Echinacea: Cultivation and Medicinal Value

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Summary. *Echinacea* species, a popular medicinal herb throughout the world, have been used by indigenous Americans for hundreds of years as an effective immunostimulant. The cultivated acreage in the United States and Canada is increasing because of the great demand for *Echinacea* products. Better cultural methods and standardization and quality control of the value-added products are needed to increase the confidence of growers, producers, and consumers in this promising medicinal herb. *Echinacea* can be propagated from seed, crown division, and root sections. Seed stratification for 4 to 6 weeks at 34 to 40 °F (1 to 4 °C) before planting can improve germination. *Echinacea* thrives under cultivation in moderately rich and well-drained loam or sandy loam soil with regular irrigation and weed control. Roots are harvested in the fall after 3 to 4 years of cultivation. The best stage to harvest flowers has yet to be determined. Leaves are a source of valuable active ingredients, but no information is available in the literature on leaf harvesting. Active ingredients in *Echinacea* include polysaccharides, flavonoids, caffeic acid derivatives, essential oils, polyacetylenes, and alkylamides.

Echinacea, commonly known as purple coneflower (Fig. 1), is a North American native plant used for medicinal purposes by indigenous Americans. It is used externally for snake or insect bites and burns (Busing, 1952; Hill et al., 1996) and internally for coughs, colds, sore throats, infections, and inflammations (Hobbs, 1989, 1994). Extensive laboratory and clinical research on *E. angustifolia* in the last few years in Germany has confirmed its immunostimulatory, antiviral, and antibacterial benefit to humans (Bauer and Wagner, 1991; Bodinet and Beuscher, 1991; Bodinet et al., 1993; Parnharm, 1996). *Echinacea* research is currently conducted in many countries including United States, Canada, Norway (Dragland et al., 1993), Romania (Muntean et al., 1993), Finland (Galambosi et al., 1992), Russia (Porada and Rabinovich, 1991), and New Zealand (Parmenter et al., 1996).

The consumption of *Echinacea* has soared to a record high in Europe and North America (Rawls, 1996). *Echinacea* products are the bestselling medicinal health remedies in the United States, with a market share of 9.9% of the medicinal herbal industry (Rawls, 1996). Most commercial cultivation is in the western United States and Canada. The two most popular species are *E. purpurea* (80%) and *E. angustifolia* (20%); the latter has higher market value. *E. purpurea* is also widely planted as an ornamental in gardens (Brown, 1986) and grown commercially for cut flowers (Starman et al., 1995).

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Fig. 1. ***Echinacea pupurea*, purple coneflower.**

Botany and description

Echinacea species are winter hardy [–13 to –40 °F (–25 to –40 °C)] and drought resistant (Chapman and Auge, 1994; McGregor, 1968). It produces stout, hairy, either single or branched stems 12 to 40 inch (30 to 100 cm) in height. Leaves are 6 to 12 inch (15 to 30 cm) long, ovate to lanceolate, rough, hairy and three- to five-veined; the upper leaves are sessile while the lower leaves have long petioles [2 to 11 inch (5 to 27 cm)] (McGregor, 1968; Oliver et al., 1995). Depending on species, root form varies from single taproot to fibrous (Awang and Kindack, 1991; Foster, 1991).

Plants flower in the second or third year, occasionally in the first year if seedlings are started indoors early in the season. Mature *Echinacea* plants bloom from early summer to early fall and produce more than one inflorescence per plant. Flowering heads are single at the end of stems with a ray (ligules strap-shaped, two- or three-notched at the end) and disc (corolla expanding below into a fleshy bulb-like base) florets (McGregor, 1968; Hobbs, 1994). Ray floret color ranges from white or yellow to pink, rose, or purple, with an elevated cone of disk florets in the center.

Fernald (1959) reported that *Echinacea* plants produce many flower heads, with rays mostly drooping, pistillate but sterile. McGregor (1968) claimed that plants of all *Echinacea* species are self-incompatible. He further indicated that ray flowers are sterile and disk flowers are fertile when cross-pollinated. I have also observed self-incompatibility.

Cultivation

In the last few years, supplies of *Echinacea* collected from wild plants have not met increased demand in Europe and North America. Thus, commercial cultivation is increasing rapidly. However, information on cultural methods and their effect on growth, yield, and chemical composition is very limited. Different species and different growing regions will provide unique responses. For example, *E. angustifolia* endures more heat than *E. purpurea* but is more sensitive to soil pH and soil moisture (Hobbs, 1989). Based on my experience with other medicinal plants, I suspect that, with optimal cultural techniques and management, we should be able to maximize the concentration of active ingredients in *Echinacea* species.

Seed and propagation

Echinacea can be propagated from seed, crown division, and by planting 4- to 5-inch-long (10- to 12-cm) root sections (Feghahati and Reese, 1994). Seeds sown outdoors immediately after ripening in the fall will germinate the following spring. However, emergence rate is affected by the degree of seed dormancy, which varies with species. Baskin et al. (1992) reported that a period of cold stratification is required to break dormancy in seeds of *E. angustifolia*. Salac and Traeger (1982) reported that November sowing is best for *E. angustifolia*, giving 75% emergence compared to 2% to 49% after sowing in other months. *Echinacea pallida* has a higher seed emergence rate than *E. purpurea* when fall sown; however, the situation is reversed for spring sowing (Smith-Jochum and Albrecht, 1987).

Seedling emergence from direct-seeded fields may not be as uniform as germinating indoors after stratification. Wartidiningsih et al. (1994) indicated that chilling stratification in water at 40 or 50 °F (5 or 10 °C) for 4 d increased germination of *E. purpurea* in the field. The length of the stratification period also affected germination. Parmenter et al. (1996) reported that *E. angustifolia* seeds stratified for >2 weeks can achieve a maximum germination of 65% to 80% in the field, whereas seed germination rate of *E. purpurea* was not affected by length of stratification. In contradiction, Bratcher et al. (1993) reported that the germination rate of *E. purpurea* increased with duration (peaked at 4 weeks) of stratification. Feghahati and Reese (1994) concluded that a 2-week prechill treatment at 39 °F (4 °C) combined with ether (0.1 mM) and continuous light, followed by a 2-week period under light (16-h day) at 77 °F (25 °C), could induce >95% seed germination of *E. angustifolia*.

Seed treatments before planting can improve germination. Samfield et al. (1991) reported that priming *E. purpurea* seeds for 6 or 9 d in distilled water at 61 °F (16 °C) or in 50 mM potassium phosphate buffer (pH 7.0) resulted in faster, more uniform germination. Furthermore, seedlings from primed seeds had a 44% to 51% increase in total root area (Finnerty and Zajicek, 1992). Gibberellic acid (GA_3 at 1 mM) during *E. purpurea* seed priming enhanced emergence rate and synchrony, seedling shoot dry weight, and petiole and lamina lengths of the first true leaf (Pill and Haynes, 1996).

Wartidiningsih and Geneve (1994) reported that seed size and inflorescence position did not affect seed germination; however, seeds harvested at physiological maturity, before senescence, had a higher germination rate than seeds harvested after desiccation. They also reported that seed source accounted for most variation of *E. purpurea* germination, and ranged from 81% to 91% to 39% to 66%. Long-term seed storage at room temperature for 3 years (T.S.C. Li, unpublished data) and salinity of the growing medium (Lee et al., 1995) reduced germination rate.

Based on my experience, the best method for seed stratification is to mix seeds with clean sand (1:1 ratio, v/v) in a plastic bag and maintain moisture at 10% during 4 to 6 weeks of stratification at 34 to 39 °F (1 to 4 °C). After seeds are separated from sand, they can be sown on the surface or 0.25 inch (0.5-cm) deep in flats or small pots filled with a mixture of 1 peat : 1 perlite (v/v). Seeds in flats held at 64 to 68 °F (18 to 20 °C) should start to emerge within 7 to 10 d. Seedlings should be grown in a greenhouse or indoors with supplementary light until transplanting. *Echinacea purpurea* has ≈116,800 seeds/lb (257,000 seeds/kg) and *E. angustifolia* has up to 145,000 seeds/lb (319,000 seeds/kg). About 1.1 lb (0.5 kg) of seed is required to provide transplants for 1.2 acre (0.5 ha) (Oliver et al., 1995).

Cell cultures

Various laboratories around the world have obtained cell or callus cultures derived from seeds (Sicha et al., 1991) or protoplasts (Al-Atabee and Power, 1990) by using in vitro techniques. Polysaccharides from *E. purpurea* cell cultures have been investigated for immunochemical properties with some success (Roesler et al., 1991; Schollhorn et al., 1993; Steinmuller et al., 1993). Khibas (1995) claimed that selecting from somaclonal variation in *Rudbeckia purpurea* (*E. purpurea*) to produce a novel plant that can be propagated via tissue culture is more efficient than conventional breeding techniques.

Soil, nutrition, and irrigation

In the wild, *Echinacea* plants typically grow in poor, rocky soil under full sun. However, they thrive under cultivation in moderately rich and well-drained loam or sandy loam soil, which is neutral to slightly acid (pH 6 to 7). *Echinacea* is drought tolerant; however, soil moisture is important for better growth (Franz, 1983). Regular irrigation is recommended for some regions (T.S.C. Li, unpublished data).

Information on the nutrient requirements of *Echinacea* is very limited. In general, high fertilization produces a high shoot yield but low root yield (Franz, 1983). A balanced fertilizer, low in nitrogen with an adequate amount of phosphorus and potassium ($1N–2P_2O_5–1K_2O$) should be sufficient (Oliver et al., 1995). Hobbs (1989) reported that bone meal or phosphatic rock [13 to 18 lb/acre (14.5 to 20 kg/ha)] and wood ash [40 to 46 lb/acre (45 to

51.5 kg/ha)] applied before sowing and cow or horse manure after planting in three applications was the best combination of organic fertilizer for growing *Echinacea*. Li (1994) reported that adding fish fertilizer ($5N–2P_2O_5–2K_2O$) at 0.14 oz/34 oz ($4\ mL·L^{-1}$) of soil increased the growth of *E. purpurea*. Besides manure, a green cover crop such as quinoa (*Chenopodium quinoa* Willd.) (Li, 1996), stinging nettle (Li, 1994), red clover (Hobbs, 1989), or composted municipal waste (T.S.C. Li, unpublished data) also increased growth.

Recently, organic and inorganic fertilization experiments were conducted in greenhouses for 6 months (T.S.C. Li, unpublished data). In the inorganic trial, eight treatments with a combination of four N levels (2, 4, 8, and 16 mM) and two phosphorus levels (0 and 12 mM) were applied. Nitrogen applications at 16 mM increased fresh and dry weight of leaves, flowers, and roots, while phosphate application only increased fresh and dry weight of leaves. In the organic fertilizer trial, a combination of BC Pork compost (Abbotsford, British Columbia), Aldergrove biowaste (Consolidated Envirowaste Industries Inc., Aldergrove, British Columbia), and Zeolite (Princeton, British Columbia) was applied as a soil amendment. BC Pork compost and Aldergrove biowaste increased fresh and dry weight of leaves, and zeolite had no effect on growth.

Transplanting and spacing

Echinacea growers have commonly raised seedlings indoors and transplanted to the field in spring. This practice results in better growth than direct-seeded plants (Smith-Jochum and Albrecht, 1987). The transplant survival rate of *E. pallida* seedlings may be enhanced by precise timing of planting in the fall or early spring; Kemery and Dana (1995) reported that 57% survival of *E. pallida* seedlings was observed with April plantings compared to 9% survival of September plantings. Traditionally, *Echinacea* plants have been grown on flat beds, but growth in raised beds has been reported to increase field establishment (Smith-Jochum and Albrecht, 1988). *Echinacea* may be directly seeded in the nursery for 2 years before being transplanted to the field in the spring ≈45 cm apart in rows (Stockberger, 1927).

Muntean et al. (1992) reported that planting *E. pallida* at 20 inch (50 cm) between rows and 12 inch (30 cm) between plants within the row [26,700 plants/acre (66,000 plants/ha)] gave the highest dry root yield—≈1,200, 4,600, 7,300, and 8,500 lb/acre (1.3, 5.1, 8.2, and 9.5 t/ha) in the first, second, third, and fourth years, respectively. Our recommendation is to plant 12 inch (30 cm) apart within and between rows, five rows/bed [50 inch wide (120 cm)] and allow 12 inch (30 cm) between beds, which gives ≈30,500 plants/acre (75,000 plants/ha). This is a maximum density, and it may be too dense if more vigorous species are used or if the plants are kept >4 years.

Mulch and weed control

Echinacea is not weed tolerant; thus, weed control is an important factor for a better growth. For organically grown *Echinacea*, instead of time-consuming hand weeding, black plastic or bark mulch is the best weed control measure, especially for newly established plantings. Plastic mulch can decrease the labor cost for weed control by 70% to 80% and produce a 114% increase in fresh plant weight (Galambosi and Szebeni-Galambosi, 1992). If seeding outdoors, a mulch of clean straw [0.8 to 1.2 inch (2 to 3 cm)] over the seed is considered essential. Bark mulching should be done immediately after planting with large size bark pieces [0.8 to 1.6 inch (2 to 4 cm)] to enable the surface to dry out and create conditions unfavorable for weed germination (Grantzau, 1987). Land preparation, at least 1 year before planting, is another way to get rid of perennial weeds and reduce the annual weed population. Galambosi and Szebeni-Galambosi (1992) reported that a row distance of 20 to 24 inch (50 to 60 cm) allowed weed control with a lawnmower but did not indicate the effect of this practice on yield.

No herbicides are registered for *Echinacea* in Canada. In other countries, herbicides available to control weeds include metolachlor (Derr, 1993, 1994), DCPA (chlorthal dimethyl), oxadiazon (Derr, 1994), pendimethalin, oryzalin, and terbacil (Hartley, 1993).

Yield

Normally the roots do not reach desirable size until 3 to 4 years after sowing. The root yield from *E. angustifolia* can be 2,200 lb/acre (2,500 kg/ha) (Hobbs, 1989). Galambosi et al. (1992) reported that *Echinacea* was cultivated as a biennial plant in Finland. The seedlings were grown indoors for 5 to 6 weeks, then transplanted into the field with a plant density of 1 to 2 plants/ft² (6 to 8 plants/m²), and the total phytomass at the end of the second year ranged from 0.6 to 1.2 lb/ft² ($3\ to\ 6\ kg·m^{-2}$) with 12% fresh root weight.

Disease and insect control

Disease does not seem to be a problem with the *Echinacea* spp. (Hobbs, 1989). Only three diseases have been reported: leaf spots caused by either *Cercospora rudbeckii* PK. or *Septoria lepachydis* Ell. & Ev. and a root rot caused by *Phymatotrichum omnivorum* (Shear) Dug. (Westcott, 1960). Three virus diseases are cited for *Echinacea*: cucumber mosaic, broad bean wilt (Schmelzer et al., 1975), and mosaic (Westcott, 1960). A mycoplasma-like organism was found in *E. purpurea* with flower phyllody symptoms (Muller et al., 1973).

Since *Echinacea* is traditionally organically grown, chemical control of diseases is not an option. Therefore, prevention is the best disease control measure. Early detection and careful removal of infected plants are important. Dense plantings may increase the incidence of fungal problems, especially if plantings are protected from the prevailing wind (Oliver et al., 1995). Biological control methods are available from Russia. A bioproduct, Bactofit (*Bacillus subtilis* strain IMP-215), was successfully tested against fungal and bacterial diseases of *E. purpurea* (Bushkovskaya et al., 1994).

Very few cases of insect or wild animal damage have been reported in *Echinacea*. Williams (1995) reported that larvae of *Chlosyne gorgone* (nymphalid) were observed feeding on the upper surfaces of leaves of *E. pallida*. *Ligyrocoris barberi* was identified as a seedbug (Sweet, 1986).

Nematodes are estimated to reduce yields an average of 10% annually (McKeown and Potter, 1994). Reductions in growth and yield may result from the invasion of nematodes alone or combined with other pests including fungi. *Pratylenchus penetrans* was found under *E. purpurea* in Ontario, Canada (McKeown and Potter, 1994).

Harvest

The best time to harvest *Echinacea* has yet to be determined. Heinzer et al. (1989) reported using the growth pattern of roots and aerial parts during the first 12 months of cultivation to decide the best time to harvest. Muntean et al. (1992) reported that the optimum time for annual harvesting of *E. pallida* herbage was during flowering and that of the root was in the third year of growth.

Normally, roots are harvested in the fall after first frost has occurred, then washed and dried in the air or in a forced-air dryer. Flowers can be harvested at ≈20% bloom when the ray flowers start to droop or when the pollen on the cone has reached 20% of the distance to the apex (Oliver et al., 1995). The best stage to harvest flowers during flowering and the best time to harvest during the day are yet to be determined. Leaves are a source of valuable active ingredients, but no information is available in the literature on the harvesting of leaves and its effect on growth of the roots.

Value-added products

Many value-added health remedy *Echinacea* products are available from health-food stores and pharmacies. The products are in the forms of dry root, capsules, tablets, crude extracts, or tincture, mainly from *E. purpurea* and *E. angustifolia*. Other forms such as injectable preparations are available only in Germany (Awang and Kindack, 1991). *Echinacea* products can also be found combined with other medicinal herbs. Product labels are not allowed to have any specific therapeutic claims. Standardization of the active ingredient extracts and quality control of the products are urgently needed to build consumer confidence.

Chemical composition

Ever since the first report of traces of a colorless alkaloid of *Echinacea* was published by J.U. Lloyd in 1897 (Hobbs, 1994), much laboratory research has been conducted, especially in Germany. Alkylamides (Schultheis et al., 1991), caffeic acid derivatives (Bauer and Foster, 1991), polysaccharides (Bauer and Wagner, 1991; Bonadeo et al., 1971), and polyacetylenes (Bauer et al., 1988; Schulte et al., 1967) are the most important and promising active ingredients in *Echinacea*. The contents of these active ingredients vary with different species. With TLC and HPLC fingerprints, Bauer et al. (1988) were able to distinguish between *E. pallida* and *E. angustifolia* based on polyacetylenes, polyene, and caffeic acid derivatives.

Interest in the chemicals derived from new plant sources for the cosmetics industry is increasing. Recently *Echinacea* was selected as a natural source for essential oil (Delabays and Slacanin, 1995). The content of essential oil varies among *Echinacea* species (Bomme et al., 1992a, 1992b), ranging from 0.1% (*E. angustifolia*) to 2% (*E. pallida*) in the roots (Neugebauer, 1949). The major essential oil components are sesquiterpene derivatives, borneol, and alpha-pinene (Bauer and Wagner, 1991).

Echinacein isolated from *E. angustifolia* and *E. pallida* is reported to contain a mosquito larvicide (Jacobson, 1967). Echinolone, a naturally occurring insect growth regulator from the roots of *E. angustifolia*, was reported for its juvenile-hormone activity in *Tenebrio molitor* L. (Jacobson et al., 1975; Tarnopol and Ball, 1972).

Medicinal uses

Since the early twentieth century, *Echinacea* has been widely used as a health remedy (Gilmore, 1911). A German physician, H.F.C. Meyer of Pawnee City, Nebr., learned the healing virtues of *Echinacea* from natives and introduced it to the medical profession (Hobbs, 1994). Tinctures or crude extracts from *E. angustifolia* have been used to treat insect bites (Hill et al., 1996) and snake bites (Busing, 1952), for wound healing (Seidel and Knobloch, 1957), infections, and inflammations (Hobbs, 1994), and also as an effective immunostimulant (Pamham, 1996).

From the medicinal perspective, *E. angustifolia* and *E. purpurea*, two of the most popular species on the market, have similar ingredients, including polysaccharides, flavonoids, caffeic acid derivatives, essential oils, polyacetylenes, and alkylamides. Several water-soluble polysaccharides isolated from *Echinacea* species have immunostimulatory and anti-inflammatory effects (Bauer and Wagner, 1991; Tubaro and Tragni, 1987). The leaves of *E. purpurea* and *E. angustifolia* have been shown to contain the flavonoid quercetin at 0.38% and 0.48%, respectively (Bauer and Wagner, 1991; Christ and Muller, 1960). Caffeic acid derivatives are the most important compounds in *Echinacea* for medicinal value. In the early 1950s, echinacoside was first isolated from roots and flowers (Stoll et al., 1950). Later, cichoric acid and chlorogenic acid were isolated and proved to have pharmaceutical properties (Hobbs, 1989).

Echinacin, an *Echinacea* extract, has also been used as a veterinary medicine to improve the fertility of cows (Fischer, 1976) and as a treatment for acute parenchymatous mastitis (Otto, 1982), puerperium in cows (Heimsoth, 1976), and respiratory diseases in horses (May, 1994; Wolter, 1977).

Conclusion

Echinacea is one of the bestselling medicinal herbs in the world. It is an effective immunostimulant officially recognized by European countries such as Britain, France, and Germany as a therapeutic drug. It is consumed by millions of people around the world to combat cough, cold, flu, and sore throats. In North America, *Echinacea* is available widely and sold as a health remedy. Cultivation of *Echinacea* has been increasing rapidly due to the huge market demand and a shortage of supply from wild plants. Information on cultural methods, suitable species, and growing regions and their effect on growth, yields, and chemical composition is very limited. Farmers are eager to learn the best cultural management to improve yields and provide top-quality products, and producers are anxious to improve methods of standardization for quality control.

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