scale cultivated tissues of *E. purpurea*. They are two neutral fucogalactoxyloglucans (polymers of fructose, galactose, and glucose), and an acidic arabinogalactan, with mean molecular weights of 10,000, 25,000, and 75,000 Da, respectively (Wagner et al. 1988). Although the structures of these three polysaccharides are different from the ones isolated from the aerial parts of plants, two of them still showed immunostimulatory activities. The fucogalactoxyloglucan with MW of 25,000 Da enhanced phagocytosis in vitro and in vivo, while the arabinogalactan specifically stimulated macrophages to excrete the tumor necrosis factor (Wagner et al. 1988). These results indicate that the process of engulfing and destroying intercellular particulate matter by immune cells is increased by these compounds. Two polysaccharides with molecular weights of about 128,000 Da and 4500 Da were extracted from *E. angustifolia* roots (Cozzolino et al. 2006). The low molecular weight polysaccharide corresponds to inulin while the high molecular weight component is a high methoxylated pectin in which the backbone structure of the smooth region is constituted by α-(1–4)-polygalacturonan partially methyl esterified (60 %) and acetylated (9 %) and with the branched area containing 2-*O*- and 2,4-*O*-rhamnopyranose; 5-*O*- and 3,5-*O*-arabinofuranose; 3,6-galactopyranose, and terminal rhamnopyranose, arabinofuranose, arabinopyranose, galactopyranose, and galacturonopyranose.

More recently, active fractions of *Echinacea* plant constituents were studied in human blood using polysaccharide-enriched materials and were found to be the active immunostimulatory substances in various *Echinacea* species (Mitscher and Cooper 2004)

Analysis of Compounds with Specific Biological Activity

Commercial *Echinacea* products are available for the public in a variety of forms, including dried plant materials, liquid tinctures (also called fluid extracts), dried extracts, capsules, tablets, and softgels. These preparations are generally used for treatment of cold, flu, and chronic respiratory infections. The treatment success may depend on the combined action of several categories of compounds, namely alkamides, caffeic acid derivatives, polysaccharides, and glycoproteins. As herbs, *Echinacea* plants contain several categories of chemical constituents, which differ between species and plant part examined. These preparations are predominantly made from different plant parts of *E. angustifolia*, *E. purpurea*, and *E. pallida*. Other factors, such as growth conditions, postharvest handling, storage, and extraction techniques, can also affect the abundance of these constituents. Therefore it is important to analyze the bioactivity (the effect of an *Echinacea* compound upon a living organism or on living tissue) and chemical profiles of *Echinacea* species plant material, as well as subsequent extracts or products, prior to human consumption. It is important to note that the differences in effectiveness of some clinical trials with *Echinacea* are likely to be directly related to some of these differences.

Biological Activity Screening

Various biological activities have been investigated for *Echinacea* species and preparations, including immune system response, antiviral activity, antifungal activity, anti-inflammatory and antioxidant properties. These biological activities of *Echinacea* species have been extensively reviewed (Bauer 1999; Mitscher and Cooper 2004; Miller 2004; Rininger et al. 2004; Sestakova and Turek 2004; Barnes et al. 2005; Hudson 2012; and Gupta et al. 2012). The bioactivity of the alkamides has been reported, such as their improvement of basal and insulin-dependent glucose uptake in 3T3-L1 adipocytes, or cells that store fat (Kotowska et al. 2014), as well as enhancement of the adipocyte differentiation of 3T3-L1 cells (Shin et al. 2014). Considerable pharmacological research has been conducted on the in vivo and in vitro immune system response of the genus, where greatest response was observed in alkamides, caffeic acid derivatives, glycoproteins, and polysaccharides.

Chemical Profile Analysis

The classical technique to determine the quality of *Echinacea* plants was a rather simple taste test, where the presence of pungent flavor that induced a strong tingling sensation on the tongue was considered to be indicative of a high-quality plant material which would be ready for medical applications. In contrast, the modern approach to analyzing plant material is far more intricate and involves developing techniques that utilize analytical tools as well as machines to analyze the specific quantity of each chemical in any given plant.

Chromophores are the key factor in the analysis. All the unsaturated bonds such as ethylenic linkages, acetylenic linkages, and carbonyls are chromophores. Chromophores are the part of a molecule responsible for its color. The color of a molecule arises when conjugation of these chromophores absorb certain wavelengths of light. Our eyes will see the color if the conjugation is strong enough to absorb visible light. The most common analytical techniques/instruments utilized for such purposes involve an ultraviolet (UV) detector in conjunction with high performance thin layer chromatography (HPTLC), high performance liquid chromatography (HPLC), and high performance liquid chromatography coupled with mass spectrometry (HPLC-MS). High performance liquid chromatography is a chromatographic technique widely used in analytical chemistry to separate the chemical constituents in a mixture. The mixture is carried by pressurized liquid solvent to pass through a column filled with a solid adsorbent material. The different constituents in the tested mixture travel at different speeds, causing them to be separated. And UV detectors and mass spectrometry are the key instruments for identification and analysis of each constituent.

UV detectors with fixed or variable wavelength are the most popular detectors used in analytical chemistry. Ultraviolet and visible light that hits molecules in tested samples can be absorbed by chromophores and the absorption continuously measured at single or multiple wavelengths.

Both alkamides and caffeic acid derivatives possess chromophores which are easily observed with an UV detector. Also, they have specific distributions in several species and plant parts. Therefore, alkamides and caffeic acid derivatives are used to identify *Echinacea* species and differentiate plant parts. They are the characteristic markers recorded in the American Herbal Pharmacopoeia (2010a, 2010b). Analytical methods applied for detection of alkamides and caffeic acid derivatives in *Echinacea* species are reviewed below, and results from these analyses are summarized.

The polarity of alkamides and caffeic acid derivatives is different due to their characteristic different chemical features. Alkamides are lipophilic (fat-loving chemical compounds) while caffeic acid derivatives are hydrophilic (water loving, that is extracted with water). Several analyses included the two categories in the same chemical profiles (Gocan et al. 2003; Luo et al. 2003; Cech et al. 2006), while most analyses of *Echinacea* species only focus on one category of chemical structure.

Unfortunately, not every chemical structural type possesses chromophores. One example is polysaccharides which require mass spectrometry for identification. Mass spectrometry (MS) is actually a detector measuring the mass-to-charge ratio and abundance of gas-phase ions. A molecule will be ionized or even broke into charged fragments and then transferred into an electric or magnetic field. Based on their mass-to-charge ratio, the ions will be accelerated and magnetically separated. Results are displayed as spectra of the relative abundance of detected ions with their mass-to-charge ratio. With the molecular weight of the molecule and fragments, the chemical constituent is identified.

Depending on extraction and separation methods, the chemical profiles of *Echinacea* plants differ considerably. The parameters selected for the extraction methodology will affect the content or composition of the chemical constituents in the extract, resulting in a profound change in the intensity of peaks of the chemical profile. These differences can be observed in different studies on different plants of the same species (Gocan et al. 2003; Luo et al. 2003; Cech et al. 2006). Four caffeic acid derivatives [caftaric acid (**33**), caffeic acid, echinacoside (**30**) and cichoric acid

(**34**)] and seven alkamides were identified in a hydroalcoholic *E. purpurea* roots extract (Gocan et al. 2003). In another *E. purpurea* roots extract prepared with methanol–0.1 % phosphoric acid, four caffeic acid derivatives (caftaric acid, chlorogenic acid, caffeic acid, and cichoric acid) and eleven alkamides were identified (70:30, v/v) (Luo et al. 2003). Two caffeic acid derivatives (caftaric acid and cichoric acid) and 11 alkamides were identified in a 50 % ethanol *E. purpurea* roots extract and the content of these two caffeic acid derivatives and alkamide, undeca-*2Z*,*4E*-diene-8,10-diynoic acid isobutylamide (**2**, Fig. 1), was quantified in the same extract (Cech et al. 2006). Therefore, a consistent methodology is essential for analyzing the chemical profile of *Echinacea* species extracts.

Generally, chemical constituents are different between *Echinacea* species (Brown et al. 2010), plant parts (Brown et al. 2010), location collected or geological environment (Luo et al. 2003), and type of storage (Luo et al. 2003). Among these, the species and plant parts are the two most important factors affecting the chemical constituents as discussed below.

Analysis of Caffeic Acid Derivatives

A high performance liquid chromatography (HPLC) analytical method was used for the detection and quantification of caffeic acid derivatives in *Echinacea* roots and aerial parts (Brown et al. 2010). It was also employed as the American Herbal Pharmacopoeia method to successfully differentiate between root samples of *E. angustifolia*, *E. purpurea*, and *E. pallida* (American Herbal Pharmacopoeia 2010a), as well as to distinguish between the roots and aerial parts of *E. angustifolia* (American Herbal Pharmacopoeia 2010b). Therefore the distribution of caffeic acid derivatives in *Echinacea* species with this method will be discussed here (Brown et al. 2010; American Herbal Pharmacopoeia 2010a, 2010b).

The solvent used for extraction was 60:40 methanol/water in this method. Five caffeic acid derivatives, **30–34** (Fig. 2), were employed as chemical reference standards for quantification (Brown et al. 2010; American Herbal Pharmacopoeia 2010a, 2010b).

Caffeic Acid Derivatives in Different *Echinacea* Species

The chemical profiles of caffeic acid derivatives in *Echinacea* are simple and clear with significant differences among the *Echinacea* species and plant parts. Analyses of roots from different species were compared and summarized briefly to determine the similarities and differences between different *Echinacea* species. Cynarin is only found in *E. angustifolia* roots. Echinacoside (**30**) is abundant in both of *E. angustifolia* and *E. pallida* roots. Cichoric acid and caftaric acid are significant *E. purpurea* root constituents, but echinacoside (**30**) is not present. Cichoric acid is a prominent constituent in the aerial parts of most *Echinacea* species.

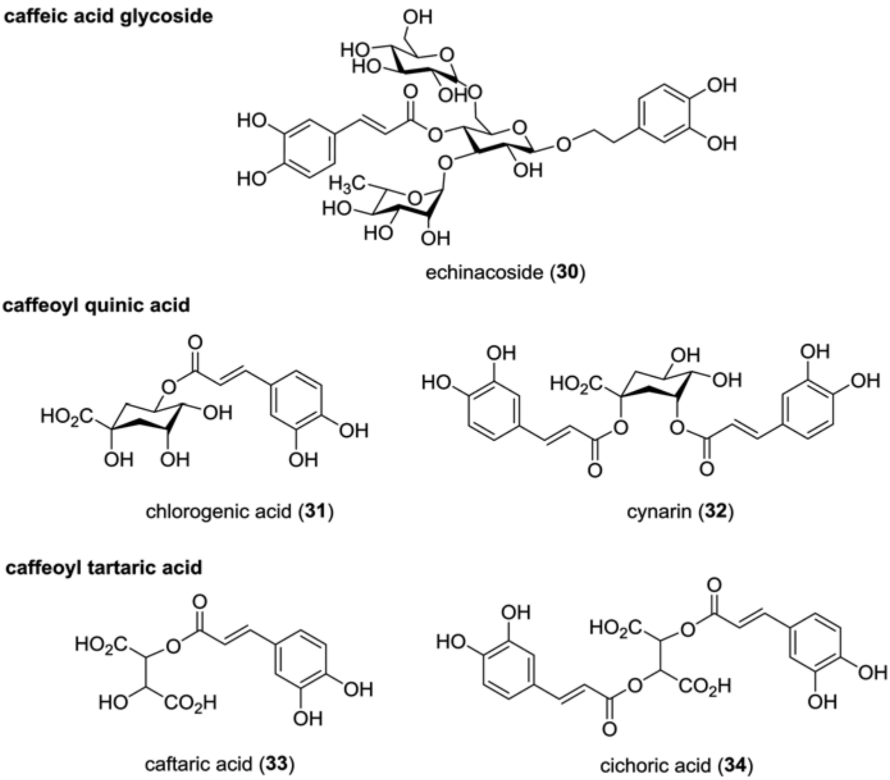

Fig. 2 Representative caffeic acid derivatives (*Source*: Congmei Cao)

Echinacea angustifolia: Four caffeic acid derivatives were detected in *E. angustifolia* roots, with echinacoside as the most abundant and followed by cynarin, chlorogenic acid, and cichoric acid with lower contents. It is worth noting that cynarin is only detected in *E. angustifolia* roots (Brown et al. 2010).

Echinacea pallida: Echinacoside is also the most abundant caffeic acid derivative in *E. pallida* roots. Its content in *E. pallida* roots is higher than that in *E. angustifolia* roots. Two other caffeic acid derivatives, caftaric acid and cichoric acid, were also found in the roots of *E. pallida* with much lower content (Brown et al. 2010). Also, HPLC-MS analysis also confirmed that echinacoside is the most abundant derivative in *E. pallida* roots (Pellati et al. 2012).

Echinacea purpurea: Echinacoside was not detected in *E. purpurea*. The most abundant caffeic acid derivative observed in *E. purpurea* roots is cichoric acid. Caftaric acid and chlorogenic acid were also quantified in the roots of *E. purpurea* (Brown et al. 2010). This agreed with the results from a HPLC-MS study of *E. purpurea* roots; however, caffeic acid was also identified in the same analysis (Luo et al. 2003). In another analysis of *E. purpurea* roots from Romania, the caffeic acid derivatives reported are cichoric acid, caftaric acid, echinacoside, and caffeic acid, whereas chlorogenic acid was not detected in this study (Gocan et al. 2003).

Caffeic Acid Derivatives in Different Plant Parts

Both root and aerial parts of *Echinacea* plants are used medicinally. Naturally, the chemical profile varies depending on which plant part is analyzed, though many of the more common, or characteristic chemical constituents are still present in all plant parts. However, due to the considerable differences in content of various herbal product formulations, the chemical may be altered dramatically to a point where an individual compound cannot be detected and would no longer be part of the biological activity.

Roots and Aerial Parts of Echinacea angustifolia

The four caffeic acid derivatives were detected in the roots and aerial parts of *E. angustifoli*a (Brown et al. 2010). In addition, caftaric acid was also quantified in the aerial parts. However, the content and relative abundance of the caffeic acid derivatives vary considerably between root and aerial part samples of the species. Caftaric acid is more abundant in the aerial parts, whereas echinacoside is more abundant in the roots.

The content of chlorogenic acid and cichoric acid in the aerial parts is still relatively close to that in the roots. The typical caffeic acid derivative identified in *E. angustifolia* roots was cynarin, though a comparatively lower content was observed in the aerial parts. As such, it was determined that cynarin is the least abundant caffeic acid derivative in the aerial parts of the species (Brown et al. 2010; American Herbal Pharmacopoeia 2010b).

Roots and Aerial Parts of Echinacea purpurea

In contrast to differences observed between the chemical profiles of the plant parts of *E. angustifolia*, the HPLC profiles of *E. purpurea* plant parts were very similar to one another. Three caffeic acid derivatives were quantified with the same order of abundance in both the root and aerial part collections of *E. purpurea*, where cichoric acid was the most abundant, followed by caftaric acid, and finally chlorogenic acid (Brown et al. 2010).

Analysis of Alkamides

Several analytical studies have been reported that focus on the identification of alkamides in *Echinacea* species which use HPTLC, HPLC, or HPLC-MS techniques. Most of these studies concentrate on the identification of alkamides in *E. purpurea* root samples (Gocan et al. 2003; Luo et al. 2003; Cech et al. 2006). Reverse phase C18 column chromatography with a mobile phase consisting of acidic aqueous-acetonitrile solutions has been adopted to analyze ethanol–water extracts of *Echinacea* plants.

The HPLC quantification of alkamides recorded in the American Herbal Pharmacopoeia is a modified method based on USP methodology, where four alkamide standards were employed instead of a single standard (American Herbal Pharmacopoeia 2010b). Due to the missing absolute stereochemistry of double bond C2═C3 and the doubtful identity of the isomers **4** and **5**, this method is not recommended here.

A method based on ultrafast liquid chromatography coupled with diode array detection and electrospray ionization mass spectrometry (UFLC-DAD-MS) for the analysis with a 15 min separation of 24 alkylamides was reported (Mudge et al. 2011). The roots of *E. angustifolia*, *E. purpurea*, *E. pallida*, and nine commercial dietary supplements were analyzed for alkamide content. The chromatograms obtained by this UFLC-DAD-MS analysis can be used to clearly differentiate between the three plant species (Figs. 3 and 4). The results from this analytical study will be used to discuss the distribution of alkamides in *Echinacea* species and their plant parts.

Alkamides in Different Species

The distribution of alkamides varies between species and between plant parts of any given species of *Echinacea*. In decreasing order, the alkamide concentrations of *Echinacea* collections are *E. purpurea* roots, *E. angustifolia* roots, *E. purpurea* aerial parts, *E. pallida* aerial parts, and *E. angustifolia* aerial parts (Bauer et al. 1988b).

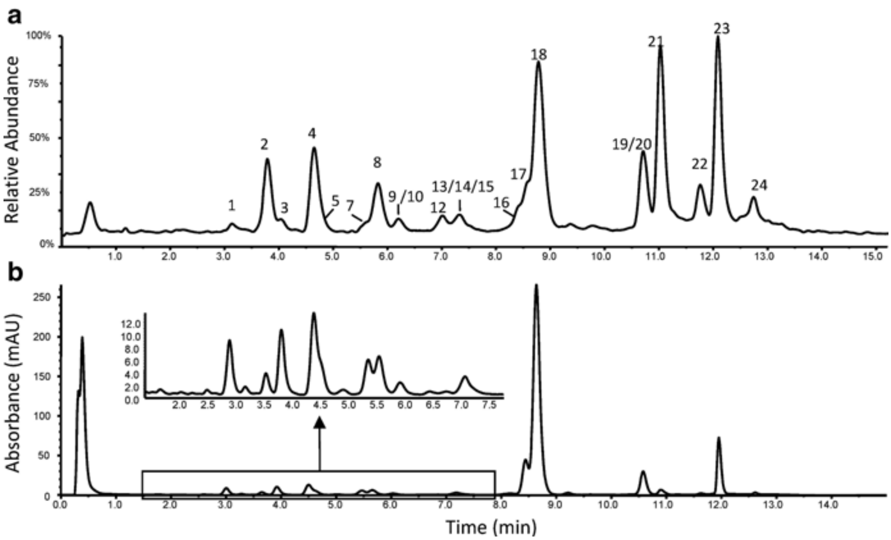

Fig. 3 Separation of alkamides from the root extract of *Echinacea angustifolia* from plants grown in Alberta was analyzed by UFLC: TIC (**a**) and UV (**b**) at 254 nm (from Mudge et al. 2011, with permission) (*Source*: Congmei Cao)

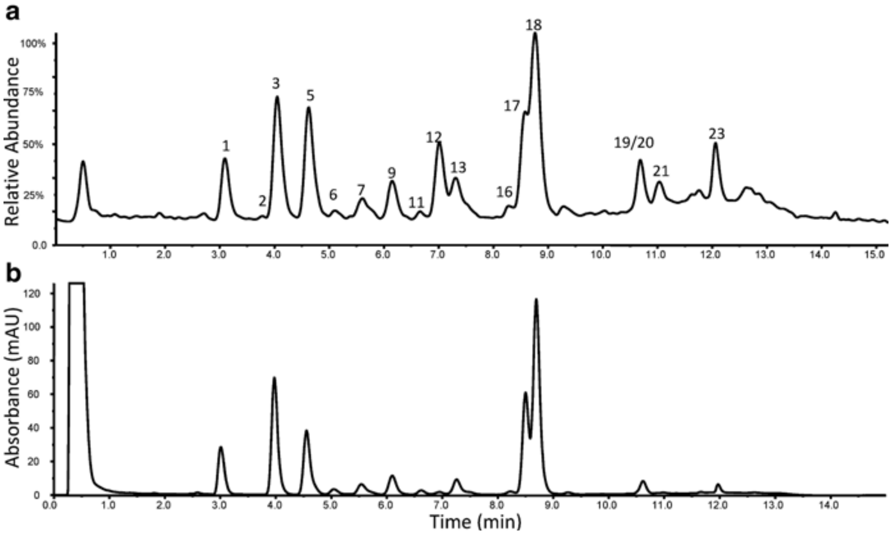

Fig. 4 Separation of alkamides from the root extract of *Echinacea purpurea* grown in Alberta was analyzed by UFLC: TIC (**a**) and UV (**b**) at 254 nm (from Mudge et al. 2011, with permission) (*Source*: Congmei Cao)

The roots of *E. purpurea* and *E. angustifolia* contain different structural types of alkamides, while the roots of *E. pallida* were almost devoid of amides (Bauer and Remiger 1989).

Echinacea angustifolia: Mudge et al. (2011) identified a total of 22 alkamides in the roots of *E. angustifolia*. Three alkamides, dodeca-2E,4E,8Z,10E-tetraenoic acid isobutylamide (**5** in Fig. 1, peak **18** in Fig. 3), pentadeca-2E,9Z-diene-12,14-diynoic acid isobutylamide (**7** in Fig. 1, peak **21** in Fig. 3) and dodeca-2E,4E-dienoic acid isobutylamide (**24** in Fig. 1, peak **23** in Fig. 3), were identified as the main constituents of *E. angustifolia* roots.

Seven of them were exclusive to *E. angustifolia* root samples, which include three previously isolated alkamides **17**, **22**, **19** in Fig. 1 (peaks **4**, **8**, **14** in Fig. 3, respectively); and four newly identified alkamides (peaks **10**, **15**, **22**, **24** in Fig. 3).

Echinacea purpurea: Mudge et al. (2011) identified a total of 17 alkamides in the roots of *E. purpurea*. Three main alkamides identified are undeca-2Z,4E-diene-8,10-diynoic acid isobutylamide (**2** in Fig. 1, peak **3** in Fig. 4), dodeca-2Z,4E-diene-8,10-diynoic acid isobutylamide (**3** in Fig. 1, peak **5** in Fig. 4), and dodeca-2E,4E,8Z,10E-tetraenoic acid isobutylamide (**5** in Fig. 1, peak **18** in Fig. 4). These three main components were the same as those reported with a LC-MS study of *E. purpurea* root, where a total of eleven alkamides were identified (Cech et al. 2006).

Two relatively polar alkamides with short retention times are exclusive to *E. purpurea* root collections. They are peaks **6** and **11** in Fig. 4, which are two peaks with low intensity.

Significant differences could be observed in the alkamide profiles of *E. angustifolia* and *E. purpurea* root collections (Figs. 3 and 4), where the *E. angustifolia* profile showed predominantly low polar alkamides compared to the *E. purpurea* profile. In fact, the *E. purpurea* root profile contained far more intense peaks in the polar portion while the peak intensities for the nonpolar peaks that elute after peaks **17** and **18** in Fig. 4 are much less than observed in *E. angustifolia* roots (Mudge et al. 2011). The distinct chromatograms obtained by this UFLC-DAD-MS analysis can be used to differentiate between the roots of these two species.

Echinacea pallida: Compared to the other species, *E. pallida* contains only trace amounts of alkamides (Bauer et al. 1988b). Its roots were also analyzed with the aforementioned UFLC-DAD-MS method; however, no alkamide was detected in this study (Mudge et al. 2011). In another study, five alkamides (**2**, **11**, **12**, **16**, **21**) were identified in *E. pallida* roots, with much less amount compared to *E. angustifolia* and *E. purpurea* root (Lalone et al. 2007).

Polyacetylenes and polyenes, which don't have the isobutyl amine substitution that is present in alkamides, are abundant in *E. pallida* roots (Pellati et al 2012).

Other *Echinacea* species: Analysis of alkamides in other *Echinacea* species, such as *E. simulata* and *E. paradoxa* (Bauer and Foster 1991); *E. atrorubens* (Dietz and Bauer 2001); and *E. simulata*, *E. sanguinea*, and *E. tennesseensis* (Lalone et al. 2007) have also been reported with much less diverse and less amount of alkamides than *E. angustifolia* and *E. purpurea*.

Alkamides in Different Plant Parts

HPLC and TLC analysis of root collections of *E. purpurea*, *E. angustifolia*, and *E. pallida* revealed that *E. purpurea* and *E. angustifolia* contain different structural types of alkamides, whereas *E. pallida* is almost devoid of alkamides. In contrast, the aerial parts of these three *Echinacea* species yielded very similar alkamide patterns (Bauer et al. 1988b).

Compared to the alkamide profiles of *Echinacea* roots, the commercial products show a more complex profile due to the blending of root and aerial parts of *E. purpurea*. In addition, the presence and levels of alkamides vary significantly between different root products (Mudge et al. 2011).

A HPLC analysis of alkamides in *E. atrorubens* aerial parts identified alkamides **4**, **5**, **11**, **24**, **25** while alkamides **4–6**, **11**, **12**, **14**, **20**, **22–25** were isolated in the roots of the same species (Dietz and Bauer 2001).

Polysaccharides and Glycoproteins

Polysaccharides and glycoproteins are complex structures that are difficult to identify, due to their high molecular weight and lack of a suitable chromophore for ultraviolet analysis. They are more difficult to purify and identify than alkamides or caffeic acid derivatives, which have small molecular weights. Hence the identification and quantification of polysaccharides and glycoproteins is far more difficult compared to caffeic acid derivatives or alkamides. Although polysaccharides and glycoproteins are determined to be immunostimulating constituents by various bioassays, they are not the best chemical markers for *Echinacea* species.

However, the content of crude polysaccharide can still be measured. The crude polysaccharide could be precipitated by adding ethanol to aqueous *Echinacea* extracts. The phenol–sulfuric method is typically used to determine the content of polysaccharides in *Echinacea* species (Glavač et al. 2012) by adding concentrated sulfuric acid to break down the polysaccharides to monosaccharides and using a UV spectrophotometer to detect and measure the absorption of light.

Though void of a suitable UV detectable chromophore, polysaccharides and glycoproteins can be analyzed by an evaporative light scattering detector (ELSD). An HPLC-ELSD method was developed to quantify these compounds in the raw *Echinacea* plant material (Bergeron and Gafner 2007). The results suggest the composition of polysaccharides differs among species of *Echinacea*, among plant parts of the same species, and among extracts based on the solvent used. Again, different results in some clinical trials could be explained by these differences.

There is no report about distribution of polysaccharides and glycoproteins in different species and plant parts determined by chemical analysis. However, Pillai et al. (2007) tested immunostimulant activity of *Echinacea* extracts prepared from different plant parts of *E. purpurea*, *E. pallida*, and *E. angustifolia* by flow cytometry using human blood cells. All plant parts tested (leaves, stems, flowering tops, and roots) produced substantial immunostimulatory activity. They identified that the main immunostimulatory activity of *Echinacea* resides in the water-soluble materials rather than the lipoidal small molecules. Polysaccharides and glycoproteins are some of the few water-soluble components that could be obtained from plant materials.

Safety Concerns

Echinacea is an herbal supplement used widely for prevention of common cold or influenza. The safety of herbal products made from *Echinacea* was reviewed by examining systematic literature searches of databases, spontaneous reporting programs of the WHO and national drug safety bodies, as well as data held on file from manufacturers of *Echinacea* (Huntley et al. 2005). The possible side effects, toxicity, frequency and type of adverse events, allergic reactions, and toxicology, together with contraindications and warnings of interactions and pregnancy and lactation were reviewed case by case based on clinical data reported before 2005 (Barnes et al. 2005). Despite some drug interaction concerns, the overall agreement is that *Echinacea* is one of the safest herbal medicines with few reports of adverse effects (Mills and Bone 2005; Freeman and Spelman 2008). Additional discussion of safety, allergic reactions, and drug herb interactions are discussed in the Research on *Echinacea* Use in Western Medicine chapter.

Conclusions

Extensive chemistry and biological studies revealed that alkamides, caffeic acid derivatives, polysaccharides, and glycoproteins are the active chemical constituents responsible for the pharmacological activities of *Echinacea*. Herbal products containing *Echinacea* differ considerably in their chemistry profiles from each other since multiple species are used, sources of plant material vary related to where they are grown and how they are handled, and preparation procedures are complicated and varied. So it is no surprise that different *Echinacea* products possess different chemical profiles. Phytochemistry studies and quality control are required to clarify the chemical constituents that produce the multiple biological activities that have been identified for the various *Echinacea* species. The identification of bioactive components supports the biological and clinical studies. Yet, more identification of active compounds is needed, especially identification of the polysaccharides, and more quality control and identification of the best preparations are needed to improve the health outcomes of people who consume *Echinacea* products. For mass marketed products of *Echinacea* species, there is no reason not to have and use materials that are standardized using modern chemistry lab practices.

Collecting roots for Rudy Bauer

Rudy Bauer has been the leading research on *Echinacea* species in Germany and Europe for many years. He has been involved, directly or indirectly, in the major chemistry discovery of new chemical compounds and properties, much of it in the 1970s and 1980s. He visited the University of Kansas once, and on short notice, I heard from the herbarium here that "this guy doing *Echinacea* research was coming through." It was great to meet him.

Later, he was interested in getting *Echinacea angustifolia* roots to look at variation within the species. Since here we are in Kansas—the famed, historical center of the *Echinacea* universe, so to speak—and I was brought into the project and gladly agreed to collect roots. I thought about where to collect. I thought I should go somewhere in western Kansas and get some grandmother roots from some gnarly bluff, from a plant that's super-stressed and surely would have the best roots ever. I also collected from the Flint Hills and from an area with deeper soil. I had a connection with a biodynamic grower, Terry Pitts, in central Kansas and got some roots from him, too. I took collections from five places, and they all were dried similarly.

We believe greater stress leads to more secondary compounds, more medicinal compounds, so you would expect those plants under the greatest stress to be the best. We sent off all the roots and got word back about the findings. To my surprise, the roots with the highest chemical content were

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from the biodynamically grown plants. Of course, those weren't just any commercially grown plants. Biodynamic farmers are highly attuned and give special attention to their soil, which you would think would make for better roots. My roots from that gnarly bluff were just middle-of-the-road.

It would have been interesting to compare several cultivated collections. There's no statistical power to the results that came back, but they were fascinating, kind of a wakeup call.

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Research on *Echinacea* Use in Western Medicine

Jeanne Drisko and Kelly Kindscher

Echinacea continues to be one of the most important and popular herbal products on the market (Blumenthal et al. 2012). It is known to have important medicinal compounds, including polysaccharides, alkamides, caffeic acid derivatives, and flavonoids (American Herbal Pharmacopoeia 2004, 2010a, 2010b, and see the Medicinal Chemistry chapter for more details). *Echinacea* species are generally viewed as safe to use, and although many questions remain as to its efficacy for colds, flu, and as an immune stimulant, recent clinical trials show positive benefits in its use as a treatment for upper respiratory tract infections, including the flu.

The popularity of medicinal plants has continued to increase over the past two decades as the result of several factors, including:

- Sharp increases in prices of prescription drugs
- Restrictive access to physicians
- Long-term use among some cultural groups
- Media reports of adverse effects of prescription drugs
- *Echinacea*'s popularity as a remedy for treating difficult ailments such as the common cold, menopause, and cancer
- The Dietary Supplement and Health Education Act (1994), which both validated herbal products and drew attention to the need for quality standards for botanical products

The Dietary Supplement Health and Education Act (DSHEA) is the primary law regulating dietary supplement products. Dietary supplements include botanical products intended for internal use. DSHEA was enacted in response to FDA actions that proposed for herbal products to be regulated in the same manner as statutorily

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defined drugs (Nutritional Labeling Education Act; Federal Register 1991). Prior to this, botanical products were considered a category of "foods" under the Code of Federal Regulations (CFR). DSHEA established the regulatory category of "dietary supplements" in recognition of their unique difference from conventional foods and pharmaceutical drugs. Among other provisions of the law, DSHEA allowed for FDA to require Good Manufacturing Practices (GMPs) that addressed the unique needs of supplement manufacturing, in addition to basic food GMPs, which were already required. In 2004, FDA released a Guidance Document of how botanical products could be approved as drugs. In 2006, the Dietary Supplement and Nonprescription Drug Consumer Protection Act was signed into law, requiring companies that market dietary supplements to maintain records and to file with FDA serious adverse event reports received regarding their dietary supplements. In 2007, dietary supplement GMPs were released and they reiterated the need for herbal dietary supplement products to be consistent, free from contamination and properly labeled. In addition, DSHEA provided further regulatory guidance regarding the inclusion of statements of nutritional support (including structure–function claims), which had historically been allowed on food products.

History of Medical Uses of *Echinacea*

Most of the early medical research on *Echinacea* has been conducted in Germany, where there is greater scientific interest in medicinal plants (Foster 1991; Foster and Tyler 1999). More than 800 products containing *E. purpurea*, and to a lesser extent *E. angustifolia*, have been 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 injection.

Echinacea species are native only to mid-latitude North America. The various species have 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 2015; Hobbs 1989; Foster 1991; Kindscher 1989; and the Uses of *Echinacea* Species chapter in this book).

Early scientific research on *Echinacea* started around 1950, and it usually incorporated more than one species, and apparently species under study were often misnamed or misidentified. 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 using *E. purpurea* (Schumacher and Friedberg 1991) (Fig. 1).

Fig. 1 Wild-harvested *Echinacea angustifolia* is often the preferred species that is used in herbal products (*Source*: Steven Foster)

Echinacea Effects on the Human Immune System

The majority of recent pharmacological studies on *Echinacea* confirm its immunostimulant activity. Most of the evidence comes from *in vitro* cell lines focused on innate immune systems including macrophage function, natural killer cell activity as well as anti-inflammatory responses commonly reported for a variety of *Echinacea*-derived preparations (Burger et al. 1997; Bauer 1998; Currier and Miller 2000, 2001; Currier et al. 2001). Evidence is also seen in experiments using animals (Rehman et al. 1999).

Immunological defense involves a complicated set of responses, but the overall objective is to increase beneficial cellular activity (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 h before exposure (Wacker and Hilbig 1978). The resistance lasted 24–48 h. The antiviral active ingredient could not be isolated and was believed to be related to several of the chemical fractions that were separated. Subsequently, a highly purified polysaccharide from *E. purpurea* was found effective against tumor cells and the human disease-causing microorganism, *Leishmania enriettii* (Luettig 1989).

This polysaccharide induced an immune response and, when injected, macrophages were stimulated, a finding that may have therapeutic implications in the defense against tumors and infectious disease (Wacker and Hilbig 1978).

Evidence also points to aqueous polysaccharide components having many immune boosting effects (Steinmuller et al. 1993; Elsasser-Beile et al. 1996; Burger et al. 1997; Bauer 1998). Also, some of *Echinacea's* important chemistry, a variety of compounds called caffeic acid derivatives, have been shown to stimulate immune boosting effects (Facino et al. 1995; DerMarderosian 1996; Bauer 1998). Overall, both of these compounds seem to be beneficial, and it is likely the synergism of these plant compounds create the milieu for increased immune response.

Currier and Miller (2000) provided evidence that *E. purpurea* root extract has an antitumor effect in aging mice. They state that the extract appeared to be the only immune-boosting agent identified to date that significantly increases natural-killer cell production and numbers in spleen and bone marrow of aging mice to levels present in young adulthood. This and other work they have conducted allowed them to conclude 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 (Currier and Miller 2001) (Fig. 2).

Investigation into targeted human immune responses to a commercially blended *Echinacea* product produced a gene expression response pattern that is consistent with *Echinacea's* reported ability to reduce both the duration and intensity of cold and flu symptoms (Randolph et al. 2003). Another study examined the immunomodulatory effect of isolated cichoric acid, polysaccharides, and alkylamides from *E. purpurea* on rat immune systems (Goel et al. 2002) and contrary to the majority of 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. Other studies reveal that two basic forms of alkylamide compounds present in *Echinacea* may have opposing effects (Matthias et al. 2007a). These opposing effects demonstrate the importance of the knowledge, not only of the

Fig. 2 Cultivated *Echinacea purpurea* is commonly used in herbal products, especially for those manufactured in Europe (*Source*: Steven Foster)

phytochemical makeup of the *Echinacea* preparation, but also of the actions of each component and the consequences of differing relative amounts in the preparation being investigated.

The dose levels of constituents from *E. purpurea* also appear to be an important influence in immune stimulation. Pharmacological studies indicate that a high oral dose (10 mg/kg daily) 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). The need for more information on dosage and timing persist to today.

The capacity for *Echinacea purpurea* to widely modulate the immune system in basic science research suggests other components must be involved in the reported pharmacological activity. Indeed, a number of other compounds have been implicated in immunostimulation, including polysaccharides, alkamides, flavonoids, and anthocyanins, suggesting a synergistic relationship between all or some of these constituents (Bauer 1998; Binns et al. 2002; Matthias et al. 2007b). Further confirmation of the synergistic relationship between compounds comes from recent trials where attempts to standardize *Echinacea* preparations with up to two or three different marker compounds (including the alkamides, cichoric acid, and polysaccharides) have shown success (Goel et al. 2004, 2005).

The general conclusion derived from the above studies is that no single *Echinacea* constituent appears to be responsible for the immunostimulant activity, but evidence seems to favor combinations of plant compounds. Both the lipophilic (those that dissolve in oil) constituents and the water soluble constituents have demonstrated immune-stimulating activity. In addition, there is still no decisive information favoring the use of one particular species or plant part. The most supportable conclusion is that certain *Echinacea* products may promote innate immune activation.

Promising areas for new research suggest addressing the immunomodulatory effect of *Echinacea* including both stimulatory effects as well as immune dampening effects needed to treat autoimmune disorders (Spelman et al. 2006; 2009a; Sharma et al. 2009). *Echinacea* research has also been directed to a much wider role than immune issues. Recent research suggests the possibility that *Echinacea* may be useful in type II diabetes and metabolic syndrome, although this remains very preliminary (Spelman et al. 2009b; Christensen et al. 2009).

Deficiency of Research and Well-Designed Controlled Human Trials

Few well-designed controlled studies have been performed to demonstrate the therapeutic value of *Echinacea* preparations, many of which resulted in lack of significance. In some of these trials, the lack of significance could be due to a lack of statistical power from too few enrolled participants.

As with many botanical medicines, and particularly in the case of *Echinacea*, there exists a wide array of medicinal preparations available for investigation (De Smet 2002). Most products in Europe contain the expressed juice of *E. purpurea* aerial parts or alcoholic tinctures of *E. purpurea* or *E. pallida* roots. In the United States, either dried whole plant products or tinctures from the roots are more commonly sold (Bauer 1998). As a result, there is considerable variability in the product used in the reported research (Tragni et al. 1988; Steinmuller et al. 1993; Burger et al. 1997). In older studies, the form of the *Echinacea* product and part of the plant is often not stated (Stahl et al. 1990; Lersch et al. 1992; Melchart et al. 1998). It is recognized that each species of *Echinacea* contains varying profiles of pharmacologically active principles and that, depending on whether the root, express juice or aerial parts of the plant are used, a variety of biological effects result (Turner 2002; Turner et al. 2005). The hallmark characteristic difference between *Echinacea* species is said to be the caffeic acid derivative echinacoside. It is present in *Echinacea angustifolia* and *E. pallida*, but not in *E. purpurea* (Dalby-Brown et al. 2005; American Herbal Pharmacopoeia 2004). However, standardization of the echinacoside content may be flawed since it represents only one possible biologically active molecule (Barrett et al. 1999). 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; Blumenthal 2010).

The most recent Cochrane Review included a total of 24 prevention and treatment trials (Karsch-Völk et al. 2014). As expected, there were a wide variety of *Echinacea* monopreparations (no other botanicals or active ingredients could be added for the studies to be included) and various preparations from different *Echinacea* species, with different plant parts, and in different forms were compared to placebo in the selected randomized trials. The review states that "the great heterogeneity of preparations tested makes conclusions difficult," and "the most important recommendation for consumers and clinicians is to be aware that the available *Echinacea* products differ greatly."

Testing *Echinacea* in Human Clinical Trials

Clinical trials are considered the gold standard in medicine. An herbal medicine may be reported as helpful, and may have some effect in a test tube, but until it is used in a controlled clinical trial, the proof is usually not considered sufficient. Systematic reviews of available clinical trials reveal inconsistent results for effectiveness when *Echinacea* is used as a preventive or treatment for upper respiratory tract infection (Barrett et al. 1999, 2010; Melchart et al. 1994; Giles et al. 2000; Percival 2000; Jawad et al. 2012; Tiralongo et al. 2012; Karsch-Völk et al. 2014). Ongoing issues associated with poor experimental design quality, small sample size, lack of defined bioactive *Echinacea* preparations, and insufficient evidence as to the appropriate dosage and optimal time of medication has precluded clear recommendations for the use of *Echinacea* for upper respiratory tract infections.

Some clinical studies have reported that *Echinacea* reduces the symptoms and severity of upper respiratory tract infections and shortens the duration of illness compared with placebo (Lindenmuth and Lindenmuth 2000; Karsch-Völk et al. 2014; Tiralongo et al. 2012). Other clinical trials have found no significant effect of chemically defined *Echinacea angustifolia* root preparations consisting of polysaccharides, alkamides, and caffeic acid derivatives on experimental or acquired upper respiratory tract infection (Turner et al. 2000, 2005; Barrett et al. 2010).

Passing on the Gift of *pejuta-ska*

I went back to the Rosebud quite a few summers. I'd go up and ask about *Echinacea* and many other plants, and I would feel honored that people would share information about the plants and how they were used, because there had been too many instances in which academics who were full of themselves had come up and asked questions. There was an understandable irritation with anthropologists, people coming up to study the Lakota people.

There was only so much information that community members could offer about medicinal plants; it wasn't as if everyone was always talking about them. I appreciated their help.

My friend Alex Little Soldier, who had been my mentor on the Rosebud, was in later years, in failing health and eventually died of a heart attack. One day sometime later I was in my office at KU and the phone rang, and it was his son Algo—a nickname, for Alex Jr. He asked, could you show me the *pejuta-ska*? I need to make some kidney medicine. He wasn't familiar with the plant, and I hadn't known him to have made medicine before. He was a little older by then, though, and this was on his mind. I hadn't spoken to him in two or three years. By chance, I was headed to Montana to monitor *Echinacea* in the next two weeks, and the Rosebud reservation is on the way.

It was the middle of summer. Algo and I went to same place his father had taken me the first time to find the jingle bell plant. We found it and dug some root, and I showed him what I knew about it: how you recognize the plant, how the roots are boiled for tea. This is how people learn about plants, one person sharing with another—and it was my greatest honor to be able to help, in some sense, keep the use of this medicinal plant alive in that family and community. It felt like knowledge had been repatriated.

One well-executed 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 the study drug containing *Echinacea* was not in the active form.

In 2010, Bruce Barrett, M.D. at the University of Wisconsin, published a study of 719 citizens in Madison, Wisconsin with common cold symptoms who were placed into four trial groups where two of the groups were given a proprietary *Echinacea* formulation (one of *E. purpurea* and one of *E. angustifolia* dried roots, respectively). The trial results did not show a statistically significant benefit for the *Echinacea* product, even though there was a trend toward a benefit in reduction of symptoms and duration of symptoms (Barrett et al. 2010). Also in 2012, new research on *Echinacea* appears to show some benefit to long-haul air travelers in avoiding respiratory illness. When Australian air travelers who were traveling at least a week oversees were given a formulated and standardized *E. purpurea* and *E. angustifolia* root tablet product before, during, and after travel, they reported significantly fewer respiratory symptoms during their period of travel (Tiralongo et al. 2012).

And in 2012 the largest clinical trial ever conducted using *Echinacea* (755 healthy people) indicated that an alcoholic extract of organic *Echinacea purpurea* leaves and roots prevents cold symptoms (Jawad et al. 2012). Using a Swiss *Echinacea* extract, British researchers instructed patients to take the product for a month and gave them a specific dosage regimen to follow. The subjects who followed the regimen had significantly fewer incidents of cold or flu symptoms than those who took a placebo, and had to rely less on over-the-counter medications such as acetaminophen or ibuprofen, which are frequently used by the public to reduce cold symptoms. In addition, patients who consumed *Echinacea* also had a decreased recurrence of cold symptoms and less influenza-type viral infections, which were measured through the use of nasal swab kits. And finally, safety was also tested and there was no statistical difference in adverse drug reactions, with there actually being fewer in the group that took the medication.

Cochrane Reviews (Linde et al. 2006; Karsch-Völk et al. 2014) sum up the reasons for lack of consistent *Echinacea* clinical trial findings. These reasons, similar to those in other trials discussed above, include different *Echinacea* species selected (*E. purpurea*, *E. pallida*, *E. angustifolia*), different plant parts used (root, herb, flower, or whole plant), differing extraction methods resulting in a variety of components in the study drug, and the addition of other plant components or homeopathy to the preparations. While some studies have shown beneficial effects following the use of *Echinacea* (Brinkeborn et al. 1999; Spasov et al. 2004), variation in patient sample size, dosage administered, and treatment period all contribute to a lack of consensus and precludes effective comparisons between these studies

(Lindenmuth and Lindenmuth 2000; Yale and Liu 2004). At this time, the Cochrane Review (Linde et al. 2006; Karsch-Völk et al. 2014) shows evidence that preparations based on the aerial parts of *Echinacea purpurea* might be effective for the treatment of colds in adults, while beneficial effects and preventive uses of other *Echinacea* preparations may exist but have not been shown in replicated rigorous randomized trials.

Evidence for Safety

In 1989, the German Commission E published the official German monograph on the use of the fresh juice of the aboveground plant parts of *E. purpurea* (Blumenthal 1998).

Overall indications are that *Echinacea* is relatively nontoxic, given:

- Its long history of safe use by North American indigenous groups
- Its widespread use as a phytomedicine in Europe
- Its use as a food, tea, and dietary supplement additive
- Recent scientific data

Multiple studies have been conducted in rat and mouse models 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). There was no evidence for mutagenicity when tested against microorganisms and mammalian cells *in vitro* and in animal models (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 animals 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 doses or concentrations.

Currently, the German drug regulatory authority recommends that *Echinacea* not be used for periods longer than 8 weeks (Linde et al. 2006). Work in healthy individuals indicates that a period of initial stimulation (typically 1-7 days) could be followed by a period (typically after about 11 days) when the immune system no longer responds (Bauer and Wagner 1991). Accordingly, *Echinacea* is often prescribed as a short-term treatment followed by a period of no administration, although no definitive research has been done to support this schedule.

While *Echinacea* is considered to be one of the safest medicinal plants with few reported adverse effects, it is particularly notable that less than 100 serious adverse events have been reported for over 10 million courses of treatment, leaving the risk estimate of less than 1 in 100,000 (Barrett 2003). Rarely, some individuals may experience immediate allergic reactions with varying degrees of severity, particularly with intravenous injections of *Echinacea*. Allergic reactions are not uncommon with species in this plant family, Asteraceae, which also includes ragweed. The United Kingdom's Medicines and Healthcare Products Regulatory Agency advised parents in 2012 to not give children under age 12 *Echinacea* products and also required manufacturers to re-label their products due to potential allergic reactions (Mader 2012). The most recent Cochrane Review advised that children should not take *Echinacea* preparations secondary to lack of scientific findings for either effectiveness or safety (Karsch-Völk et al. 2014). When administered intravenously, dose-dependent chills, self-limited febrile reactions, and nausea and vomiting may occur. And in some medical editorial reports, an increase in temperature associated with IV administration is cited without reference to which *Echinacea* species, plant part used, product form used, route of IV administration, or primary source literature cited.

One report noted that drug–herb interactions related to *Echinacea* products were cited in some 49 articles, but only 8 of these 49 papers contained primary data relevant to interactions between *Echinacea* products and pharmaceuticals (Freeman and Spelman 2008). Two of the cited studies were clinical trials and the remaining were in vitro assays, three of which did not contain complete information about the concentration of extract used and only half of the studies verified the authenticity of the *Echinacea* species. The authors concluded that of the published scientific papers on *Echinacea* most of the papers were reviews. In other words, the same information from a few studies get cited frequently creating the impression of abundant evidence contrary to reality.

In a recent publication, Ardjomand-Woelkart and Bauer (2015) noted that due to long-term published studies of different *Echinacea* preparations, used for up to 6 months with no reported toxicological concerns, *Echinacea* can be recommended for long-term use. Also the contraindications in cases of autoimmune diseases and immune-suppression are questionable, since lipophilic *Echinacea* preparations containing alkamides suppress cellular immune responses, and beneficial effects in autoimmunity were reported. Altogether, the different *Echinacea* preparations that have been evaluated are well-tolerated herbal medicines for both children and adults (Ardjomand-Woelkart and Bauer 2015).

Herb and Drug Interactions

Available data on the metabolic influence of *Echinacea* spp. and the alkylamides focus predominantly on the alkylamides known to be responsible for drug interactions such as the associated with cytochrome p450 enzymes and especially the CYP1, CYP2, and CYP3 families (Toselli et al. 2009; Matthias et al. 2005, 2007a, 2007b; Woelkart et al. 2005, 2008) which are known to facilitate the body's use or metabolism of drugs. Three different reviews conclude that *Echinacea* supplements pose minimal risks for interacting with most conventional medications (Freeman and Spelman 2008; Gurley et al. 2012; Toselli et al. 2009). Studies show *E. purpurea* herb and root may minimally inhibit CYP1A2. Patients taking drugs by

CYP1A2 such as theophylline and clozapine should avoid taking them with *E. purpurea*. There appears to be no clinically significant interactions between *E. purpurea* and substrates of CYP2D6, CYP2C19, and CYP2E1. There is not enough information at this time to conclude if there is interaction with CYP2C9. Human studies have shown *E. purpurea* root extracts influence CYP3A4 but found no significant changes in the metabolism of midazolam, a 3A4 substrate, after participants ingested 1600 mg of *E. purpurea* root daily for 8 days (Gorski et al. 2004). However, there appears to be some negative interactions (Molto et al. 2012; Bossaer and Odle 2012) between *Echinacea* and anti-HIV drugs, and specifically Etoposide which uses the CYP3A4 substrate. And finally, using *E. purpurea* whole plant extract (aerial and root combined) in a human trial found no statistically significant differences in 3A4 phenotypic ratios (Gurley et al. 2004, 2012).

It can be concluded from the above reports that *Echinacea* is relatively safe at recommended administered doses. 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 nontoxic. Some individuals may experience rare immediate allergic reactions of varying degrees of severity, particularly with intravenous use of the substance, but this is a very small number considering the millions of doses that have been taken. Despite varying clinical results, and clear-cut evidence of efficacy, the apparent lack of adverse effects suggest that the lay use of *Echinacea* is probably harmless and should not be discouraged (Giles et al. 2000).

Limitations in Interpreting Research

An obstacle to a systematic approach to the study of *Echinacea* is that neither its active components nor the mechanisms of action for treatment of infections have been completely identified or defined. Several constituents of *Echinacea* have been evaluated and shown to have various biological activities with some being quite promising. Until 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 has been difficult for researchers to generalize the results of an individual study beyond the specific conditions under which the study was conducted (Turner 2002).

Testing for Identity, Purity, Strength, and Composition

In the past, intentional adulteration of herbal products was a concern. Reports of *Parthenium integrifolium* as an adulterant in wild-harvested *Echinacea* products have been noted (Hobbs 1989; Foster 1991; Bauer 1998). Though *Parthenium*

Fig. 3 *Echinacea pallida* is only occasionally used in herbal product formulations (*Source*: Steven Foster)

integrifolium is not similar in appearance to *Echinacea* species in the field, once the root is cut and sifted, it has an uncanny resemblance to *E. angustifolia* or *E. pallida* roots, though it possesses a characteristic different 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 integrifolium* in geographic distribution and are the most likely to be contaminated. Today, a multitude of macroscopic, microscopic, and chemical methods are used by manufacturers to differentiate *Echinacea* species and to check for potential adulterants (American Herbal Pharmacopoeia 2004, 2010a, 2010b). Manufacturers usually rely on in-house laboratories that are equipped with an array of analytical equipment and staff skilled in performing complex analyses on a wide range of ingredients. Analytical techniques used for testing raw material and finished products include: high performance liquid chromatography (HPLC), thin-layer chromatography (TLC), gas chromatography (GC), Fourier transform infrared spectroscopy (FT-IR), and mass spectrometry (MS) (Fig. 3).

Conclusions and Suggestions for Further Study

Echinacea shows promise for treating upper respiratory tract infections, and generally modulating the immune system for a wide array of health benefits. The identification of species and the chemistry are now well documented and the materials used in medicine can be known and standardized. There are now quality products on the market that can be trusted and safely used. Pharmacological investigations over the past 25 years have shown immunostimulatory activities for cichoric acid, alkamides, and polysaccharides extracts of the roots and aboveground parts of *E. purpurea*. The clinical trials have been mixed, but some of the most recent trials have shown *Echinacea* to be very useful in treating and preventing upper respiratory tract infections, and have perhaps set the stage for even more interesting research on the positive benefits of *Echinacea*.

There are several research questions that need further study. They include:

- Determining what specifically are the active compounds and how do they work alone and in combination
- Determining which is the most appropriate species and plant part to use in preparations
- Determining the most appropriate dosage and the length of time that the medication should be administered
- Deciding if there should be a maximum length of time for taking *Echinacea* products
- Determining the extent of the allergic reaction in some users and find ways to protect against such reactions; investigate any other side effects from *Echinacea* products

Answering these questions will help establish *Echinacea* as a valuable medicine for the public.

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The *Echinacea* Market

Maggie Riggs and Kelly Kindscher

Echinacea has been one of the most important medicinal herbs in the USA and international marketplace, used and revered by Native Americans for thousands of years, but we still are not sure exactly how it works. As for the most beneficial uses of this plant, we are still in the discovery stage. Is *Echinacea* a booster for other herbs, pharmaceuticals, and vaccines as well as our own immune systems? Is this plant efficacious as part of the protocol for upper respiratory infection and if so, which parts. How do the polysaccharides work and are they best extracted in water such as tea?

Even without definitive answers to many of these questions, people discover *Echinacea* products and continue to use them, making it one of the top ten herbs sold in 2013 (Blumenthal et al 2012). Overall herbal product sales, which include several *Echinacea* products, have continued to increase almost every year during the last 20 years (Soller et al. 2012), and by 2011 annual sales of *Echinacea* products grossed $16.6 million (Blumenthal et al. 2012).

Quantifying the Harvest

In an attempt to quantify the amount of wild medicinal plants harvested for commerce, the American Herbal Products Association conducted five tonnage surveys of regional buyers (American Herbal Products Association 2000, 2003, 2007, 2012). These are the people and businesses that purchase roots and herb directly from numerous wild crafters. Then they sell them in large quantities to companies

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that distribute bulk raw herbs to manufacturers of various product lines. Although this data may not be scientifically accurate, it is the best indicator we have of the quantity of *Echinacea* harvested. A summary of this recent data is in Table 1.

Even as the market for *Echinacea* products continues to grow, there are decided shifts in consumer preferences. These fluctuations represent preferences for the root of the wild harvested plant, then the root from cultivated plants, then herb from cultivated, then back to wild harvested roots for some things (see Table 1). These shifts can play havoc for the growers who may have a reduced price or even no market when their crop is ready to harvest.

Historically, only the wild harvested roots were in commerce. Over the last 30 years, cultivated *E. purpurea* tops are commonly in the market, along with other cultivated products. An example of the shift in preference from wild harvested to cultivated *Echinacea angustifolia* root, beginning about 1992 and peaking in 1999. Concern grew that wild *E. angustifolia* stands were being over-harvested, endangering the future of wild populations. By 1998, fears were confirmed; the harvest totals of wild *E. angustifolia* root had skyrocketed 400–500 % to 226,372 lb (Table 1).

During the same period, an education campaign was mounted asking consumer to request and look for products made from cultivated *E. angustifolia* roots to lessen the pressure on the wild stands. Manufacturers and retailers were educated as well. A few farmers in Kansas saw an opportunity and began cultivating *E. angustifolia* using irrigation with no certainty that cultivated roots would produce the same constituent levels that the native plants produced. And there was the reality that it would be three years before their roots were large enough to be harvested. Still, several gave it a try, beginning around 1995. Both 1998 and 1999 were record harvest years for the cultivated *E. angustifolia* root, as over 300,000 lb were sold, while the trade in wild roots dropped 80 % in 1999. Unfortunately for the growers, the huge harvests of cultivated root in 1998–1999 inadvertently saturated the market and it took several years for the market to adjust. Then European manufacturers discovered that cultivated *E. angustifolia* roots tested much lower for desired secondary compounds than wild ones (Steven Foster, pers. comm., September 2002) and demand for wild roots began to increase again.

Surplus cyclically affects the bulk market for raw *Echinacea*, and also effects the decisions being made: roots or herb, *E. purpurea* or *E. angustifolia*. During the years 1997–2003, the bulk market for cultivated *E. purpurea* herb reached its peak in 1997–1999 (Table 1), then falling off drastically for several years. The same is true for cultivated *E. angustifolia*. After bumper years in 1998–1999, markets dropped off by 85 % and gradually built back up. In the case of cultivated *E. angustifolia*, the market is even more vulnerable because the 3-year lag time between demand (when someone might plant) and harvest allows for unanticipated surpluses when the producer is ready to sell. The boom and bust trend for supply and prices is not new, in our 120 Years of *Echinacea* Harvest chapter we have documented this cyclical trend for 120 years.

Table 1 Dried *Echinacea* traded by regional buyers (in pounds), 1997–2010

	E. angustifolia				*E. pallida*				*E. purpurea*			
	Root		Herb		Root		Herb		Root		Herb	
	Cultivated	Wild	Cultivated	Wild	Cultivated	Wild	Cultivated	Wild	Cultivated	Wild	Cultivated	Wild
1997	54,644	0	18,388	5000	18,350	0	0	0	163,428	0	1,088,144	0
1998	104,858	226,372	45,756	3034	45,896	11,200	0	0	338,914	0	2,538,872	67,200
1999	219,211	49,984	24,108	0	3100	0	0	0	390,066	0	1,591,922	0
2000	36,081	9337	11,167	1300	0	11,000	0	0	53,291	2545	398,382	0
2001	38,778	33,554	7000	2000	0	14,092	0	0	50,156	0	8634	0
2002	40,396	37,980	9280	600	2500	32,849	0	0	76,104	3583	303,973	0
2003	46,210	64,594	9500	6636	0	15,355	0	50	85,513	5080	258,583	50
2004	90,469	8512	23,322	1100	45	2252	0	0	275,412	0	936,900	0
2005	38,169	20,152	11,986	2100	61	30	2850	0	22,908	1000	242,844	102,340
2006	65,289	36,061	24,062	1235	0	1223	0	550	165,270	0	136,546	0
2007	20,942	32,143	8597	3305	11	2276	0	2147	35,122	1000	151,411	0
2008	46,174	26,891	26,480	568	2000	0	2012	0	87,263	80	89,098	0
2009	95,717	24,558	42,492	5997	2661	0	0	0	78,865	276	170,492	15,000
2010	96,735	47,615	0	3599	956	0	0	0	188,748	3616	212,370	0

Source: American Herbal Products Association (2000, 2003, 2007, 2012)

Market Fluctuations for Raw Materials

Because we know less for certain about *Echinacea* than many other herbs in the marketplace, new research findings can and will play an important part in growing for the *Echinacea* market. *Echinacea* has a complicated chemistry and throughout the recent resurgence of botanical medicine, there is much debate over possible advantages of root over foliage, *E. angustifolia* over *E. purpurea*, wild-crafted or cultivated, fresh or dried, tincture or tea, echinacosides or polysaccharides. More specific protocols for using *Echinacea* as medicine could launch another market preference for one species over another. As *Echinacea* research trials proceed, evidence is emerging that treatment with specific forms of *Echinacea* reveals different mechanisms and results (Brinker 2013) which could launch another market shift for one species over another (Fig. 1).

Market Price for Wild-Crafted *Echinacea* Roots

It is hard to predict the future market price for wild harvested roots, but certainly it is affected by the quantity and quality of the roots collected throughout the country. For example, in 1998, the price paid for a pound of dried *E. angustifolia* varied between US $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 many *E. angustifolia* roots are extracted from native stands annually. Since roots are not uniform size, only a calculated guess can correlate pounds harvested to number of plants. For roots that we harvested as we were taught by Kansas diggers, we calculated that 112 roots would make one pound, dry weight (see Fig. 2 in the 120 Years of Harvest chapter for an example of the number of roots per weight class in a harvest).

Fig. 1 Many *Echinacea* products are on the market. Here is an *Echinacea* salve from the German company Madaus (*Source*: Steven Foster)

Fig. 2 *Echinacea purpurea* roots being harvested for market (*Source*: Steven Foster)

The Retail Market

Additionally, there is a robust market for herbalists and gardeners who compound their own *Echinacea* products and market them directly to the public at festivals, farmers markets, and on the Internet. Table 2 lists *Echinacea* products available locally in a typical college town, five of which are local companies that have found niche markets for their herbal products. One can glean a wealth of information at farmers markets or by visiting with local herbalists and naturopaths and employees in wellness sections of food coops and natural product stores.

For those who want to retail their *Echinacea* products nationally, there are just a few natural products distributors such as Tree of Life, United Foods, and Whole Foods who will deliver your products to stores regionally or nation-wide but the competition can be stiff to fill the *Echinacea* slots in their warehouse. The Internet also is a vehicle for sales, but it requires time and products to stores regionally or nation-wide but the competition can be stiff to fill the *Echinacea* slots in their warehouse. All *Echinacea* product makers need to budget a substantial amount for advertising in their ordering catalogues or online web pages and plan to participate in some natural product trade shows (such as unbelievably large, Expo West, held each March in Anaheim, California), which are also expensive, several thousand dollars each. Brand recognition on a national scale takes time and dedication to establish and the cost is often prohibitive for small compounders.

Table 2 *Echinacea* products on the market in 2013

Brand	Species	Plant part	Product type
Blessed Thistle Farm	*Echinacea purpurea*	Aerial	Liquid drops
Crystal Star	*E. angustifolia, purpurea*	Root	Capsule
Dr. Dunner	*Not specified*	Whole plant	Syrup
Enerhealth	*Not specified*	Root/flower	Liquid drops
Esberitox	*E. purpurea, pallida*	Root	Chewable
Finest Nutrition	*E. purpurea*	Whole plant/root	Tablet
Frontier	*E. purpurea*	Root	Dried Bulk
Frontier	*E. purpurea*	Herb	Dried Bulk
Future Biotics	*E. angustifolia, purpurea*	Root/leaf/stem	Capsule
Gaia	*E. purpurea, angustifolia*	Root/seed/aerial	Capsule
Gaia	*E. purpurea, angustifolia*	Root/seed/aerial, root	Liquid drops
Gaia	*E. purpurea, angustifolia*	Root/stem/aerial, root	Throat spray
Generic	*E. angustifolia*	Root	Capsule
Generic	*E. purpurea*	Whole plant	Capsule
Herb Pharm	*E. purpurea*	Root/stem/leaf/flower	Capsule
Herbpharm	*E. purpurea*	Root/stem/leaf/flower	Liquid drops
Herbs etc.	*E. angustifolia*	Root	Liquid drops
Irwin Naturals	*E. purpurea*	Root	Softgel
Natural Factors	*E. purpurea*	Root/aerial	Softgel
Nature's Answer	*E. purpurea, angustifolia*	Root/aerial, root	Liquid drops
Nature's Way	*E. purpurea*	Stem/leaf/flower	Juice, Capsule
Nature's Way	*E. purpurea, angustifolia*	Stem/leaf/flower, root	Capsule
Nature's Way	*E. purpurea*	Stem/leaf/flower	Liquid drops
Nature's Way	*E. purpurea*	Stem/leaf/flower	Lozenge
Nature's Way	*E. angustifolia, purpurea*	Root, flower	Syrup
Now	*E. purpurea*	Root	Capsule
NOW	*E. purpurea*	Root	Liquid drops
NOW	*E. purpurea*	Root	Syrup
Oregon's Wild Harvest	*E. purpurea, angustifolia*	Tops/root, root	Capsule
Quantum Health	*E. angustifolia*	Root	Capsule
Quantum Health	*E. purpurea*	Whole plant	Tablet
Solaray	*E. purpurea*	Aerial	Capsule

(continued)

Table 2 (continued)

Brand	Species	Plant part	Product type
Solaray	*E. purpurea, angustifolia*	Root	Capsule
Solaray	*E. angustifolia*	Root	Capsule
Source Naturals	*E. purpurea*	Root	Fizz tablet
Source Naturals	*E. purpurea, pallida*	Root	Tablet
Super Lysine	*E. purpurea*	Not specified	Liquid drops
Teeter Creek	*E. purpurea*	Root/flower	Liquid drops
Urban Moonshine	*Not specified*	Root/leaf/flower	Liquid drops
Wish Garden	*Not specified*	Root	Liquid drops
Zand	*E. angustifolia, purpurea*	Root, herb	Liquid drops

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 February 15, 2013, by Schuyler Kraus, University of Kansas

Media Coverage and Its Effect on Consumer Use of Herbal Products

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 in the market. Blumenthal (1998) noted 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."

Since the majority of consumers using botanicals are self-medicating (Ambrose and Samuels 2004; Perkin et al. 2002; Kuo et al. 2004), what they read in the popular press has a significant influence on their herbal buying habits. Segments on prime-time television shows like 20/20 and daytime talk radio shows inform these consumers, along with magazine and other print sources. Unfortunately, journalists, rather than scientists or medical professionals, write much of what the consumer reads. Rowena K. Richter (2003), in her book, *Herbal Medicine*: *Chaos in the Marketplace*, wrote: "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." For more discussion of this topic, see our chapter titled: The Media and *Echinacea* Sales and Use.

Much of the popular literature on herbal treatments promotes health 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 effective.

Echinacea has received some fantastic publicity in the media. The best example is Time Magazine's cover on November 23, 1998, featuring a beautiful *E. purpurea* flower with the words "The Herbal Medicine Boom." That year the market for wild harvested *E. angustifolia* root skyrocketed hitting an all-time record high. 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* had consistently led herbal sales since the 1990s, it was not until 2003 that it became the subject of clinical trials funded by the National Institutes of Health (Richter 2003). These results from these trials, and other studies, are reported in the Uses of *Echinacea* in Western Medicine chapter. It is important to stay informed about any ongoing or planned research or clinical trials involving any *Echinacea* species. Positive results, such as have occurred in two 2012 studies (Jawad et al. 2012; Tiralongo et al. 2012), could lead to increased demand and price for producers. And there has been considerable research funded by NIH, including the Center for Dietary Supplements Research at the University of California, Los Angeles, which received NIH support to conduct pilot research on specific immune-enhancing actions of *Echinacea*. And Iowa State University received a multi-year, NIH-funded grant to establish a botanical center to study both *Echinacea* and St. John's wort. Unfortunately, these NIH centers have seldom produced significant results of any type for the public about herbal product use.

Potential Effects of Medical Insurance Coverage of Herbal Products

Another consideration related to the future market is the increasing interest of insurance companies and managed-care organizations in reimbursing the cost of herbal product use. 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 health insurance costs are at record highs, the lower-cost botanical treatment alternative may become increasingly 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 increase significantly.

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).

It was consumers demand for the legal right to unrestricted use of botanicals that shaped the Dietary Supplement Health and Education Act (1994) (also just called

DSHEA) which codified that right. That same political force may drive major insurance companies to provide coverage for Naturopathic and Homeopathic consultations and the botanical products they prescribe.

Social Media and the Impact on Marketing *Echinacea* Products

Is social media posed to be our most effective means of dissemination of positive research results? At this point one must at least speculate about the potential impacts of social media info sharing. What if peer reviewed double-blind controlled research concluded flu shots taken with a protocol of *Echinacea* were 25 % more effective than the control taken without *Echinacea*. What if this was broadcast on social media during a horrible flu season? How might that effect sales?

The International Marketplace

Herbal product use continues to be important worldwide as they are used for primary heath in many countries and some like *Echinacea* are marketed internally as an important medicinal plant. And medicinal plants are important in Canada and Europe. The World Health Organization (2003) predicted 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. In a European Advisory Services survey for the European Union in 2007, *Echinacea* was recognized as one of the top four most important herbal products in Europe (Vargas-Murga et al. 2011), and may have been second only to gingko in its use. And with this market, there has been a considerable history of *Echinacea purpurea* production in Europe, and imports of US wild-crafted *E. angustifolia*.

One can easily find products on the Internet from China, India, and Taiwan. And Taiwan's Research and Extension Stations are exploring growing organic *Echinacea* for use in boosting the immune system, fighting viruses, and aid in wound-healing and its promoting it for use in extracts, health supplements, and drinks. One researcher, cited in November 27, 2014 publication *Taiwan Today*, who is overseeing the research station's development project has captured the excitement of the opportunity that *Echinacea* continues to offer, stating "There is a huge global market out there worth roughly US $1 billion." For all of these reasons, *Echinacea* is grown worldwide and there are markets for its production. The international markets also fluctuate, but they are very responsive to the demand, and if there is even greater demand in the USA or Europe, or Asia, growers in China, India, or Taiwan will also have products to sell.

Conclusion

It is clear that the market for *Echinacea* has generally been strong and it has a bright future. Research results, which are often positive, and publicity will continue to shape the market, but efficacy for the consumer will still be the most important aspect for its use and continued herbal market share. Because of the long and safe history of *Echinacea* use, because there is a strong herbal product industry that considers *Echinacea* as an important product, and because there is considerably wild harvest and cultivation, it is hard to imagine a future that does not include the marketing of *Echinacea* species.

Plant Population Resilience

Echinacea plants are long-lived, grow slowly and have deep roots, and flower easily. All of this protects them in the face of overharvest. Most mature plants flower in a good year and produce a lot of seeds; each cone can have 100 to 200 seeds, and there can be several flowers on one plant.

It takes two or three years to see recovery after *Echinacea* root has been harvested. Each harvested site I've seen has flowering plants, in addition to resprouting roots. It's hard to determine the origin of the flowering plants. Likely they were young plants that just weren't harvested—or a plant that was missed, because not all the plants bloom each year.

We know from the data we've collected that not every plant that's harvested resprouts the first year. Some resprouted the second year. So, with reseeding and staggered resprouting, there are mechanisms that keep a population going even if you have pretty severe harvest. Dana Price and I spent a number of years on research projects tracking resprout rates of specific *Echinacea* populations; what we don't know about the damaged sites we've visited is what the *Echinacea* population was before the overharvest.

Still, I'm optimistic that plants could come back from a harvest, though we don't know to what extent that would be if there is extensive harvest year after year. It's possible that you could eliminate a population if only half the plants resprouted and there was harvest every year. The young seedlings, at some point, would sprout and come up, but with continuous harvest, the stand could be wiped out.

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The Media and *Echinacea* Sales and Use

Rachel Craft and Kelly Kindscher

In order to understand the media's impact on *Echinacea*'s sales and use, we looked at how the print media shapes the dialogue about its safety and efficacy. When analyzing how print media, specifically newspaper articles in major newspaper markets, portray *Echinacea*, we found that negative reporting, essentially stating that *Echinacea* does not work, was more prevalent and remained in the press longer than positive news uncovering the efficacy of *Echinacea*. If the negative information was first reported in a prestigious medical journal such as the *Journal of the American Medical Association* or *The New England Journal of Medicine*, then it is likely to be referenced and discussed in many other publications, keeping it in circulation longer. Reasons for this media bias reflect sensationalism, professional ethics in journalism, and a bias toward pharmaceutical medicine with quantifiable doses and specific outcomes.

Echinacea hovers on the cusp of being taken seriously by the medical establishment. But the tone of the articles we reviewed, across the board, positive and negative, was that *Echinacea* is novel and efficacy is questionable. Despite the importance that Plains Indians and early American colonialists attributed to *Echinacea's* medicinal efficacy (Kindscher 1989), our ideas about medicine and our perceptions of the safety and efficacy of medicinal plants have changed over time. The idea of taking a whole plant, such as *Echinacea*, as a tea, with varying degrees of myriad compounds swirling around in your cup, and somehow quantifying the positive effects, such as subsiding physical symptoms and reduced duration of the flu, is novel but not really part of the current dominant medical paradigm.

However, the proof of efficacy handed down from hundreds of generations of Plains Indians was based on a different system, one of wholeness. The idea of

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separating one constituent out, like the echinacosides which have a numbing effect, doesn't make sense from a holistic perspective because the plant also has antimicrobial and immune boosting properties. Yet the concept of using all the compounds that are drawn from the plant when making a tea or tincture has no parallel in pharmaceutical medicine. Without an understanding of the cultural context that awarded *Echinacea* its most revered status, the print media sources we analyzed are likely to predispose the reader with superficial accounts of inconclusive clinical trials and negative accounts of novel *Echinacea* therapies. For instance, conflicting perspectives are found in leading newspapers in the USA:

> According to a recent review of research, *Echinacea*, an immune-system stimulant, can help reduce the duration and lessen the symptoms of a cold. A number of studies have found that the supplement, if taken within a few hours after the onset of a cold, can shorten the misery by one or two days and ease symptoms by 10 % to 40 %.
>
> Daily News (2004) (New York).

> Shots of hooey. The flu vaccine scarcity has inspired sales pitches for nostrums from *Echinacea* to "systemic enzyme therapy" as stand-ins for the shot. All bunk, according to Adriane Fugh-Berman, an alternative medicine expert and associate professor at Georgetown University's School of Medicine. "There's no evidence that any alternative medicine prevents flu, and no reliable evidence that alternative therapies are effective treatments," Fugh-Berman wrote in response to an e-mail query.
>
> Washington Post (2004).

> US consumers have been abandoning *Echinacea* in recent years. Sales of products derived from the herb fell more than 16 % in 2006, according to the Nutrition Business Journal. But the science suggests that *Echinacea*—in the right form—may be one of the more promising alternative cold remedies on the market. Last summer, an analysis in the journal Lancet Infectious Disease showed that in well-designed studies, *Echinacea purpurea* shortened colds by an average of 1.4 days and reduced the odds of getting a cold by 58 %.
>
> Los Angeles Times (2008).

And in a subset of articles, extreme prejudice against herbal remedies was broadcast but not substantiated by evidence, such as the following L.A. Times article:

> The formulations for herbal supplements—or botanicals, as they are correctly called—such as St. John's wort and *Echinacea* are often complex, highly variable and impure. Not very different from the 19th century snake-oil preparations that were dangerous but minimally (if at all) effective, many are toxic, carcinogenic or otherwise dangerous. Known side effects include blood-clotting abnormalities, high blood pressure, life-threatening allergic reactions, abnormal heart rhythms, exacerbation of auto-immune diseases and interference with life-saving prescription drugs.
>
> Los Angeles Times (2009).

In most cases, the reporting does not disclose the variations in research methods or design that could impact the conclusions, perhaps leaving the public under-or misinformed. For example, when it comes to herbal use data, the National Health Interview Survey (NHIS) documented that the use of *Echinacea* dropped from 40.3 % of US adults natural products users in 2002 to only 19.8 % of US adult natural product users in 2007 (Barnes et al. 2004; Barnes et al. 2008). While this may seem to indicate a precipitous decline in use, it more likely reflects that the measurement of use was changed from once in the past 12 months (2002 survey) to once in the past 30 days (2007 survey). While disclosed in the 2002 and 2007 survey reports, this difference in measurement periods is not indicated in the 2012 survey press release where the use of *Echinacea* is shown as declining in use by over 50 % during each survey period (2002–2007 and 2007–2012) (National Institutes for Health 2015). Since *Echinacea* is often used only during cold and flu season and there is no indication of when in the year the NHIS was administered, the NHIS may not have captured much of the *Echinacea* use in 2007 and 2012.

The US government, scientific research, and medical professionals largely determine the safety and efficacy of medicinal plants using evidence of adverse effects and the outcome of randomized-controlled trials. Independently, the public and medicinal plant users largely rely upon media, friends, and relatives, and experience to make choices regarding safe and effective medicinal plant use (Ambrose and Samuels 2004; Perkin et al. 2002; Kuo et al. 2004; Lohse et al. 2006). Prior to print media, personal experience and oral narratives were the principle means of generating and transmitting knowledge about safe, effective medicinal plant use and those accounts were rich in information that contributed to the benefits gained from the plant. Now, it is often framed as medicinal plant versus pharmaceutical prescription drug, with comparisons often made to antibiotics or antidepressants while crafting the message.

While the medicinal plants that remain in the herbalist lexicon are tried and true, the knowledge of pharmaceutical medicines are publicized and legitimized by the fact that a licensed doctor prescribes them. Any undesirable side effects are not generally discussed in the media or held up as reasons not to use the drug, but by law, as disclosed even on TV ads.

However, despite the steady increase in money spent on natural products in the USA, sales of *Echinacea* steadily declined in major markets from 2002 to 2007. Despite small increases in sales during 2008–2009 (perhaps due to the swine flu scare), *Echinacea* sales continued their downward trend until 2012, and are now increasing again (see Figs. 1 and 2).

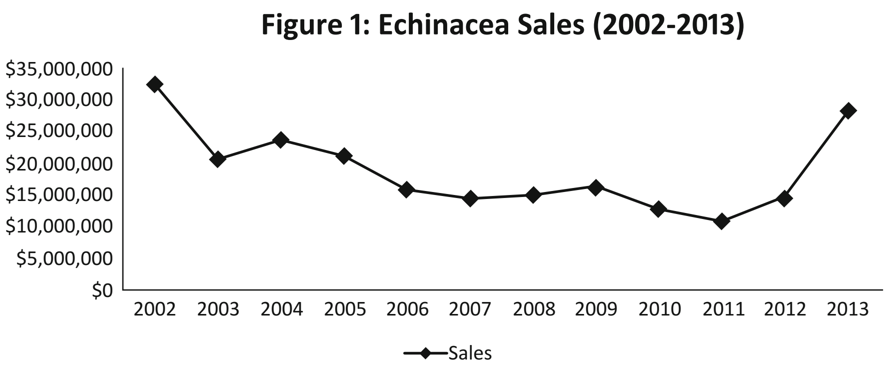

Fig. 1 Sales of *Echinacea* from 2002 to 2013 in major markets. However, these data do not include herbal sales by Walmart, Sam's Club, warehouse buying clubs, or convenience stores. (Blumenthal 2002, 2003, 2005; Blumenthal et al. 2006, 2011, 2012; Cavaliere et al. 2010a, 2010b, 2010c; Lindstrom et al. 2014) (*Source*: Rachel Craft)

Fig. 2 *Echinacea purpurea* has an iconic flower and is used in marketing (*Source*: Steven Foster)

According to Google Trends when searching on the key word *Echinacea* (http://www.google.com/trends?q=echinacea), the number of searches from 2004 to 2010 was higher after the media release of results from two *Echinacea* studies that concluded that *Echinacea* was medicinally ineffective (i.e., Turner et al. 2005; Barrett et al. 2010). That is, media coverage of *Echinacea* research does prompt readers to search for more information on the plant.

Methods

There are many studies that analyze the content of news articles to understand the relation between media portrayals and the use of complementary and alternative medicine (see Seale 2003; Weeks and Strudsholm 2008). We wanted to contribute to this research by locating news articles from popular news sources that referenced *Echinacea* from 2004 to 2010 by searching Lexus Nexus and Factiva news databases. Specifically, we searched the following newspapers: the *New York Times*, *Washington Post*, *USA Today*, *Wall Street Journal*, *Los Angeles Times*, *Daily News* (New York), *New York Times*, *San Jose Mercury Times*, *Boston Globe*, *San Francisco Chronicle*, *Chicago Tribune*, and *Houston Chronicle*. After reading through 212 articles and cataloguing them in an Excel spreadsheet, we found they could be descriptively classified into four groups:

1. Those that referred to gardening
2. Those that discussed the results of scientific studies on the safety and efficacy of *Echinacea*
3. Those that discussed other information regarding the medicinal qualities of *Echinacea*
4. Those that mentioned *Echinacea* in miscellaneous contexts (e.g., as a mention in a photo or an ingredient of a drink)

Of 63 articles that referenced scientific studies of *Echinacea*, the most often referenced studies were Turner et al. (2005), Shah et al. (2007), and Barrett et al. (2010). Turner and colleagues (2005) performed a randomized, placebo-controlled study that found that *Echinacea* did not significantly reduce the duration or severity of colds. Barrett et al. (2010) more or less duplicated Turner's 2005 study with twice as many participants and found similar results. On the other hand, Shah and colleagues (2007) performed a meta-analysis of 14 *Echinacea* studies (including Turner et al. 2005) and found that *Echinacea* significantly reduced the duration of the common cold by 1.4 days and the severity of cold symptoms by 58 %.

E. angustifolia Fails as a Conventional Crop

Some years ago, I heard secondhand that a well-known company had leased a center pivot (one of those large circular fields you can see flying over the Great Plains) in southwestern Kansas, near Garden City, and was growing *Echinacea angustifolia* roots. The word was that they hoped to corner the *Echinacea* market, particularly the European market, by cultivating a lot of really good roots and sending them to the big buyers in Europe. Europeans cultivate a lot of *Echinacea purpurea*, but they can't grow *angustifolia* there—the roots rot as it rains too much. It likes the dry western Kansas climate.

This center pivot planting would be a Kansas crop, which is to say, from the right place and the right environment—but in this case it would be grown conventionally. It was not an organic crop; it was irrigated, likely fertilized and treated as any other crop. I wanted to see the field, but no one would tell me where it was, and I think it was proprietary.

I was out in western Kansas studying *Echinacea* populations, and I met with the broker near Plainville. He told me about this large amount of roots that he was selling—from a crop field. I was surprised; they had always sold only wild harvested roots.

I delved into the story and heard that the roots had been harvested from southwestern Kansas, and a good sample was sent off to Europe, where they were rejected because they did not meet the standards for medicinal content. So someone approached the Plainville broker. I believe that because the grower couldn't sell the inferior root to the high-dollar market, they were marketing it through the wild channels. I'm sure this grower lost money, because in the end, they discontinued the center pivot growing operation.

Major crop production practices increase yield. But if you increase yield, you often decrease quality. The more you fertilize and irrigate, the more you get volume, biomass—but that doesn't mean more secondary compounds per unit. You might get more compound per acre, but you're not getting more compound per dose or per root.

Our analysis of media articles referencing these three studies illuminated two main categories relating to how *Echinacea* safety and efficacy are represented that would guide our analysis: (1) the number of times each article was referenced in the media, and (2) the adequacy of and types of information to support the author's assertion of efficacy and safety or the lack thereof. We counted the number of news references to *Echinacea* research studies, and coded these news articles according to how they referred to *Echinacea*, including how *Echinacea* itself was framed and what evidence was presented to support the authors' statements.

In addition, following the media response to the study by Barrett et al. (2010) and to update our research, we examined news articles published by *The New York Times* and *The Washington Post* from 2011 to 2014. We chose *The New York Times* and *The Washington Post* for further analysis because they are not only the most popular news sources that we analyzed (i.e., have the largest readership in the USA), they also referenced *Echinacea* more often than the other news sources in our previous analysis.

Findings

There are four distinct periods in news stories about *Echinacea*: In the first, from January 2004 to March 2005, four articles in these newspapers referenced Barrett et al. (2002) and Taylor et al. (2003) studies demonstrating that *Echinacea* was not significantly effective. In addition, three news articles vaguely mentioned *Echinacea* studies on its efficacy. That is, information identifying the research study referred to in these three articles was so vague that we could not locate the scientific study referred to. For example, in the USA Today (2005) article titled, "Best Defense? A bar of soap," the author contends that "The herbal remedy [*Echinacea*] does not help cold symptoms in children, a National Institutes of Health study has shown."

In the second period, from July 2005 until May 2007, Turner's 2005 study is referenced in the selected media 17 times as a stand-alone description of research on *Echinacea* and as evidence that it was ineffective. Turner's research was also used to explain the results of other studies identified only as National Institute of Health studies and an arthritis study, and as evidence to back-up claims made by the author during the flu season, all suggesting that *Echinacea* does not work as a cold and flu remedy.

In the third period, from June 2007 to February 2010, following Shah's supportive 2007 review of *Echinacea* research, the media referenced it only seven times. In contrast to Turner's referenced articles, which were all negative about *Echinacea's* potential, only three of these seven Shah articles refer to *Echinacea* as wholly effective. Three of these articles reporting Shah's positive perspective on *Echinacea* also invoke Turner's negative study as a counterpoint to balance the review. While Shah's review is referenced for only 2 months following publication, Turner's study is invoked over 5 years following its 2005 publication. In December 2010, it is used to back-up Barrett and colleagues' findings that *Echinacea* did not significantly reduce the duration or severity of colds.

In the fourth period, from January 2011 to December 2013, *The New York Times* and *Washington Post* reference *Echinacea* studies only four times, including reference to Taylor et al. (2003) and Barrett et al. (2010), to demonstrate its inefficacy as treatment for the flu or to express concern over the purity of *Echinacea* supplements. In summary, we found that news articles casting doubt on *Echinacea*'s efficacy, such as Turner et al. (2005) and Barrett et al. (2010), were more widespread and referenced for longer periods of time than reviews of research that found evidence of *Echinacea*'s efficacy, such as Shah et al. (2007).

In addition, over 70 % of the articles analyzed did not state the limitations of the randomized-controlled trial to measure medicinal plant safety and efficacy, including, for instance, that the trials began treatment after cold symptoms appeared, relied on subjective symptom reporting, may not have standardized the medicinal components of *Echinacea* used in the trial, or may not have used a high enough dose of *Echinacea* to produce medicinal effects. All of these concerns have been discussed in these research study articles and in subsequent discussions (see Turner et al. 2005; Barrett et al. 2010; Oliff 2011). Nor was there much discussion of the findings aside from reporting that there was no statistically significant evidence of *Echinacea*'s ability to prevent, ease symptoms, or shorten the duration of colds. For instance, Turner et al.'s (2005) results indicated that the infection rate for the placebo group was 66 %, while the average for groups that received either a 60 % or 20 % extract of *Echinacea* both before and during a cold was slightly lower at 53.5 %. While not statistically significant, this result is typical of research on *Echinacea's* efficacy. Further, while not statistically significant, Barrett et al.'s 2010 study found that *Echinacea* reduced the duration of colds by half a day. Yet, this was not addressed in news articles.

Discussion

Despite the assertion made by Tilburt et al. (2008) that sales trends in *Echinacea* did not significantly change following media's representation of research publications that concluded that *Echinacea* was ineffective, the National Center for Complementary and Integrative Health maintains that "sales of *Echinacea* have fallen as research findings have indicated that certain preparations do not prevent or reduce the severity of the common cold" (National Center for Complementary and Integrative Health 2014). In response to Tilburt et al.'s claim, the American Botanical Council counters that Tilburt et al.'s methodology was "admittedly simplistic" for examining only negative research results for five dietary supplements in only three major US medical journals published during 2001–2006 (Garner-Wizard 2008). Additionally, as a limitation in our own research, there is no clear causal connection between media reports of *Echinacea* research and use of this supplement. And a related problem is that there are no daily sales records on *Echinacea*; only annual compilations of sales; therefore, one cannot see immediate feedback on sales.

While many scholars have found that herbs are often positively reviewed (or at least as positively reviewed as pharmaceuticals) in the media (Bonevski et al. 2008;

Weeks and Strudsholm 2008; Seale 2003), our results are more consistent with Bubela et al.'s (2008) finding that clinical trials of herbal products were negatively covered by the media (in comparison with pharmaceutical trials) in the USA, the UK, and Australia. This could be due to the media's tendency for sensationalism, or by disrupting widespread common sense beliefs. That is, by claiming that contrary to thousands of years of use, *Echinacea* is actually not effective. As the majority of media and herbal research is performed in the UK and Australia, it may also be that in the USA, herbs are reviewed in a more negative tone.

Consistent with previous scholarly observations (see Seale 2003; Hollenberg and Muzzin 2010; Weeks and Strudsholm 2008), we confirmed that journalists draw upon research results on *Echinacea* and complementary and alternative medicine as a rhetorical tool and without a discussion of underlying philosophical issues or, in this case, not reporting findings beyond effective or ineffective in order to provide supporting evidence for the journalist's story. That is, studies are selected for only their demonstration of efficacy or inefficacy in the shadow of other studies or as evidence for the author's claims. Further, media draws from *Echinacea* research and confounds the logic of it. According to Seale (2003), the media often reverses the dichotomies employed in stories by way of "twitching." In this case, the dichotomy of *Echinacea* as effective and ineffective is twitched by reporting that *Echinacea* is ineffective, then a few months or years later that *Echinacea* is effective, and back to being ineffective again.

Finally, criticism of the randomized placebo-controlled research design to determine herbal safety and efficacy must be discussed. Harding (1998) and Hollenberg and Muzzin (2010) assert that using biomedical evidence (e.g., limiting research to specific indicators of efficacy and linear causal relations) for herbal efficacy is a form of covert ethnocentrism, in that the randomized, placebo-controlled trial is seen as the only legitimate means of producing medical knowledge. The reliance upon randomized-controlled research designs reinforce professional boundaries in medical studies and reproduces the supremacy of this method of knowledge production (e.g., it is a dominate method of producing knowledge on medicinal efficacy because that is the only way scientific medical knowledge is produced). In addition, the randomized-controlled trial is criticized for its failure to account for the participants' whole diet (including nutrients gained from other sources) and lifestyle, poor quality research designs actualized in studies, and for the move away from testing use in humans to laboratory testing for herbal safety and efficacy. And for herbal products, such as *Echinacea*, the active ingredient(s) have not been fully identified or determined as to dosages and formulations, and results must be discussed in terms of what was actually tested, which is not a single compound. Ultimately, research results are comparative in science and products and remedies are chosen on a comparative basis. It has been reported by the US Center for Disease Control that the 2014–2015 flu shot was not very effective, dropping to just an average of 23 % vaccination effectiveness estimate from a high of 60 % in 2010–2011 (Center for Disease Control 2015). Yet in all of these reports there is no comparison to *Echinacea*.

Also in 2015, new research indicates that *Echinacea* is as effective as Tamiflu (oseltamivir), but without the side effects (Rauš et al. 2015). A randomized double-blind clinical trial compared an *Echinacea* product, Echinaforce Hotdrink, which contains E. purpurea herb and roots and elderberry (*Sambucus nigra*) fruits, to Tamiflu for clinically diagnosed patients with influenza. Rauš et al. (2015) concluded that both treatments were considered efficacious and noted recovery in a significant number of patients. Further, complications and total adverse side effects were much lower in patients who used the *Echinacea* product. It will be interesting to see how the media will play these results in the near future.

Conclusion

We found that news media reports on research regarding *Echinacea* and its lack of effectiveness were more widespread and referenced for longer periods of time than reviews of research that found evidence of *Echinacea's* efficacy. It could be that research doubting *Echinacea's* efficacy were published in more prestigious journals, from which journalists tend to draw from, than meta-analyses that found *Echinacea* effective. That is, randomized-controlled studies demonstrating that *Echinacea* was not effective were published in the *Annals of Internal Medicine*, *Journal of the American Medical Association*, and the *New England Journal of Medicine*, while studies and meta-analyses demonstrating *Echinacea's* effectiveness were published in the *Lancet Journal of Infectious Diseases*, the *Journal of Pediatrics*, and *Cochrane Reviews*.

It is additionally difficult to statically prove that news reporting of *Echinacea* impacts use and sales as undoubtedly many factors need to be accounted for, such as: individual, demographic, and cultural patterns of use; health; lifestyle; and information sources. Without additional research on how people interpret and use media portrayals of herbal research to inform their purchase of herbal products, it is difficult to determine the impact of media on herbal sales and use. Further, news stories suddenly emerge, spread, and dominate media channels for short periods of time, which may temporary reach a larger pool of herbal consumers; however, we assume that many interested consumers find information regarding use from other online sources at other times. We believe that media has a significant, discernable impact upon herbal use and it is well known that the media is an important influence on sales. And it is also clear that the positive and negative media reports on *Echinacea* (or Tylenol, or a brand of cell phone) significantly impact the decisions of consumers. After all, if media had no discernable impact on consumer's purchasing behaviors, there would be no reason for companies to utilize the media for advertising.

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Part V
Conservation

Legal Protection of *Echinacea* and Other Medicinal Plant Species

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 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 late 1990s, about 65 million goldenseal plants and 34 million ginseng plants were harvested from the wild in the forests of the eastern United States each year (Robbins 1999). A recent report from the Fish & Wildlife Service (2012) estimated that up to 47 million ginseng roots were dug from the wild in 19 states between 1990 and 2011. 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 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 more than 500 % in sales in one year. Between 300,000 and 500,000 lb of black cohosh root were wild collected in 2001 (Schlosser 2002). In 2010, an estimated 315,000 lb of wild, dried black cohosh root was sold on the market (AHPA 2012).

More than 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 overharvest. Not only does such protection help maintain healthy, usable forests, it also engages the public who value

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these non-timber forest products. The harvest of *Echinacea* species and legal efforts to protect them provide a case study for such involvement.

An estimated 155 million *Echinacea* plants were dug from the wild between 2000 and 2010 (AHPA 2012). The average harvest of *Echinacea angustifolia* was 155,000 lb per year from 1997 to 2001 (American Herbal Products Association 2003), and this does not include other *Echinacea* species. 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 is only one species. The market fluctuates according to demand and supply. After a year of high supply, there is a much lower harvest. We can see this effect after 1999 and 2003 when 25 t and 32.3 t were sold on the market. Only about 4.5 t were harvested in the following years. The most recent tonnage survey (AHPA 2012) reported 23.8 t of dried wild *Echinacea angustifolia* sold in 2010. It is this very high demand and harvest that has driven the discussion of the need for laws to protect against the overharvest 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 (Fig. 1) (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. Overharvest 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 overharvesting 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 bring about 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 (Fig. 2).

Fig. 1 *Echinacea pallida* on private hay meadow near Eudora, Kansas with pink globes of cat's claw sensitive briar, *Mimosa nuttallii* flowers, and goat's rue, *Tephrosia virginiana*; and yellow black-eyed susans, *Rudbeckia hirta*. Since this photo was taken, this *Echinacea* stand was destroyed due to the building of a house and rural suburban development (*Source*: Kelly Kindscher)

Fig. 2 Landowners did not want trespassers harvesting their *Echinacea*, so this farmer in eastern Kansas (Miami County) posted this sign to protect the *Echinacea pallida* on his native prairie hay meadow (*Source*: Hillary Loring, Kansas Biological Survey)

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 U.S. 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 and 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 and 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.

Fig. 3 *Echinacea laevigata* flowers (*Source*: Steven Foster)

The threatened and endangered *Echinacea* species listed under the Endangered Species Program of the U.S. Fish and Wildlife Service (2005) includes only:

Scientific name	***Common name***	***Listing status***	***Current range***
Echinacea laevigata	Smooth coneflower	Endangered	GA, NC, SC, VA

Echinacea tennesseensis was delisted in 2011 due to recovery in Tennessee. Recovery plans are created after species are federally listed and provide the steps that need to be taken in order for those species to be removed from the endangered species list. For *E. tennesseensis*, the recovery goal was 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) (Fig. 3).

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 3250 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.

What Are Your People Doing up Here?

As a researcher, you become known for your work, and I have been known to work with "diggers" of *Echinacea*, and osha wild harvesters, Native Americans, and many other groups of people who use and harvest plants. One time, about ten to fifteen years ago, my phone at work rang, and Dave Ode, a colleague and botanist for the South Dakota Game, Fish and Parks Department, identified himself and said: What are your people doing up here? And he went on to say that several cars had been seen with Kansas plates and they were digging *Echinacea* roots (hence my people). This activity had been reported to him and he was concerned about overharvest. I laughed and said that I did not know these people, and explained what I knew about the root harvest and how it affected *Echinacea* populations.

Later I did learn that it was some of my people, some diggers I knew from western Kansas, who had been heading up to Sturgis to the motorcycle rally and decided to look for roots to dig on the way; and they exclaimed at the size of the "carrots" they found in prairies in South Dakota that they said appeared to have never been dug.

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
- 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 et al. 2002).

Chamberlain and his colleagues at the USDA Forest Service research station in Virginia 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
- 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 more than 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 and incorporated into forest plans, and that their harvesting activities be 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], roots, bulbs, berries, seeds, wildflowers, beargrass, salal, ferns, and transplants (trees, flowers, and bushes) (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 there (Crawford 1998). The Rosebud Sioux Tribal Council also has passed 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 overharvesting has been cited as a significant problem.

State Laws

In the United States, 15 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 valuable on the medicinal product market. Florida law also protects other native plants that are commercially exploited.

Many states have laws concerning the transportation and ownership of forest products such as coniferous trees, Christmas trees, saw logs, poles, cedar products, pulp logs, and fuel wood. But these laws 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 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 overharvest 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 passes 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,

Table 1 States that have laws in 2013 relating to wild harvesting of native plants

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

(continued)

Table 1 (continued)

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

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 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 nonnative *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 harvesting.

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

Fig. 4 The beautiful flowers of *Echinacea tennesseensis* (*Source*: Steven Foster)

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 that 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* (when it was listed) are technically allowed to be harvested on private lands (Fig. 4).

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 concerned with 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 that law enforcement officials from all agencies (state and federal) could apprehend violators.

Experienced commercial harvesters are very sophisticated 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 assess. Only one huckleberry harvester was known to have purchased a permit in the Flathead Valley in Montana one year, despite an estimated 8700 lb being harvested that summer by local businesses (Klein 2000). Most wildcrafters chafe 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 permit-less 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 $5000, or imprisonment for not than 6 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 is helpful 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 serve as examples of wild native plants that are stressed by overharvesting and may need legal protection.

Because of the consistently high value of wild ginseng, there is constant pressure on wild populations (Burkhart et al. 2012). 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 towards wildcrafters and the general public 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 of *Echinacea* Species

Kelly Kindscher

Echinacea is among the most important plants in the herbal product industry. 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 a matter 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 or populations, which means that overharvesting is possible and can lead to concern for their conservation status.

With the exception of the two species that have been federally protected—*E. tennesseenis* and *E. laevigata*—there is little scientific information available related to the actual amount of *Echinacea* in the wild. It is difficult to determine to what extent the harvest of *Echinacea* has affected its conservation status. Concerns of 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 for our study of *Echinacea* conservation status, resulting in these recommendations from our research group.

In this book's analysis of the status of *Echinacea* species, we identified key issues relevant to the continued health of *Echinacea* populations. These served as the basis for the following recommendations.

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Develop 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 in the "A Species by species overview" chapter and are also available and will be updated online at (http://kindscher.faculty.ku.edu/research/ethnobotany/distribution-maps-for-echinacea-species).

We recommend that more surveys be conducted and collections made to aid in the study of *Echinacea* species ranges, especially in some under-collected areas where several species co-occur, as in central and southeastern Texas, the Ozarks, and throughout the Southeast.

Increase Ecological Research

After reviewing the literature on the biology, ecology, and conservation status of *Echinacea*, my colleagues and I became 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 other than our research, and consequently there is little understanding of how *Echinacea* species survive in their environment.

Clearly more research is needed, especially on the plant population dynamics related to wild harvest, sustainability, effects of drought, and rates of recovery by seeds and root resprouts for all species in different habitats. The Natural Heritage Programs across North America 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 in the field, which are relatively common throughout much of their ranges (Fig. 1).

Conduct Additional Population Monitoring and Specimen Collection

Perhaps our greatest understanding of the status of *Echinacea* species in the wild has been our collection and monitoring research on *E. angustifolia*. One of our most compelling findings is that historic populations continue to exist as long as land use

Fig. 1 More research is needed on *Echinacea* populations. Here is our research crew collecting data on *Echinacea angustifolia* root resprouting at our eastern Montana field site (*Source*: Kelly Kindscher)

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. And a very good example of using this technique in finding *Echinacea* species in Missouri is the work of Applequist et al. (2007).

Much of our work has focused on *E. angustifolia* because it has supplied 80–90 % of the wild-harvested Echinacea supply in the national and international markets. Our monitoring indicates that there are healthy *E. angustiolia* populations 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 demonstrates that 50 % of wild-harvested *E. angustifolia* roots resprouted 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, other *Echinacea* species and locations to see if they are typical.

We have developed a monitoring protocol that can be used for all species (see "Science in Action: A Model for Monitoring *Echinacea* Populations" in the Appendix). It is a suitable tool for monitoring *Echinacea* or other species. 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. We will gladly share our *Echinacea* data with other researchers upon request.

Undertake Further Study into Ethnobotanical Information

There is a strong interest in the ethnobotany of *Echinacea*, and much is known about traditional medicinal uses, 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* species were used there.

There should be further ethnobotanical studies of less common *Echinacea* species, as well as continued study into the ethnobotanical uses of *E. angustifolia*. During our recent work, we have uncovered additional historical accounts of *Echinacea* species use. These ethnobotanical uses are not just historical; I have observed *E. angustifolia* being used on the Rosebud, Fort Peck, and Crow Indian 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.

Personal vs. Commercial Harvest

There's an ongoing debate about just what personal and commercial harvest mean. The US Forest Service generally requires interested harvesters to check in at the local office and perhaps get a permit, just as you have to get a permit to cut firewood.

The problem with medicinal plants and herbals is that it's hard to determine what is an acceptable amount for either personal or commercial harvest. Taking some *Echinacea* root is an act that borders on picking wildflowers in a national forest; it seems trivial, and it's hard to regulate. And what does commercial harvest mean? Is it just enough to make a small amount of tincture? There could be a mom-and-pop business picking a small amount, or there could be a large group of people harvesting as much as possible for sale to a broker. It still is difficult to determine how best to monitor and regulate harvest on these public lands.

There also are cases in which the Forest Service encourages and facilitates traditional plant use and harvest by nearby Native American tribes. In the Custer National Forest, for example, there's a unit in Montana that is adjacent to the Cheyenne reservation and they recognize that there is a special relationship and encourage traditional harvest.

Support Sustainability of Wild Harvest

In documenting the commercial harvest of wild *E. angustifolia* in Kansas for the past 120 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 and on Indian reservations. Historic and ongoing market cycles of demand—high prices followed by market collapse—also affect wild harvest.

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

Echinacea and the At-Risk List

Echinacea species are currently considered as At-Risk for over harvest for use in the herbal products trade by the United Plant Savers (see: http://www.unitedplantsavers.org/content.php/426-Echinacea). We conducted research that has led to a numerical rating scale for the At-Risk list that we recently published (Castle et al. 2014), which shows that Echinacea species can be considered at a rank of "At-Risk." Our techniques included a wide range of biological, ecological, market, and other factors. The demand, confusion of which species is being harvested in the wild, coupled with it being a perennial species whose roots are being dug up, resulted in its score and rank. We encourage future reevaluation of this score, and also in developing scores for all of the species. Specific issues that should be considered in future scoring would include market demand, future climate change, habitat modifications, and the regulatory environment.

Support Further Study into Medicinal Compounds and Their Effectiveness

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. Also, it may have future uses related to immunotherapy, superbugs, or other uses. Current research is somewhat mixed in its results, but many applications appear promising, and the quality of the plant material being tested is now much higher than often studied in the past.

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, especially in the flowers and seed. The yield of these compounds from leaves and stems is slightly

Fig. 2 Educational information about *Echinacea* is important. Here, we planted *Echinacea angustifolia* at the University of Kansas School of Pharmacy garden to help educate Pharmacy students about native medicinal plants, including when they were listed in the US Pharmacopeia and National Formulary (*Source*: Kelly Kindscher)

less than that from the root, 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 or a higher percentage of it in the formulations, the nature of market demand would change, and harvesting would leave roots to grow undisturbed, while harvest would be of the plant tops that are now discarded. These long-lived plants could produce a significant amount of biomass throughout their 10–30-year life spans.

We encourage the continued study of *Echinacea's* active medicinal constituents and their efficacy, and especially related to the common cold, flu, and especially related to flu pandemics (Fig. 2). And we feel there is still significant opportunity to test its efficacy against two of its original Native American uses—to treat rabies and snakebite, which have not had good medical treatment regimes.

Continue Study of the Market and Tracking of *Echinacea* Harvest

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

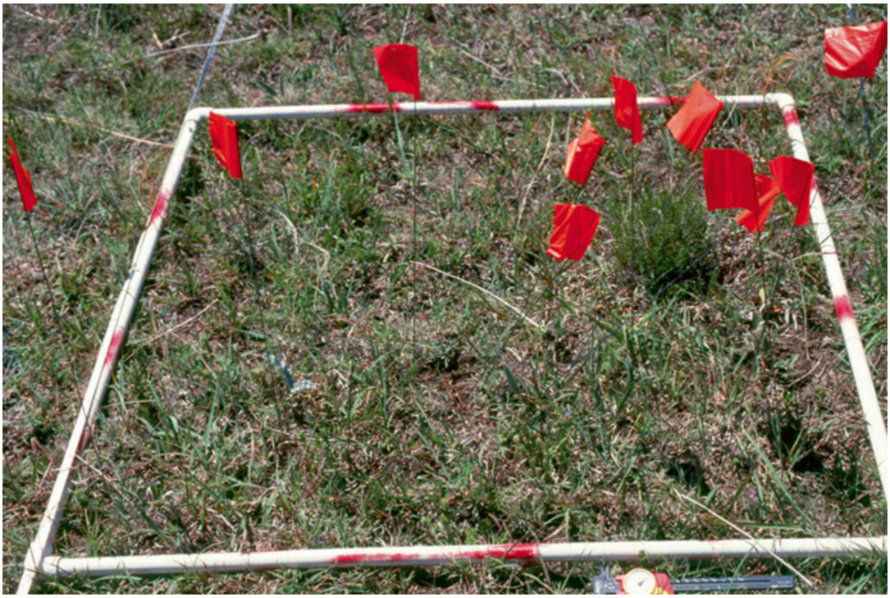

Fig. 3 Research is essential to understanding what rate of harvest of *Echinacea angustifolia* is sustainable from wild populations. This meter square plot has all *Echinacea angustifolia* plants marked in the plot. Note how it is hard to see any of these juvenile and small plants, even though many are several years old, because they are grazed annually by cattle (*Source*: Kelly Kindscher)

cycling is likely to continue, and it will greatly affect the demand for wild-harvested *Echinacea*. So we encourage future market analysis and study of quality issues related to the products being marketed.

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 (Fig. 3).

Continue Careful Consideration of Legal Protection and Encourage Educational Efforts

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

We do not think that it is necessary to propose listing any other *Echinacea* 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, or if climate change or land use practices, significantly impact *Echinacea* populations, the legal status of *Echinacea* species might need to be reevaluated.

Continue Cultivation of *Echinacea*

Cultivation, in place of wild harvesting, can provide relief to wild stands and will continue to be the major share of all *Echinacea* material used in the market. However, the difficulty of cultivating *Echinacea angustifolia*—combined 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 enthusiastic about growing a crop, and especially *E. angustifolia*. An *Echinacea* crop ties up land for more than one year and may or may not have a market when it is ready to harvest. Recently, growers are successfully meeting the challenge. 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 continued for more than 120 years) may be relatively sustainable.

We encourage both the cultivation of *Echinacea* species and the continuation of sustainably harvested wild *Echinacea* to meet future market demand (Fig. 4).

Retain Current 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.

To avoid confusion in the academic arena, the marketplace, and the public, we encourage the retention 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.

Fig. 4 *Echinacea purpurea* can be easily cultivated, such as in this field at Trout Lake Farm in Washington state (*Source*: Steven Foster)

Restoration and 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, oil and gas fields (especially in North Dakota and the High Plains), and other development. However, it is not an imminent threat for the majority of remaining stands, which usually now are 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.

We recommend the restoration and conservation of *Echinacea* habitats. Degraded habitats can be restored through financial incentives that encourage less intensive grazing, more rotational grazing, use of fire, and the reduction of herbicide use. In addition, Conservation Reserve Program and similar programs throughout the ranges of *Echinacea* species should encourage the inclusion of local genotype seeds in planting and restoration efforts. In areas in the northern Plains, where Dakota skipper butterflies, with their October 2014 federal listing as threatened (U.S. Fish and Wildlife Service 2014), would be helped by the replanting of local genotype *E. angustifolia* seeds, which are an important nectar source for these rare butterflies. Many of these management objectives could be considered together through funding of one or several of these programs.

Echinacea habitats should also be a focus of 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 native habitat. All conservation easements should be voluntary, but state and federal funding 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 for human and animal health. And we would expect that it would continue to have 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 ads for roots. When these 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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Appendix A: Science in Action: A Model for Monitoring *Echinacea* Populations

Kelly Kindscher and Dana M. Price

We want to encourage monitoring of populations of *Echinacea* because currently no comprehensive long-term data exists on wild populations of *Echinacea* species. Monitoring is specifically needed as the effects of harvesting are not fully understood. We provide here a model for monitoring wild *Echinacea* populations; one that also can be used for other species. Monitoring cannot clearly determine what happened in the past, but can provide a baseline against which to compare the effects of management or harvesting into the future. This appendix provides a specific example of our monitoring program of *Echinacea angustifolia* stands on private lands in Kansas and on the Little Missouri National Grasslands in North Dakota—as well as a summary of the baseline data taken the first year of this monitoring program which show the potential benefits of long-term data collection and summarized data.

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 also 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 would be impractical for most researchers or conservationists because the region of harvest is large and harvesters or wildcrafters are numerous when the price for *Echinacea* roots is high, but hard to find otherwise. It is understandable that they don't want to be watched or studied, with notes taken on what they do. In exceptional cases where the researcher takes time to make contact with harvesters, we recommend requesting their consent to participate in or observe harvesting, and conducting pre- and postharvest monitoring if possible.

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And some harvesters have been eager to demonstrate the resilience of their *Echinacea* patches. For the most part, however, we must rely on plant 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.
- 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* and other species of interest.

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, 1 m×1 m 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 (private land) and four additional sites in southwestern North Dakota (federal land, specifically, the Little Missouri National Grasslands). These eight sites were selected because they have a history of wild harvest. 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 Plainville, Codell, and Natoma.

Specific site selection was based on density of *Echinacea* populations and ease of access. Proximity to permanent human structures (e.g., fence lines, telephone poles, road signs) also was considered, as it made marking and relocating plots easier. We wanted to be close to a structure to more easily find our sites again, but at a measurable distance away so that we did not sample disturbed areas related to the structures.

For each *Echinacea* patch, the recording of notes is very important. 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 for the site data sheet). Sites

Table 1 Sample site data sheet for monitoring *Echinacea* plots

Observers:	Date:
Site: Section__________	T______ R______
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: [why 19 here?]	
(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 = 0.90:	90 % sure of missing a false change
a = 0.10:	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 smallest of the standard deviations, we would technically need only 4 plots. 20 plots allow us to detect a change of 0.2 plants per plot (about 2 % in Price's data, but 4 % if we only average 5 plants/m^2). Using the largest of the standard deviations (which includes some incomplete data and seedling data), 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 0.95 and decrease alpha to 0.05. To detect a 10 % change at the stats 0.99/0.01 levels, we would need 31 plots	

also were marked on a topographic map. All project notes were typed soon after fieldwork as this helps greatly with recalling details.

Twenty plots per site were established. Based on Kansas *Echinacea angustifolia* data collected by Dana Price Hurlburt (1996–1998) for her doctoral dissertation (Hurlburt 1999), 20 plots per site were determined a sufficient sample size. This number of plots will allow researchers to detect a change in population size from 1 year to the next of 10 % or greater, with greater than 90 % certainty and a false-change error rate of less than 10 % (see Table 2 to see how this is determined).

Plot size was 1 m^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 5 m intervals along a 100 m measuring tape so that they could be found again easily. For odd-shaped populations of *Echinacea*, two or three shorter-length transects were used (Table 3).

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. We recommend using points on a fence line because they are easy to locate, but any obvious landmark is suitable. Steel posts also are recommended because they do not rot and can be added if other obvious landmarks are not available. We suggest marking both triangulation points with spray paint for easy relocation. We spray-painted the top one-third of the steel posts.

Table 3 Equipment and supplies used in baseline monitoring

Data sheets printed in advance on waterproof paper
Pencils and erasers
Waterproof clipboards
2 long (100 m) tape measures
1 m × 1 m lightweight plot frame (we make ours of PVC pipe and elbows)
Pins to hold the starting point of the tape in place
Nails, bolts, and 10″ long rebar (cut before fieldwork)
Heavy hammer or sledge (if rock is present) for pounding in rebar
Brightly colored plastic flagging tape
Outdoor spray paint in a nonnatural color (use red or orange; be bold)
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

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 ft 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. (The reason a tall steel post is not simply pounded in at the starting point is that cattle tend to rub against the post and disturb the site. Also, steel rebar is pounded flush with the ground so that it will not be disturbed by cattle or vehicles, and in some cases it is best if the area sampled is not visibly marked; such as monitoring to determine if harvesting is occurring in protected areas).

We used GPS (Global Positioning System) coordinates to record, in our field notes, 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 other feature. Although the research team recorded GPS data, most GPS units do not currently offer the accuracy needed to locate a plot within inches or centimeters. We hope that will change in the near future so that GPS data can be used to easily establish and relocate plots. Our GPS location information was later transferred to a field data file.

From the starting point (marked with the rebar), a 100 m tape measure was laid out in the direction that passes through most of the patch (Note: The goal is to sample the population by randomly locating plots in the population.) A compass was used to determine the direction of the line, which was recorded in the field notes. Flags were placed along the 100 m tape at 5 m intervals, the first being the starting point. At each flag, a 1 m × 1 m plot frame, made of 1-in. 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.

One team member walked the perimeter of each patch taking GPS measurements. These measurements later were used in conjunction with mapping software to determine the size and location of the patch. Where there was an obvious edge to 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, and sometimes the efficiency. When available, third and fourth team members 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 (measuring below any branches of the crown) 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 diameter, rarely having multiple stems per crown, and not flowering.

Medium: Root crown measuring 3–5 mm diameter.

Large: Root crown greater than 5 mm diameter.

Dormant or dead plants: Can only be recorded when re-sampling occurs in the future

Data sheets were prepared in advance. A copy of the sheet used to record species data in plots 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,

Table 4 Species list was a guess from the literature of the area

Bare ground											Site:		
Aster ericoides													
Astragalus											**T**	**R**	**Sec**
Bouteloua gracilis													
Calylophus serrulatus											**Date**:		
Carex __________													
Carex eleocharis											**Observers**:		
Carex filifolia													
Chrysopsis													
Cirsium __________													
Dalea candida													
Dalea purpurea													
Echinacea angustifolia													
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 (3–5 mm)													
Flowering													
Large (>5 mm)													
Flowering													

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 in Kansas. The ratio of

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 3 mm dia)	483	6.04
Flowering	0	0.00
Medium (3–5 mm)	166	2.08
Flowering	18	0.23
Large (>5 mm)	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 (3–5 mm)	266	3.33
Flowering	2	0.03
Large (>5 mm)	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 3 mm dia)	1095	6.84
Flowering	0	0.00
Medium (3–5 mm)	432	2.70
Flowering	20	0.13
Large (>5 mm)	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			**Medora 2**	
	Sum	Average/plot		Sum	Average
Seedlings	45	2.25		10	0.50
Small (to 3 mm dia)	124	6.20		68	3.40
Flowering	0	0.00		0	0.00
Medium (3–5 mm)	33	1.65		39	1.95
Flowering	5	0.25		3	0.15
Large (>5 mm)	21	1.05		27	1.35
Flowering	8	0.40		16	0.80
Total all *Echinacea*	223	11.15		144	7.20
	Medora 3			**Stony Butte**	
	Sum	Average		Sum	Average
Seedlings	20	1.00		53	2.65
Small (to 3 mm dia)	77	3.85		214	10.70
Flowering	0	0.00		0	0.00
Medium (3–5 mm)	55	2.75		39	1.95
Flowering	6	0.30		4	0.20
Large (>5 mm)	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			**Codell 1**	
	Sum	Average		Sum	Average
Seedlings	3	0.15		2	0.10
Small (to 3 mm dia)	43	2.15		275	13.75
Flowering	0	0.00		0	0.00
Medium (3–5 mm)	15	0.75		95	4.75
Flowering	0	0.00		1	0.05
Large (>5 mm)	19	0.95		24	1.20
Flowering	0	0.00		1	0.05
Total all *Echinacea*	80	4.00		396	19.80
	Codell 2			**Natoma**	
	Sum	Average		Sum	Average
Seedlings	2	0.10		0	0.00
Small (to 3 mm dia)	110	5.50		184	9.20
Flowering	0	0.00		0	0.00
Medium (3–5 mm)	56	2.80		100	5.00
Flowering	0	0.00		1	0.05
Large (>5 mm)	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

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 dasystachyum	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			

(continued)

Table 7 (continued)

Latin name	Common name	Sites			
		Davis	Medora	Magpie	Stony butte
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 %	
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

(continued)

Table 7 (continued)

Latin name	Common name	Sites			
		Davis	Medora	Magpie	Stony butte
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 %

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 pensylvanica	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 integerrimus	Lambs tongue groundsel	Trace	0.7 %		
Shepherdia canadensis	Russet buffaloberry			0.3 %	
Sisyrinchium 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 %

(continued)

Table 7 (continued)

Latin name	Common name	Sites			
		Davis	Medora	Magpie	Stony butte
Symphoricarpos 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	Hookedspur 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[a]		59	60	63	70

[a]Species richness is the total number of plants observed at a site
Twenty plots of 1 m^2 were sampled at each site. Data were collected in June 2002. Names are from *Flora of the Great Plains*, 1991

small to large plants is noticeably high, approximately 6:1. We do not know if this is due to the fact that most small plants never make it to maturity or if past harvests are having an effect on population. Data that list all species found and their cover, including *E. angustifolia*, are in Table 7 for North Dakota and Table 8 for Kansas.

Sampling over a period of years would help determine the population dynamics of *Echinacea* species at these sites 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 also 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 changes to the site or poor memory.

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.

Table 8 Vegetative composition of *Echinacea* population in north-central Kansas

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 herbaceus	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 maximiliani	Hairy sunflower			1.3 %
Hymenopappus scabiosaeus	Old plainsman	0.2 %		
Hymenoxys scaposa	Smooth hymenoxys	0.1 %	Trace	
Lactuca ludoviciana	Louisiana lettuce			Trace

(continued)

Table 8 (continued)

Latin name	Common name	Sites		
		Codell 1	Plainsville	Codell 2
Leucelene ericoides	White aster	0.5 %	1.8 %	
Liatris punctata	Dotted gayfeather	0.2 %	0.2 %	
Linum rigidum	Flax	Trace	0.1 %	
Latin name	Common name	Sites		
		Codell 1	Plainsville	Codell 2
Linum sulcatum	Grooved flax	0.1 %		
Lithospermum caroliniense	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 %

(continued)

Table 8 (continued)

Latin name	Common name	Sites		
		Codell 1	Plainsville	Codell 2
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[a]		47	56	46

[a]Species richness is the total number of plants observed at a site
Twenty plots of 1 m^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

Reference

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

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Dana Price, Botanist
Dana Price studied *Echinacea angustifolia* populations and harvesting as a central part of her Ph.D. research at the University of Kansas. Her work at KU with the Kansas Biological Survey included prairie and wetland conservation, ethnobotany, and prairie restoration projects. She went on to conduct rare plant conservation projects for the Texas Parks and Wildlife Department and is a coauthor of "Rare Plants of Texas: A Field Guide." Dana currently serves as Botanist for the U.S. Army Corps of Engineers, Albuquerque District.

Maggie Riggs, Professional Landscaper and writer
Maggie Riggs is a professional landscaper, writer, and entrepreneur. She oversees a rooftop garden in downtown Kansas City, writes children stories, and has been involved in small-scale business development. Her expertise in Echinacea dates back to working with Kansas farmers procuring Echinacea seeds, being the national sales manager for the natural Product Company, Pines International, and she has been involved in fieldwork studies of Echinacea with many other coauthors in this book.

Rebecca Wittenberg, Botanist
Rebecca Wittenberg, MS received her B.A. in Mathematics from Bard College. After college, she started and later sold an herbal manufacturing company. While pursuing her Master's degree in plant physiology and botany, she worked on Echinacea and learned about prairie ecology with Kelly Kindscher at the University of Kansas.

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