Turk J
Field Crops
2015, 20(2), 174-178
DOI: 10.17557/tjfc.68776

THE EFFECTS OF PLANT DENSITY AND YEAR ON YIELD OF PURPLE CONEFLOWER (*Echinacea purpurea* (L.) MOENCH)

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Received: 06.05.2015

ABSTRACT

Purple coneflower, one of the most popular medicinal plants, is not naturally found in Turkey. Here, Purple coneflower plants were grown in the Cukurova Region of Turkey and the effect of plant density and year on the herb yields were studied. Plants were harvested in June, 2011 and 2012 as second and third seasons of growth in Cukurova. Since flowering plants were not available for one-year-old plants in 2010. Purple coneflower were harvested at the aerial parts when the flowering time at the 2nd and 3 nd season, roots were harvested in fall. Although the weight of different aerial parts and roots per plant (g plant^{-1}) were not changed according to different plant densities (30×90, 45×90, 60×90 cm) these parameters were changed according to the years. Also, fresh weight of herb (g plant^{-1}), dry weight of flowers (g plant^{-1}) and number of main stems (number plant^{-1}) were not changed in pertinent to years and plant densities. Fresh yield of herb, fresh yield of stem, fresh yield of leaf, dry yields of stem, dry yields of leaf, number of seconder buds (kg ha^{-1}) had differences according to plant densities and years.

Key words: ***Echinacea purpurea*, plant year, plant density.**

INTRODUCTION

Purple coneflower is widely cultivated for medicinal preparations. Medicinally all parts of the plant may be used, but the leaves and flowers or the root/crown tissues are often extracted and used in capsules and tinctures (Binns, 2002; Li, 1998).

McGregor, (1968) reported the classification system of the genus *Echinacea* contains nine species and four varieties, all native to North America. Among them, *E. angustifolia* DC., *E. purpurea* (L.) Moench, and *E. pallida* have been widely used as dietary supplements (Kindscher et al., 2008; Li, 1998). In recent years, *E. purpurea* has become the primary species for field cultivation so its product and characteristics were extensively studied. (National Center for Biotechnology Information, 2011). This may be due to less effort is required for its cultivation, resulting from the little or no seed dormancy in commercial seed lots (Qu et al., 2005; Qu and Wirdlechner, 2012), relatively rapid growth, and broad adaptation to various soil types (Li, 1998).

The market demand of Purple coneflower material was initially provided by collecting from natural plants. But the increasing uses for herbal products has enhanced the field cultivation of these species the last decade (Dall'Acqua et al., 2010; Li, 1998). Purple coneflower is not naturally found in Turkey but its leaves, flowers and roots from the small scaled cultivation are exported (Cebi, 2013). Although the cultivation of Purple coneflower has been expanded in formation regarding the effects of genetic diversity, growing condition climates and cultivation practices on active constituents (e.g. caffeoyl derivatives) and production of Purple coneflower are still very limited (Chen et al., 2008). Therefore, this study could be important in terms of its agronomic management, to maximize yield in field cultivation.

In addition determination as the effects of plant density and plant maturity at harvest of foliage, flowers, and roots on yields is significant as well as, the effects of foliar and flower harvesting on subsequent root development (Callan, 2005).

Purple coneflower is not a good weed competitor in its first year, during the summer months, weed control is critical during the first year; clean cultivation between rows is desirable, with hand weeding within the row as necessary. The ideal field density of Purple coneflower has been controversial, ranging from 6070 to 22258 plants per ha. Some commercial sellers of Purple coneflower plugs have advocated much higher planting rates (Anonym, 2009).

The purpose of this study was determined the effect of plant density and year on the yield of different parts of Purple coneflower.

MATERIALS AND METHODS

Plant material

Seedlings of Purple coneflower were obtained from the Atatürk Horticultural Central Research Institute, Turkey in 2010.

Methods

Plants were grown under field conditions, at the Research Station of the in Field Crop Department, Faculty of Agricultural, Çukurova University in Adana from 2010 to 2012. This location, in southern Turkey, has a typical Mediterranean-type climatic conditions (latitude 36° 42\` N and longitude 26° 45\` E and at 23 m asl). Mean daily maximum, minimum temperatures and annual rainfall at this site in 2011 and 2012 were 29.3 °C, 8.48 °C, and 628 mm, 30.2 °C, 9.9 °C and 1034.3 mm respectively (Anonym, 2013). The means of maximum temperatures and total rainfall from beginning sprouting to flowering period (April-June) in 2011 and 2012 were 31.9, 36 ºC and 180.9, 109.8 mm respectively.

Seedlings were transplanted at three different densities (30×90, 45×90 and 60×90 cm) into plots (3.60x6.30 m sized) on May 20, 2010. Each plot contained seven rows. Plots were hand-weeded and sprinkler irrigated as needed to maintain vigorous plant growth. Flowering is delayed, and occurred in September 2010, at this time, plants was dwarf and the optimum density was not reached. Therefore, data taken from the plants harvested in 2010 were not analyzed. Plants developed were harvested in June 2011 and 2012 second and third seasons of growth. Plants were harvested by cutting to about 5cm above ground level 2nd and 3nd season during in full flowering stage on June 26, 2011 and 2012. So ten plants were harvested from each plot for collecting data. Also, in order to determine two plants from each plot were harvested on November 14, 2011 and 2012 washed and air dried for three weeks in shade. Root harvesting were performed when plants were dormant, when leaves begin to turn brown. Plant lengths were measured from ground to tip in the longest stem at the harvest time. Harvested plants were separated by hand into stems, leaf, flower buds and flowers.

Field trials were arranged in Randomized Complete Block design with 3 replications. The collected data over two years were statistically analyzed using Anova technique according to the split-plot design where plant densities as main plot and years as sub-plot, the means were compared by using the LSD test (Steel and Torrie, 1980). Year was considered as independent factor because Purple coneflower is perennial plant.

RESULTS AND DISCUSSION

Since, full flowering plants were not available in first year, the data of obtained from the second and the third years were presented here.

The higher fresh and dry biomass weight per plant (except for flowers) with fresh and dry biomass yields per unite area were found for in plant spacing of 30×90 cm spacing (3703.3 number of plant da^{-1}), in the second year (Table 1, 2, 3, 4, 5, 7). Falk et al. (1999) and Kleitz et al. (2003) reported that in row plant spacings of 30.5, 45.7, 61 cm had higher plot yields of Purple coneflower at the 30.5 cm spacing (358780 number of plant ha^{-1}). Yields of herb, stem and leaf were changed significantly depending on the years and plant densities (Table 4).

Table 1. Plant height and fresh weight per plant of different plant parts of Purple coneflower (g plant^{-1})

Plant Densities	Plant Height (cm)			Fresh Weight of Herb (g plant^{-1})			Fresh Weight of Flower (g plant^{-1})			Fresh Weight of Bud (g plant-^{1})			Fresh Weight of Stem (g plant^{-1})			Fresh Weight of Leaf (g plant^{-1})		
(cm)	Years			Years			Years			Years			Years			Years		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
30x90	114.7	96.0	105.4	941.1	567.0	754.0	221.0	165.7	193.3	36.0	16.3	26.2	395.7	218.3	307.0	288.3	154.1	221.2
45x90	111.2	94.9	103.1	882.9	645.7	764.2	205.0	163.0	184.0	38.6	25.7	32.1	383.0	243.7	313.3	256.3	215.0	235.7
60x90	108.7	91.4	100.1	921.6	676.3	798.9	250.7	202.0	226.3	35.4	28.3	31.9	374.5	234.0	304.3	261.0	192.7	226.8
Mean	111.5a	94.1b	102.8	915.1a	629.7 b	772.4	225.6	176.9	201.2	36.6a	23.4b	30.1	384.4a	232.0b	308.2	268.5a	187.3 b	227.9
LSD (%5)	9.40		NS	214.4		NS	NS		NS	5.0		NS	89.1		NS	64.3		NS

Table 2. Dry weights per plants of different plant parts of Purple coneflower (g plant^{-1})

Plant Densities (cm)	Dry Weight of Herbs (g plant^{-1})			Dry Weight of Flower (g plant^{-1})			Dry Weight of Bud (g plant^{-1})			Dry Weight of Stem (g plant^{-1})			Dry Weight of Leaf (g plant^{-1})		
	Years			Years			Years			Years			Years		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
30x90	288.8	202.0	245.4	42.7	54.0	48.4	16.0	12.7	14.3	161.4	93.7	127.6	68.7	41.7	55.2
45x90	279.1	201.0	240.1	40.7	44.3	42.5	20.9	11.7	16.3	150.8	96.7	123.7	66.8	48.7	57.7
60x90	273.6	210.0	241.8	45.5	53.3	49.4	15.8	12.3	14.1	146.5	99.0	122.8	65.8	46.0	55.9
Mean	280.5 a	204.3 b	242.4	43.0	50.6	46.8	17.5 a	12.2 b	14.9	152.9 a	96.4 b	124.7	67.0 a	45.4 b	56.3
LSD (%5)	73.9		NS	NS		NS	4.6		NS	41.2		NS	14.6		NS

Table 3. Numbers of flowers bud, stem and seconder stem of Purple coneflower (number plant^{-1})

Plant Densities	Numbers of Flowers (number plant^{-1})			Number of Buds (number plant^{-1})			Number of Main Stems (number plant^{-1})			Number of Seconder Stems (number plant^{-1})		
(cm)	Years			Years			Years			Years		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
30x90	29.1	25.7	27.4	25.3	14.1	19.7	16.5	17.6	17.1	31.3	17.3	24.3
45x90	28.8	25.6	27.2	31.5	23.3	27.4	19.2	18.3	18.8	35.3	24.4	29.8
60x90	32.2	28.6	30.4	25.2	23.5	24.3	18.0	19.6	18.8	33.3	22.6	27.9
Mean	30.0 a	26.6 b	28.3	27.3 a	20.3 b	23.8	17.9	18.5	18.2	33.2 a	21.4 b	27.4
LSD (%5)	11.9		NS	4.3		NS	NS		NS	10.1		NS

Table 4. Fresh yield of different plant parts of Purple coneflower (kg ha^{-1})

Plant Densities	Fresh Yields of Herb (kg ha^{-1})			Fresh Yields of Flower (kg ha^{-1})			Fresh Yields of Bud (kg ha-^{1})			Fresh Yields of Stem (kg ha^{-1})			Fresh Yields of Leaf (kg ha^{-1})		
(cm)	Years			Years			Years			Years			Years		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
30x90	34854	20536	27695 a	8185	6136	7160 a	1334 a	605 c	970	14656	8086	11370 a	10679	5709	8193 a
45x90	21800	15983	18892 b	5062	4025	4543 b	952 b	634 c	793	9457	6016	7736 ab	6329	5309	5818 b
60x90	17067	12167	14617 c	4642	3741	4191 b	656 c	525 c	590	6935	4333	5634b	4833	3568	4200 b
Mean	24574 a	16229 b	20401	5963	4634	5298	981 a	588 b	784	10349 a	6145 ab	8247	7281 a	4862 b	6071
LSD (%5)	1049.0		416.0	NS		154.1	12.4 (int) 21.44		NS	686.0		447.4	187.0		179.3

In calculation from Table 1 and Table 7, The higher weight of fresh herb + root (4.1 kg m^{-2}) was found for spacing 30×90 cm (3.7 plant m^{-2}), in the second year. Galambosi (1992) reported fresh biomass (herb + root) as 4.5 kg m^{-2} for spacing 40×40 cm (6-7 plant m^{2}). Fresh biomass decreased significantly with increased in intra row-spacing from 30 to 60 cm (Table 4). Callan et al. (2005) have stated that very dense plant populations (over 15 plants per m^{2}) resulted in high biomass production.

Plant height (cm) and fresh herb weight (g plant^{-1}) were decreased significantly in 2012 as compared to second year (2011) (Table1). Galambosi et al. (1992) reported that Purple coneflower was cultivated as a biennial plant in Finland. Plant height in third years could be adversely affected by maximum temperature of, 53 ºC in June 2012 (Anonym, 2013). The higher plant height (115 cm) was obtained due to abundant rainfall in April-June months in 2011.

Table 5. Dry yield of different plant parts of Purple coneflower (kg ha^{-1})

Plant Densities	Dry Yields of Herb (kg ha^{-1})			Dry Yields of Flower (kg ha^{-1})			Dry Yields of Bud (kg ha^{-1})			Dry Yields of Stem (kg ha^{-1})			Dry Yields of Leaf (kg ha^{-1})		
(cm)	Years			Years			Years			Years			Years		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
30x90	10696	7481	9088 a	1581	2000	1791 a	591	469	530 a	5979	3469	4724 a	2544	1543	2043 a
45x90	6892	4963	5927 b	1005	1095	1050 b	515	288	401 a	3723	2387	3055 b	1649	1202	1425 b
60x90	5067	3889	4477 c	842	988	914 b	293	228	260 b	2714	1833	2273 b	1219	852	1035 c
Mean	7552	5444	6487	1143	1361	1252	466	329	397	4139 a	2563 b	3351	1804 a	1199 b	1501
LSD (%5)	NS		131.9	NS		31.7	NS		13.6	128.3		85.8	42.4		38.8

Table 6. Numbers of flowers, bud, stem and seconder stem of Purple coneflower (number ha^{-1})

Plant Densities	Numbers of Flowers (number ha^{-1})			Number of Buds (number ha^{-1})			Number of Main Stems (number ha^{-1})			Number of Seconder Buds (number ha^{-1})		
(cm)	Years			Years			Years			Years		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
30x90	1076543	953086	1014802 a	937037 a	522222 c	729567	612346	650617	631433 a	1157967	641933	899950 a
45x90	711934	632922	672400 b	776954 b	576132 c	676500	473251	452675	462917 ab	870533	602400	736467 b
60x90	595679	529012	562300 b	466666 c	434568 c	450567	332716	363580	348083 b	616049	417867	516933 c
Mean	794719	705007	749834	726886 a	510974 b	618878	472771	4888957	480811	881500 a	554067 b	717783
LSD (%5)	NS		27910.0	9187.0 (int)15910.0		NS	NS		18900.0	30200.0		16230.0

The numbers of main and secondary stems per unite area changed significantly as influenced by plant density although the numbers of main and secondary stems per plant were not changed (Table 3, 6). The average of main stem two years (18.2 number plant^{-1}) was similar to the value reported by Starman et al. (1995). *E. purpurea* grows taller (to 150 cm), branches more and has wider leaves than *E. angustifolia* and *E. pallida* (Hobbs, 1989). The minimum acceptable stem length for marketing as a cut flower was reported by Barr (1992) as 40.6 cm.

We observed a few plants infected with Aster yellows disease in our experiment in second and third years. Aster yellows disease is more likely to be recognized in second or third year crops. Symptoms include yellowing or reddish-tinged foliage, stunting, and abnormal flowering, with flowers becoming malformed, and losing their purple pigment (Anonym, 2009; Muller et al., 1973). Aster yellow did not damage at harvesting time in June in the Çukurova conditions but aster yellow type mycoplasma-like organisms caused damage only aerial part of plants towards to the last mid-August with high temperature and moisture.

Table 7. Yields and weight of roots of Purple coneflower (g plant^{-1})

Plant Densities	Fresh Weight of Root (g plant^{-1})			Dry Weight of Root (g plant^{-1})			Fresh Yields of Roots (kg ha^{-1})			Dry Yields of Roots (kg ha^{-1})		
(cm)	Years			Years			Years			Years		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
30x90	188.3	125.0	156.7	79.3	53.3	66.3	6975	4630	5803	3722	1975	2849
45x90	181.7	168.3	175.0	76.7	48.3	62.5	4486	4156	4321	1893	1770	1832
60x90	176.7	116.7	144.6	78.3	71.7	74.9	3272	2160	2716	1451	895	1173
Mean	182.2	136.6	159.4	78.1	57.8	67.9	4911	3649	4279	2205	1547	1876
LSD (%5)	NS		NS	NS		NS	NS		NS	NS		NS

The higher the number of flowers (101480.2 number ha^{-1}), yields of fresh (7160 kg ha^{-1}) and dry flowers (1791 kg ha^{-1}) per unite area, weight of fresh and dry flowers per plant were found for the 30 cm in spacing (Table 4, 5, 6). Similar tendency for the effect of plant spacing (30 cm spacing) at yields of flowers were reported by Kleitz et al. (2003).

The mean of fresh roots in the second year (4911 kg ha^{-1}) was higher than (3649 kg ha^{-1}) value of third years while yields and weight of fresh roots of Purple coneflower were not changed significantly for years and spacing (Table 7). Since they grow underground and smaller roots may break off and remain in the soil, decreasing biomass, as reported (Kleitz et al., 2003). Plant density can have a major effect on plant form (Harper, 1977), and these effects can change the root proportions (Parmenter, 1997).

The higher root yield (5803 kg ha^{-1}) was found for spacing 30×90 cm (Table 7). This indicated that root yield could be increased by increasing plant density above the 8 plants per m^2 as recommended in Germany (Anonymous, 1986). However, although high plant density maximizes yield, and is likely to help suppress weeds, it carries some risks (Parmenter, 1997). High plant densities increased the danger of fungal rots such as those caused by *Sclerotinia* spp., especially in combination with heavy soils, poor drainage in the absence of beds or of ridging, or wet and humid conditions (Fry, 1982). But in our conditions number of plant per plot did not reached the risky levels.

CONCLUSION

Purple coneflower can be grown successfully under the Cukurova conditions. Based on the results of this study under the Cukurova conditions, (30×90 cm) spacing of Purple coneflower resulted in the higher yields in comparing to the 45x90 cm and the 60×90 cm spacings. Therefore, high plant density or narrow plant spacing could be recommended for high plant yield. Under the Cukurova conditions where the Mediterranean type climate prevail with has hot and drought summer and mild rainy winters consequently, growth rates were accelerated and covered spacing of 30×90 cm but, at the other plant spacing the same effect was not observed such as, plants did not covered inter rows spacing even in the later growing years.

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