Resprouting of *Echinacea angustifolia* Augments Sustainability of Wild Medicinal Plant Populations[1]

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Resprouting of *Echinacea angustifolia* Augments Sustainability of Wild Medicinal Plant Populations. Overharvest of wild *Echinacea* species root has been a significant concern to the herbal industry. Harvesters of wild *Echinacea angustifolia* showed us that even after harvesting the top 15 to 20 cm of root, some plants resprout. We marked locations of harvested plants at sites in Kansas and Montana and reexamined them two years later to see if they resprouted from remaining root reserves. Approximately 50% of the roots resprouted at both Kansas and Montana sampling sites, despite droughty weather conditions in Montana. The length of root harvested significantly affected the ability of the plant to resprout. Those plants that were more shallowly harvested and had less root length removed were more likely to resprout. These data indicate that echinacea stands can recover over time from intensive harvest if periods of non-harvest occur. Our echinacea harvest study emphasizes that the entire biology of medicinal plants must be considered when evaluating their conservation status.

Key Words: Wild harvest, medicinal plants, roots, dormancy, resprouting, overharvesting, echinacea.

Introduction

The greatest concern for overharvest of medicinal plants in North America is for species that have high demand and a significant amount of wild harvest (Cech 2002), including echinacea (*Echinacea* species), goldenseal (*Hydrastis canadensis* L.), and American ginseng (*Panax quinquefolius* L.). These plants are slow-growing, long-lived perennials of specialized habitats, whose roots are the primary medicinal plant part used in the commercial trade (Klein 2000).

Echinacea is one of the most popular, and most researched, plants in the herbal product industry. A sizable portion of the demand for echinacea is for wild-harvested plant material, especially roots of *Echinacea angustifolia* DC. Echinacea species grow wild only in North America. The taxonomy is confusing, with nine species recognized (McGregor 1968). Recent attempts to lump echinacea into four species (Binns et al. 2002) have not been accepted due to insufficient molecular support for this classification (Blumenthal and Urbatsch 2006). *Echinacea angustifolia* and *E. purpurea* (L.) Moench make up the bulk of the herbal product trade, with small amounts of *E. pallida* (Nutt.) also being marketed. *Echinacea angustifolia* is the only species with a significant quantity of wild harvested plant material (American Herbal Products Association 2000, 2003.) This species is native to the Great Plains of the U.S. and Canada (Fig. 1).

Echinacea Production

Echinacea purpurea is relatively easy to cultivate. There is a potential market for cultivated *E. angustifolia*, but it is difficult to grow due to fungus and disease in humid areas with moist

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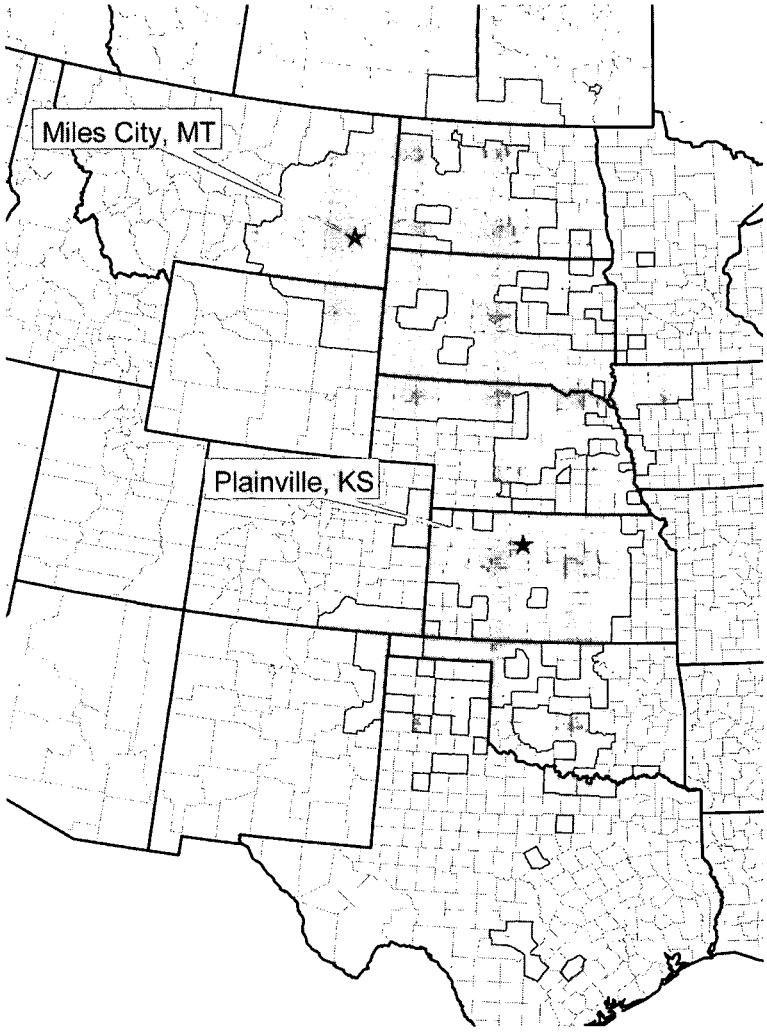

Fig. 1. Location of study sites in Montana and Kansas within range from known and verified herbarium records of *Echinacea angustifolia* (Kindscher 2006).

soils, such as in central and northern Europe. In addition, the crop requires two to three years growth before it is harvestable, concerns have been raised about its quality, and the lag time between demand and harvest can create unanticipated surpluses, or unpredictable prices. For all these reasons, *E. angustifolia* is primarily obtained through the harvest of native wild stands.

Concerns of Overharvest of Wild Echinacea Species

Echinacea angustifolia roots were used by many Native American tribes, but the quantity used was relatively small (Kindscher 1991). The popularity of echinacea products has repeatedly risen and fallen in recent history, cyclically renewing concerns that unregulated harvesting will decimate wild populations (Price and Kindscher 2007). In addition to harvest pressures, wild echinacea stands are threatened by overgrazing, herbicide use, and conversion of habitat to other uses.

When the price of wild *E. angustifolia* roots is high, harvesters can decimate a stand in a relatively short amount of time. Echinacea harvesting has been likened to a "gold rush" (Crawford 1999) that begins abruptly, occurs intensely, and spreads to other potential root mining districts once resources become depleted.

Harvesting of *Echinacea angustifolia* root increased considerably in the mid-1990s, spreading northward from historical harvesting areas in Kansas to the essentially untouched large native stands on rangeland in eastern Montana and western North Dakota. Harvesting increased even more when the market demand doubled from 1997 to 1998. The Fort Peck Reservation in northeast Montana was one focal point of this expansion of commercial markets. In 1995, herbal brokerage companies approached the tribes on the Turtle Mountain and Fort Berthold Reservations in North Dakota and the Fort Peck Reservation in northeast Montana, offering money for echinacea roots (Kolster 1998). Echinacea root digging was encouraged by contests promoted by local root buyers, and the Fort Peck tribal newspaper, *Wotanin Wowapi*, published a picture of the winner of one such contest, a 96.5 cm long echinacea root (Kolster 1998; Stewart 1999). Kolster (1998) estimated that 350 to 400 people were harvesting *E. angustifolia* on native prairie lands in the Fort Peck Reservation area in the spring of 1998. One local company bought as much as 545 kg of root per day and paid out over $1.1 million to echinacea harvesters in 1998 (Solberg 1999). Some tribal leaders on the reservation initially endorsed harvesting but subsequently became concerned over the greediness of some harvesters and the observed decline in stands over several years of harvesting. At the height of the harvest, one elder described pickup trucks being used at night so that the last remaining elevated seed heads could be seen with the truck lights, and then the roots were harvested.

Harvesters from Texas who had applied for but had not received a commercial permit were arrested in 1998 in the Ashland District of the Custer National Forest with 38 kg of fresh roots in gunny sacks that they said were for "personal use" (Stewart 1999; Scott Studiner, personal communication 2002). By 1999, wild harvest of *E. angustifolia* was reported in 14 counties in North Dakota, and U.S. Fish and Wildlife Service workers reported cases of poaching in both Wells and Stutsman Counties (Torkelson 1999). There were also at least two or three cases of poaching in the Ouachita National Forest in Arkansas in 1997 and 1998, where harvesters were charged for illegal harvest and *Echinacea* species roots were confiscated (J. Hicks, patrol office, Ouachita National Forest, personal communication, 2002). Well outside the range of *E. angustifolia*, the harvested roots in this area were sold to buyers as "snakeroot" and then most likely sold to some broker in the area as *E. angustifolia*. The threat of wild harvest was one factor in the listing of *Echinacea tennesseensis* (Beadle) Small and *E. laevigata* (Boynton & Beadle) Blake under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 1989, 1995).

The Effects of Wild Harvest on Echinacea Populations

The demand for echinacea reached its highest level in 1998 has since declined, but the market activity of the past decade suggests that the boom-and-bust harvesting of *E. angustifolia* is likely to continue (Price and Kindscher 2007).

The initial threat of wild harvest to echinacea populations is caused by the sheer number of lost plants. Owing to the substantial number of harvesters across the region, the remote location of wild *E. angustifolia* populations, and variation in root size and weight, it is difficult to quantify the number of *E. angustifolia* roots extracted from native stands annually.

The American Herbal Products Association (AHPA 2000, 2003) surveyed regional buyers of wild-harvested *E. angustifolia*, *E. purpurea*, and *E. pallida* and found that over 145,000 kg of dried roots of *E. angustifolia* were wild-harvested during the four years from 1998 to 2001 inclusive We have calculated that it takes over 220 *E. angustifolia* plants to make 1 kg of dried echinacea root (determined from weighing commercial wild-harvested roots in north-central Kansas). We therefore believe that over thirty million *E. angustifolia* plants were harvested during this time.

Beyond the actual loss of plants, an additional threat to wild echinacea populations is that the largest plants are harvested, and these plants are the most successful at reproduction. Harvesters believe that the largest roots come from old plants. They select plants by observing multiple seed heads in the air or lying on the ground, or seeing large and numerous basal leaves. Based on three years of field data gathered from population monitoring and modeling in Kansas, Hurlburt (1999) calculated that wild *E. angustifolia* plants can reach 18 to 44 years of age.

Skilled harvesters in north-central Kansas visit favorite areas about once every three years and harvest moderately to ensure future opportunity. Hurlburt (1999) projected that populations can sustain a harvest of 4–5% of medium- to large-sized roots per year. Years without harvest allow for some recovery.

Ability to Resprout Helps Sustain Echinacea Populations

In both Kansas and Montana, we have observed *E. angustifolia* root resprouting after commercial harvest (Kindscher, personal observation; Hurlburt 1999). We postulate that root resprouting significantly benefits echinacea populations and that some of the observed population reductions may be due to temporary absence of the aboveground parts from harvested plants which subsequently resprout.

Only by joining echinacea harvesters in the field in north-central Kansas did we learn about the resprouting of *Echinacea angustifolia* plants after being harvested (Hurlburt 1999). We learned and observed that echinacea harvesters in north-central Kansas were harvesting roots that had previously been harvested and that populations would recover after harvest, even if the harvest had been intensive. During the summers of 2001–2003, we made reconnaissance trips to areas where the wild harvest of *E. angustifolia* was described as being excessive (Kolster 1998). These areas included sites at Fort Peck Indian Reservation and Custer National Forest in Montana, the Missouri National Grasslands in North Dakota, and the Smoky Hills of north-central Kansas. We looked for areas where echinacea had become locally extinct due to overharvesting. At all sites we found evidence of harvest and we saw at least some flowering echinacea plants. For example, at the Custer National Forest, shovel holes ca. 12.5 cm deep left by poachers in 1998 were still visible when we visited the sites in July 2002. Small echinacea plants that had not been harvested had subsequently reached maturity and were observed flowering between shovel holes. In addition, some harvested roots had resprouted and were noticeably positioned squarely in the middle of the persistent shovel-dug depressions. We did not know how large any of these populations had been prior to repeated harvest, but we were encouraged that they had persisted despite reported overharvesting.

For all of these reasons, we needed to determine the percent of *E. angustifolia* plants that would resprout after harvest. We also wanted to collect data relating resprouting of plants to the sustainability of its harvest.

Methods

Study Areas

The stands of *Echinacea angustifolia* we chose to study in Kansas and Montana include different climatic regimes, range management practices, and soil types. It should be noted that throughout the *E. angustifolia* range (Fig. 1), the species occurs in habitats with less competition with grasses and is most often found in rocky or thin soils, often limestone (as in the north-central Kansas study area), or other fragmented rock types (such as scoria in the eastern Montana study area).

Both study areas were in native rangeland where large populations of *E. angustifolia* occurred. The first study area was 4.5 km (10 miles) south of Plainville, Kansas. We established 7 study transects in Buster, GLC, and Wassinger pastures occurring across an area of 160 square km (45 square miles). Grazing at all transects was moderate to heavy. These echinacea stands were located in typical mixed-grass prairie dominated by little bluestem (*Schizachyrium scoparium* [Michx.] Nash), big bluestem (*Andropogon gerardii* Vitman), and side-oats grama (*Bouteloua curtipendula* [Michx.] Torr.). The second study area was comprised of 10 transects located on Buck Mountain Ranch about 32 km (20 miles) east of Miles City, Montana. Transects were located across approximately 100 square km (60 square miles) and were either lightly grazed by livestock or ungrazed. Echinacea stands were located on a variety of soils in typical northern mixed grass prairie, comprised of needle-and-thread grass (*Stipa comata* Trin. & Rupr.), little bluestem, bluegrass (*Poa pratensis* L.), and side-oats grama.

Both the Kansas and Montana study sites are of continental climate with hot summers and cold winters. The average annual rainfall for the Plainville, Kansas, area is 62.5 cm (24.6 in), while the average rainfall for Miles City, Montana, area is significantly less at 34.2 cm (13.5 in).

Selection of Sampling Transects and Methods

Individual sampling transects were chosen based on an abundance of *E. angustifolia* plants

and uniform distribution. Transects were established by laying out a 100-m tape measure. A variety of harvestable-sized plants were selected and harvested if they were within 1 m of the tape measure and at least 60 cm (2 feet) from any other echinacea plant in order that they could be definitively marked. This eliminated confusion between resprouts and other echinacea plants that would grow over the two-year monitoring period. At both transects we were accompanied by a harvester familiar with the specific area and who advised us on which plants would typically be harvested. Roots can extend 150–250 cm deep or more (Weaver and Fitzpatrick 1934). The roots remain large (1–2 cm wide) for 30–80 cm into the soil, but we followed typical harvesting protocol and harvested only to the depth a pickaxe or shovel can easily reach (15–20 cm).

Plants were harvested using the field tools of our professional harvesters (a small pick axe in Kansas and a specialized harvesting tool in Montana). After a root was severed by the harvesting tool, its length and diameter were recorded to determine root reserves. We measured diameter just below the crown. We also recorded whether there was any stem borer damage or whether the root had been previously harvested. Evidence of resprouts after previous harvest was easily observed as a smaller shoot emerged from the juncture of a healed cut on a larger root (Figs. 2 and 3). All harvesting holes were filled in (except one transect, discussed below). All harvested plants were marked by a GPS unit, flagged, and 15-cm (6-in) nails attached with marked metal tags were driven into the ground to enable finding their locations in subsequent years.

Roots along transects were originally harvested in July 2003 in Montana and September 2003 in Kansas. Our harvest times are typical because wild harvest of echinacea roots occurs whenever the price is high and whenever the ground is not frozen, with peaks in harvest when the plants are most evident in the summer due to blooming or in the fall due to prominent fruiting stalks. We returned to Kansas transects in the fall of 2004 to record presence of resprouted roots, and to both Kansas and Montana transects in July and September 2005, respectively, to destructively collect data by reharvesting and unearthing roots two years after the original harvest.

Despite careful marking and the use of a GPS device, there was considerable difficulty in relocating harvested plants, especially at Kansas transects where heavy cattle grazing produced considerable disturbance of the soil, vegetation, and flags. Grazing of leaves very early in the spring was also observed at these sites. In 2005, all previously harvested roots that could be found were redug to determine if the roots had resprouted. Conclusive evidence occurred when we observed a narrow, young, and lighter-colored shoot emerging from the residual larger root that had previously been severed (Fig. 2). New seedlings were easily distinguished from resprouts because they are slow growing and small, have root hairs, and are not attached to a larger root.

All data were entered into a Microsoft Excel database file and analyzed using SPSS (SPSS 2003). We used a T-test to determine whether resprouted roots had larger diameters or greater length than those that failed to resprout.

Results

All Kansas transects were revisited 12 months after harvest (in September 2004). An estimated 60% of the plants appeared to be resprouts, but we knew that this figure was high as we were not able to tell without destructive harvest and examination if we were observing seedlings or resprouts in some cases. Therefore, we report only 2005 results from reharvesting our Kansas and Montana sites two years after the original harvest. At the Kansas transects, all the plants that had been observed to resprout in 2004 survived until their 2005 reharvest. At least one plant went dormant for an entire growing season after the 2003 test harvest, with evidence of an initial resprout in spring 2005. Some plants sent up a second or third sprout during their second year of growth following root harvest.

In Kansas, 261 plants were harvested from all transects in 2003. Of these, only 173 could be relocated in 2005, primarily due to heavy grazing and disturbance by cattle at two transects. Eighty-six plants resprouted, while 87 died after harvest. In Montana, 392 plants were harvested from all transects in 2003. Of these, 328 plants were relocated in 2005 and 165 plants resprouted while 163 died after harvest.

Variation in Root Resprouting

During the 2003 harvest at our Kansas site, we noted that 13 roots that we dug had resprouted after a previous commercial harvest. These roots

Fig. 2. Dried *Echinacea angustifolia* root showing young flowering shoot emerging in the lower left of photo from juncture with the larger root that had remained in the ground after the original harvest. Plant from our field research site near Miles City, Montana.

were distinguished by having an upper, smaller diameter portion attached to a lower, larger diameter section. We knew that root harvesters had been working in this area during the last few years. Of these 13 plants, 7 were relocated two years later and all had resprouted again. In contrast, we also observed that at initial harvest, root-borer larvae had damaged six plants at our Kansas transects. Five out of six of these plants did not resprout.

Transects within Kansas had different soil types and grazing history. Resprout percentages showed statistical differences between transects and ranged from 36 to 85% (mean=50%) (Table 1). For Montana, resprout percentages ranged from 11 to 76% (mean=49%) (Table 2). The highest resprout percentage in Montana was at a transect where 25 of 33 echinacea plants resprouted. This was the only site in which a shovel was used to harvest roots, but soil was not put back in the holes. This practice allowed the plants to have a shorter distance for resprouts to reach the soil surface. The Montana transects resprouting percentages were statistically different from each other whether this shovel-dug transect was included or not.

Root Reserves Related to Resprouting

The length of root harvested (from the base of the crown to the point where the root was severed during harvest) was significantly different ($p < 0.001$) between all resprouted roots and those that died. The resprouted plants had less distance to reach the soil's surface (mean=11.72 cm), and had less root material removed from the ground compared to those that died (mean=14.47 cm to reach the soil's surface). The data for Kansas and Montana transects considered separately confirm the overall result ($p=0.037$ and $p<.001$, respec-

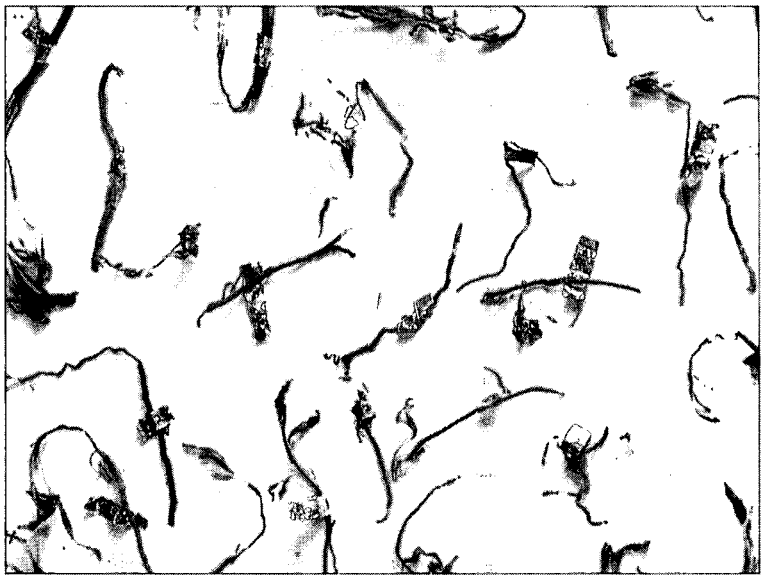

Fig. 3. Dried roots of resprouted *Echinacea angustifolia* harvested from a typical Buck Mountain Ranch field site near Miles City, Montana, showing mixed sizes of tagged larger roots and dried sprouts emerging from the juncture where the root had been harvested two years before.

TABLE 1. COMPARISON OF NUMBER OF ECHINACEA ANGUSTIFOLIA PLANTS THAT RESPROUTED VERSUS THOSE THAT DIED TWO YEARS AFTER SUMMER HARVEST FOR TRANSECTS IN NORTH-CENTRAL KANSAS.

Kansas Transects		
	Resprouts	Plants That Died
Buster A	10	18
Buster B	10	9
Buster C	11	11
Buster D	20	22
GLC A13	11	
GLC B	17	3
Wassinger	5	13
Total:	86	87

Mean resprout rate: 49.7%.

tively) (Fig. 4). In contrast, the diameter of roots that resprouted (mean=6.91) versus those that died (mean=7.12) was not statistically significant ($p=0.358$). There were also no significant differences between diameters of resprouted vs. dead roots at either Kansas ($p=0.132$) or Montana sites ($p=0.97$) (Fig. 5).

Discussion

Remarkably, almost exactly 50% of plants harvested at both Kansas and Montana sites resprouted. This may be even more surprising due to the fact that rainfall was below normal for the year of harvest and the following year in Kansas, and substantially below normal for the year following harvest at the Montana locations. The Montana study sites were designated as being in a stage of drought 102 out of 118 weeks (86%) during the study, while the Kansas sites were only in drought for 35 weeks (29%) (data from U.S. Drought Monitor at http://drought.unl.edu/dm/monitor.html).

The harvest of about 30 million roots of *Echinacea angustifolia* during the peak harvest years of 1998–2001 could have a major impact on the medicinal plant's conservation status and harvest sustainability. The ability of half of the plants in this study to resprout after being harvested an average of 11.72 cm below the soil surface is remarkable and dramatically affects any estimate of the post-harvest populations and their long-term survival. Most other tap-rooted perennial plants do not have this consistent ability to resprout after a significant portion of their root is removed. We have also observed this resprouting ability in *E. atrorubens* Nutt. and *E. pallida*, but do not know how prevalent it is. *Echinacea purpurea* and *E. sanguinea* Nutt. most likely do not have the ability to resprout, as they are fibrous-rooted species.

THE ABILITY TO RESPROUT

We have observed the ability of *E. angustifolia* to resprout at two widely disparate areas within its range. The proportion of resprouting plants in our Kansas and Montana transects varied from 11 to 76%, reflecting various soils, slope, moisture content, and other environmental factors. There is likely to be variation among individual plants in their ability to resprout. All seven harvested roots at Kansas transects that showed evidence of previous harvest before our original experimental harvest in 2003 had resprouted by 2005. One plausible reason for *E. angustifolia* to resprout after extensive damage may be an evolutionary one—to recover from insect or animal damage or from dying back after erosion. The Plains pocket gopher (*Geomys bursarius*) was observed near some echinacea populations, as was damage by the hooves of livestock. We also observed that the roots of *E. angustifolia* plants growing on limestone slopes sometimes become exposed by erosion and die back to the ground.

TABLE 2. COMPARISON OF NUMBER OF ECHINACEA ANGUSTIFOLIA PLANTS THAT RESPROUTED VERSUS THOSE THAT DIED TWO YEARS AFTER SUMMER HARVEST FOR TRANSECTS IN EASTERN MONTANA.

Montana Transects		
	Resprouts	Plants That Died
A1	13	12
B1	12	27
B2	17	17
C1	15	13
C2	23	23
D1	18	15
D2	2	16
E1	14	24
E2	26	15
F	25	8
Total:	165	170

Mean resprout rate: 49.2%.

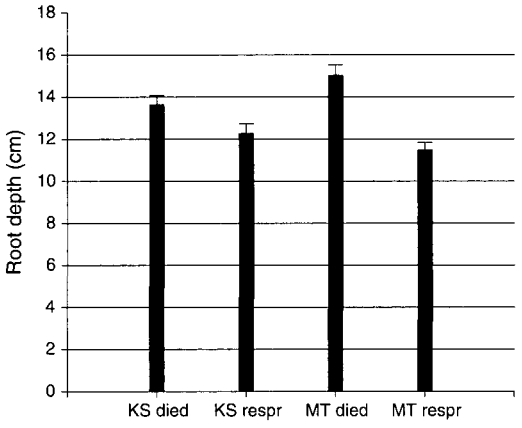

Fig. 4. Comparison of root length removed (approximate depth of the root harvested) from *Echinacea angustifolia* plants that died compared to plants that resprouted two years after summer harvest in north-central Kansas and eastern Montana. T-test for comparing data within each state. Root depths (shown with standard error) were significantly different for Montana ($p<0.001$) and for Kansas sites ($p=0.037$).

The holes left by harvesters who used shovels and did not fill them in has been disturbing to range managers concerned about their livestock being injured by tripping on them when running, and by conservationists who were concerned about disturbance, disease, and noxious weeds (Kolster 1998). The one transect in which we used a shovel to harvest roots and left holes had the highest resprouting percentage of all Montana transects sampled (76%). These holes did not cause root rot or disease, although rainfall was below normal. In fact, the holes may have served as small reservoirs to capture the sparse moisture that did fall on this site.

Echinacea Conservation

Concerns related to overharvest of wild *E. angustifolia* roots will most likely continue because wild populations still provide a substantial supply of the market. For a wild plant that is harvested from Texas to Montana with little monitoring, it is difficult to determine exactly how many roots are being harvested, although industry reports (AHPA 2000, 2003) have been helpful. Determining that root harvests are only killing half of the plants suggests potential recovery of these populations, even after severe harvests. Full population recovery would require a period of at least two years without harvest plus the combination of root resprouting, seed bank germination, and small plants reaching flowering size. The loss of flowers could also negatively affect populations of the Dakota skipper butterfly (*Hesperia dacotae*), a candidate for the Endangered Species list, for which echinacea flowers are a major nectar source (Cochrane and Delphey 2002).

The market for wild *E. angustifolia* root has been inconsistent, including years with low price or no market, which helps give populations time to recover. The conversion of rangeland to cropland and encroachment by development appears to be the greatest ongoing population threat. Educating harvesters and consumers on sustainable echinacea harvest strategies of remaining stands (such as visiting stands only every few years and leaving plants of all age classes) would be very useful. According to our data, encouragement of harvesting shorter lengths of roots could also be beneficial, as it would result in higher rates of resprouting. Promoting sustainable harvest strategies would probably be more effective in conserving *Echinacea angustifolia* stands than trying to regulate harvest over millions of hectares of sparsely-populated rangelands. Monitoring should be in place to observe population changes for both widespread and rare *Echinacea* species, especially in years when advertisements are posted for buying echinacea roots. When these want ads appear, they are a signal that the demand for echinacea root is on the upswing, and it is time to monitor and reexamine the impact of wild harvesting on echinacea

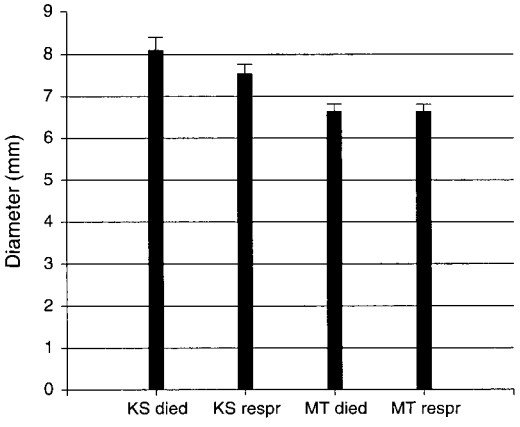

Fig. 5. Comparison of root diameter means (with standard errors) of *Echinacea angustifolia* plants that died versus those that resprouted two years after summer harvest in north-central Kansas and eastern Montana. T-tests were conducted separately for each state. There were no significant differences between these two groups in Montana ($p=0.97$) and in Kansas ($p=0.132$).

populations. Knowing that resprouting is a significant factor in continued viability of echinacea populations can be useful for those concerned about determining its potential overharvest. Research on the factors that encourage resprouting, the percentage of resprouting in other species, and its long-term implications on plant health and population dynamics would be very useful.

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