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THE EFFECT OF DIFFERENT HARVEST DATES ON THE YIELD AND QUALITY OF THE GOLDEN THISTLE (*Scolymus hispanicus* L.)

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ABSTRACT

The objective of this study was to determine the yield and quality characteristics of golden thistle (*Scolymus hispanicus* L.) harvested at different maturity stages. The trial was arranged in the Randomised Complete Block Design under the ecological conditions of Izmir, Turkey in 2017 and 2018 growing seasons and the plants were harvested from November to August at 10 monthly periods. Root lenght (cm), root yield (kg ha^{-1}), root bark yield (kg ha^{-1}), dry root bark yield (kg ha^{-1}), root collar diameter (mm), root xylem diameter (mm), cortex thickness (mm), taraxasterol rate (%) taraxasterol acetate rate (%) were determined. The highest root and root cortex yields were obtained from the plants harvested in july, the average of two years as 19770.64 kg ha^{-1} and 6480.65 kg ha^{-1}, respectively. The highest taraxasterol and taraxasterol acetate rates were obtained in May harvest as 0.042% and 0.015% in two years respectively.

Keywords: Golden thistle, harvesting time, quality, yield

INTRODUCTION

Golden thistle (*Scolymus hispanicus* L.) is called as golden thistle and it also has different local names. Golden thistle is naturally distributed in Aegean, Marmara, Black Sea, Mediterranean and Central Anatolia Regions of Turkey (Baser, 1993; Baytop, 1999; Davis, 1982; Ertug, 2004). As golden thistle commonly found at many geographical areas, it is commonly consumed as a food in Aegean Region. Root barks and fresh rosettes are usually the parts that are used in many traditional ways (Ugurlu and Secmen, 2008). Its root barks and fresh rosettes are consumed as food in Western Europe (Flymen and Afolayan, 2006; Tardio et al., 2006). The use of golden thistle in Europe is very old and dates back to 11^{th} century (Abak and Duzenli, 1989; Lentini and Venza, 2007). It is known that the golden thistle is used in some soups and special meals in Cyprus, Spain and Italy (Guarrera, 2003; Paraskeva and Hadjichambis, 2006; Pieroni et al., 2002; Polo et al., 2009; Tardio et al., 2005).

Besides its culinary usage, golden thistle has some medicinal characteristics. Its roots and above ground parts are handled as the aims of diuretic and kidney stone expelling (Baytop, 1999). Golden thistle is one of the licensed plants for medicine production. The medicine obtained from its roots is licenced under the name of “Lityazol Cemil”. The strong effect of the medicine on kidney stone, pelvis renalis stone, ureter and bladder stones are observed with clinical experiments. The medicine “Lityazol Cemil” is commercialy produced in a factory in Manisa for 60 years, later its production was abandoned due to shortage of raw material (Baser, 1993).

Its effect for expelling the kidney stones is derived from the tripertene saponins called taraxasterol and taraxasterol acetate. After a while, when these active substances are taken orally, they cause sudden spasms and relaxations on gastral and nephritic route. It is estimated that the effect of expelling the kidney stones is caused by this situation (Kirimer et al., 1997). Besides, it is reported that the plant has some anti-artic, anti-bacterial, anti-herpetic, anti-inflammatory, anti-spasmotic characteristics because of the glycosides, bioactive nitrogen compounds, cafeol, flavonoid, rosmarinic acide and beta carotene which are present in the roots and the leaves of the golden thistle and it has also some anti-tumour effect on colon, kidney and lung cancers (Esiyok et al., 2004).

Similar to Turkey, in the countries such as Spain, Italy, Portugal, Cyprus, Russia and Ukraine the plant is collected from the nature. The studies in Turkey about cultivating the golden thistle had some successful results and the first field production in the world was achieved. Breeding activities in this plant was started in the near past, as a result of the breeding activities in 2018, a variety called “Sari” is registrated. In İzmir province the golden thistle is cultivated on an area of 100 ha^{-1}.

In a study conducted by Cicek et al. (2013) on sowing time of the plant shows that the late autumn and winter sowings the seeds are not successful due to low soil temperatures. Spring sowings the seeds were germinated with an inadequate root growth in spring sowing. So, it was stated that the favorable sowing time of golden thistle is summer months (Cicek et al., 2013). Generally when the seeds are sown in August, the first harvest is done in November and then the plants can be harvested until the end of February. But the root growth continues until summer, this situation causes drastic yield loss. The objective of the present study was to determine the root yield and active ingredient alterations of golden thistle on different harvest times in Menemen-Izmir/Turkey ecological conditions.

MATERIALS AND METHODS

The field experiment was conducted at the research and experimenatl unit of of the Aegean Agricultural Research Institute located at Menemen-Izmir/Turkey in 2017 and 2018 growing seasons. Izmir province, at located in the Western Turkey, has typical Mediterranean climatical conditions. The highest temperature in the area was recorded as 27.4 ºC in July in 2016, 30.2 ºC in July in 2017 and 27.9 ºC in August in 2018 (Table 1.). The total annual precipitation was 688.5 mm, 601.8 mm and 659.0 mm in 2016, 2017 and 2018, respectively. (Anonymous, 2018).

Table 1. Long term mean temperatures(ºC) and total precipitation (mm) at Menemen-Izmir location

Climate Factors	Years	Months												
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
Average Temperature (C^0)	2016	5.3	11.4	10.8	16.3	18.3	26.2	27.4	27.1	22.7	17.3	11.8	10.6	17.8
	2017	6.5	10.9	13.7	17.2	22.3	27.3	30.2	29.8	25.1	19.4	12.5	12.7	19.6
	2018	8.1	11.3	14.7	18.3	23.1	25.1	27.8	27.9	23.9	18.6	14.5	9.6	18.6
	Long Yeras	9.2	11.8	13.7	17.4	22.7	26.8	29.8	29.2	25.4	19.3	10.1	10.2	19.3
Precipitation (mm)														Total
	2016	241.3	88.2	128.6	28.9	37.8	2.4	0.0	0.5	9.2	0.8	128.2	22.6	688.5
	2017	238.7	59.4	78.7	18.2	27.5	2.2	0.0	0.0	1.6	25.3	67.3	82.9	601.8
	2018	113.8	140.0	62.2	3.8	16.0	74.4	0.0	0.8	19.0	18.2	98.6	105.0	659.0
	Long Yeras	173.4	77.6	72.5	32.3	42.7	19.6	0.7	6.9	7.2	45.8	73.5	54.8	607.0

Experimental area is located 28 m above the sea level with mild Mediterranean climate conditions. Soil texture of the experimental area is generally a composition of silty-clay. The 30 cm depth of soil was silty-clay with pH of 7.45 and organic matter medium amount with 2.3% in the experimental field (Table 2.)

Table 2. Some physical and chemical characteristics of the soils of the experimental sites

Soil Depth	Texture (%)	Salinity EC_{25} (mmhos/cm)	pH	Lime (%)	Organic Matter (%)	P (ppm)	K (ppm)
0-30 cm	55	0.30	7.45	3.84	2.30	27	598
	Ca (ppm)	Mg (ppm)	Fe (ppm)		Mn (ppm)	Cu (ppm)	Zn (ppm)
	4816	410	4.55		4.28	0.90	1.13

Cultivar "Sari" of the plant golden thistle (*Scolymus hispanicus* L.), which was developed by Aegean Agricultural Research Institute, and registrated in 2018, was used as plant material in this study. Seeds were sown on August 30 directly to the field in both growing years. The seeding rate was 1500 g ha^{-1}. In two years fertilization was performed at the rate of 500 kg ha^{-1} with composition of 15.15.15. for N P K as composed fertilizer. After seeding drip irrigation system was installed in the trial area and was irrigated until November twice and two hours long per week. The trial was arranged according to the Randomized Complete Blocks Design with four replicatioons. The all experimental treatments were consisted of 4 rows of 5 m long, (5x4 m= 20 m^2). Spacing between rows was 1 m. Two rows in every plot were harvested by hand, the measurements and evaluation were done and calculated as total yield of one hectare. The roots of the plant were harvested from November until August for 10 months, variations of yield (root lenght, root yield, root bark yield, dry root bark yield, root collar diameter, root xylem diameter, cortex thickness) and quality (taraxasterol and taraxasterol acetate) were determined. Golden thistle plants in the field trial and their messured parts are shown in Figures 1-4.

For the analysis of the active ingredients taraxasterol and taraxasterol acetate, firstly the calibration curves were formed. Standart substance chromatogram of taraxasterol was obtained in 10-11 seconds and the standart substance chromatogram of taraxasterol acetate was obtained in 15.5-16.5 seconds.

Figure 1. Golden thistle (*Scolymus hispanicus* L.) trial plots

Figure 2. Harvested golden thistle (*Scolymus hispanicus* L.) roots

Figure 3. Root cortex and root xylem of golden thistle (*Scolymus hispanicus* L.) roots

Figure 4. Edible parts of golden thistle (*Scolymus hispanicus* L.) roots

The cortex tissue (5 g) was pulverised and extracted for four hours under the cooler which repels with 70% ethanol. The solvent of filtred extract was removed on rotary evaporator, than it was solved in 70% ethanol to fill until 10 mL in volumetrik flask. The solution was filtred through 0.45 μm pore fliter and after it was injected to the High Pressure Liquid Chromatograph (10 μL).

Working conditions of High Pressure Liquid Chromatograph

Equipment: Shimadzu LC20 A Prominence serial Detector: Shimadzu ELSD (60 °C, gain 6, nitrogen pressure 350 kPa). Column: GL Sciences C18 (150 x 4.6 mm, 5 μ). (Mobile phase: A, Methanol: B) THF (0% B per minute to %15 B). Flow rate: 1 mL/min.

The statistical analysis of variance for all the measured characters was performed according to the Randomised Complete Block Design by using the MSTAT-C package program. Significant characteristics of harvest time means compaired using average over years. Two-way table were used comparing for characters with significant harvest time x year interaction. Comparison of the means was done according to LSD (5%) test as described by (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The results of analysis of variance of golden thistle (*Scolymus hispanicus* L.) are shown in Table 3. It could be seen in Table 3 that the mean squares for root yield, cortex yield, dry cortex yield, taraxasterol rate and taraxasterol acetate rate were statistically significant; however, root lenght, root collar diameter, root xylem diameter and cortex thickness were not significant for years. All the characteristics (root lenght, root yield, cortex yield, dry cortex yield, taraxasterol rate and taraxasterol acetate rate, root collar diameter, root xylem diameter and cortex thickness on individaual plants) were statistically significant. The interaction variance of harvest time x year were significant for root lenght, root yield, cortex yield, dry cortex yield and taraxasterol acetate rate, whereas taraxasterol, root collar diameter, root xylem diameter and cortex thickness were not significant.

Characteristics with year x harvest date interaction are shown in Table 4 and traits without year x harvest date interaction are shown in Table 5. It could be seen in Table 4 that the root length value increases from the November to May, reaches the highest value in May and after June it decreases again. The shortest root length was obtained in November (22.17 cm and 22.45 cm) and the longest root length was obtained in May (34.82 cm and 36.50 cm). (Table 4.). Sari et al. (2011) found the mean root length as 24.13 cm in the first year and as 23.75 cm in the second year in their study. The root growth of the plant continues until generative maturity, it stops on flowering period (Sari et al., 2011). The transition to generative period begins generally in May, so the root length growth was found as expected.

Root yield was, statistically significant for the years and harvest dates. The lowest mean were obtained in November in the first year with 7250.02 kg ha^{-1} and the highest root yield was obtained in the first year with 19940.95 kg ha^{-1} in July. In both years, the lowest root yield was obtained in November (7250.02 kg ha^{-1} and 7300.37 kg ha^{-1}) and the highest root yield was obtained in July (19940.95 kg ha^{-1} and 19600.40 kg ha^{-1}) (Table 4.). Cicek et al. (2013), reported the mean root yield of golden thistle (*Scolymus hispanicus* L.) as 12010.3 kg ha^{-1} under the Menemen ecological conditions. In general assessment root yield, increased with delayed harvest dates. It was observed that the root growth continues until July, while at the seed maturation period in August, the plant formed rosettes, the roots begin to become thin and lose their weight. This is considered to be the main reason of the decreasing root yields in August. Salter (1980) and Lana (2012) examined the relation between harvest time and root yield in carrot, they stated that the root yield increases with delaying harvest time. Heidari et al. (2008), Ozturk et al. (2008) and Sefaoglu et al. (2016) studied the change of root yield according to the harvest time in sugar beet. They reported the highest root yield in November, the latest harvest, from the harvests of September, October and November. The root yield means of the plants of are similar the results of our study.

The cortex yield had significant F values for the years and harvest dates. Like root yield, with delaying harvest dates cortex weight increases as well. The lowest cortex weight values were obtained in November for the first and second year as 3910.70 kg ha^{-1} and 3520.25 kg ha^{-1}, respectively. The highest cortex yield was obtained in July for the both years as 6380.00 kg ha^{-1} and 6590.30 kg ha^{-1}, respectively. The mean cortex yield was 5200.67 kg ha^{-1} in the first year and 5260.70 kg ha^{-1} in the second year. The lowest cortex yield was obtained in November harvest (3710.70 kg ha^{-1} and 3520.25 kg ha^{-1}) and the highest cortex yield was obtained in July harvest (6480.00 kg ha^{-1} and 6590.30 kg ha^{-1}) (Table 4.). Cicek et al. (2013) reported the mean cortex yield as 6000.70 kg ha^{-1} in their study which was lower than our result.

Table 3. Results of analysis of variance combined over two years for characteristics observed in trial conducted in 2017 and 2018

Source of variation	d.f.	Root length (cm)	Root yield (kg ha^{-1})	Cortex yield (kg ha^{-1})	Dry cortex yield (kg ha^{-1})	Taraxesterol (%)	Taraxesterol acetate (%)	Root collar diameter (mm)	Root xylem diameter (mm)	Cortex diameter (mm)
Year	1	0.002^{ns}	11165.175**	727.218**	1462.905**	3.362*	3.781*	3.21602 ^{ns}	4.4604013 ^{ns}	1.3030513 ^{ns}
Harvest time	9	150.823**	1590384.2**	50850.233**	1794.413**	0.0012417**	1.515**	120.46781**	162.27758**	19.89871**
Harvest time x year	9	2.554**	9498.796**	715.798**	101.404**	9,212 ^{ns}	2.164*	11.0908 ^{ns}	1.6677 ^{ns}	0.0172 ^{ns}
Error	57	0.589	454.993	77.834	5.635	5.451	8.054	13.722359	1.5885	0.7128

*: significant at the p≤0.05 probability level
**: significant at the p≤0.01 probability level
ns: not significan

Table 4. Means of the root length, root yield, cortex yield, dry cortex yield and taraxasterol acetate at different harvest dates of golden thistle (*Scolymus hispanicus* L.)

Harvest dates	Root Lenght (cm)			Root Yield (kg ha^{-1})			Cortex Yield (kg ha^{-1})			Dry Cortex Yield (kg ha^{-1})			Taraxasterol acetate (%)		
	2017	**2018**	**Mean**	**2017**	**2018**	**Mean**	**2017**	**2018**	**Mean**	**2017**	**2018**	**Mean**	**2017**	**2018**	**Mean**
November	22.17i	22.45i	22.31	7250.02n	7300.37n	7270.70	3910.70k	3520.25l	3710.97	710.20n	740.02n	720.61	0.001b	0.001b	0.001
December	25.60gh	25.60gh	25.60	7580.55n	7570.77n	7580.16	4550.62j	4580.12j	4560.87	840.85m	870.20lm	860.02	0.002b	0.002b	0.002
January	25.05h	26.40g	25.72	8850.72m	8890.02m	8870.37	4760.65i	4840.47i	4800.56	880.05lm	930.20k	900.62	0.003b	0.003b	0.003
February	28.35f	28.95f	28.65	9390.50ı	9470.87l	9430.68	5040.00h	5040.10h	5040.05	890.82l	970.75ij	930.78	0.004b	0.004b	0.004
March	31.60e	32.40d	32.00	10310.25k	11590.52j	10950.38	5180.37g	5250.45g	5210.91	960.87j	1030.35g	1000.11	0.005b	0.005b	0.005
April	33.55c	32.55d	33.05	13050.05i	13310.95h	13180.50	5420.70f	5490.82ef	5460.26	1000.05hi	1070.87e	1030.96	0.007b	0.007b	0.007
May	34.82b	36.50a	35.66	14060.57g	15500.10f	14780.33	5520.92e	5800.77d	5660.85	1070.20ef	1140.27c	1100.73	0.014a	0.015a	0.015
June	33.97c	33.32c	33.65	17380.32d	17800.57c	17590.45	6080.42c	6330.52b	6200.97	1070.40ef	1240.37b	1150.88	0.011a	0.011a	0.011
July	33.75c	32.37d	33.06	19940.95a	19600.40b	19770.67	6380.00b	6590.30a	6480.65	1100.87d	1350.95a	1230.41	0.011a	0.010a	0.010
August	32.60d	31.02e	31.81	17180.45d	16320.07c	16750.26	5180.32g	5190.20g	5180.76	1020.00gh	1050.85f	1030.92	0.009a	0.008b	0.008
Mean Years	**30.14**	**30.15**		**12500.34b**	**12730.96a**		**5200.67b**	**5260.70a**		**95.83b**	**1040.38a**		**0.0070a**	**0.0069b**	
Harvest Time LSD (5%)															
Harvest timex year LSD (5%)		**2.175**			**60.406**			**24.984**			**6.723**			**8.037**	

Means with the same letter are not significantly different at 5% probability level

Table 5. Means of taraxasterol, root collar diameter, root xylem diameter and cortex diamater at different harvest dates of golden thistle (*Scolymus hispanicus* L.)

Harvest dates	Taraxasterol (%)	Root collar diameter (mm)	Root xylem diameter (mm)	Cortex diameter (mm)
	Mean	Mean	Mean	Mean
November	0.005J	19.51D	7.83F	6.38B
December	0.008İ	22.62CD	8.97F	6.80B
January	0.012H	25.15BC	11.75E	7.68A
February	0.014G	30.47A	15.94D	8.42A
March	0.025F	32.76A	18.30C	8.17A
April	0.035B	25.34BC	20.73A	6.19B
May	0.042A	23.69C	18.94BC	4.50CD
June	0.032C	26.49BC	15.57D	5.11C
July	0.030D	24.88BC	14.63D	4.56CD
August	0.027E	28.88AB	19.93AB	4.14D
Mean Years				
Harvest Time LSD (5%)	**7.393**	**3.709**	**2.253**	**0.845**
Harvest time x year LSD(5%)				

Means with the same letter are not significantly different at 5% probability level

Besides, golden thistle (*Scolymus hispanicus* L.) has been used as a kidney stone expelling drug material as stated previously (Baser, 1993). The part of the plant used for drug raw material is the dry cortex, for that reason dry cortex yield were also recorded in our work. In a direct proportion to the cortex yield, dry cortex yield was found statistically significant for the years and harvest periods. Dry cortex yield was the lowest in November for the both years as 710.20 kg ha^{-1} and 740.02 kg ha^{-1}, respectively. The highest values of dry cortex yield were obtained in July in both years as 1100.87 kg ha^{-1} and 1350.95 kg ha^{-1}, respectively. The lowest dry cortex yield was obtained in November in the first year with 710.20 kg ha^{-1} and the highest dry cortex yield was obtained in the second year with 1350.95 kg ha^{-1} in July. The lowest dry cortex yield was obtained in November 710.20 kg ha^{-1} and the highest dry cortex yield was obtained in July (1350.95 kg ha^{-1}) in the second year (Table 4.). When the mean values were examined, it was seen that the dry cortex yield was 954.4 kg ha^{-1} in the first year and 1040.38 kg ha^{-1} in the second year (Table 4.).

Taraxasterol and taraxasterol acetate are pentacyclic triterpenoid and anti-inflammatory, anti-bacterial agents which are found in the roots of dandelion (*Taraxacum officinale*), roman daisy flowers (*Anthemis nobilis*) and many other plants (Xuemei et al., 2012). The highest taraxasterol acetate rate was obtained in May as 0.015% and the lowest taraxasterol acetate rate was found in November such as 0.001% (Table 4.). Sari et al. (2011) stated that the taraxasterol rate was between 0.001%- 0.041% , the taraxasterol acetate rate was between 0.001%- 0.014% in the cortex of 85 different golden thistle plants. The highest and lowest values of our study which are 0.005%- 0.043% and 0.001% - 0.015% are similar to the their findings. The taraxasterol acetate causes relaxation on the isolated mouse intestines, however a spasm occurs just before the relaxation (Kirimer et al., 1997). It was stated that the kidney stone expelling effect of golden thistle is caused by this relaxations and spasms. The plant is consumed mainly in the first year of its growth period and there are not any information about the age of the plant which is used by drug manufacturers so it shows that very few numbers of these active substances are enough to be effective at expelling the kindey stones. The highest taraxasterol rate obtained in May harvest as 0.042% and the lowest value was obtained in November harvest as 0.005%. When the mean values are examined, it was seen that they were 0.023% for the first year and 0.024% in the second year (Table 5.).

When the root collar diameters were examined, it is seen that the highest values of both years were in March as 32.71 mm and 32.81 mm. In both years, the lowest root collar diameters were obtained in November (19.50 mm and 19.52 mm) and the highest root collar diameters were obtained in March (32.71 mm and 32.81 mm). When we examined the two years together, the average root collar diameters values of the two years were the lowest in November (19.51 mm) and the highest in March (32.76 mm) (Table 5.). Sari et al. (2011) reported the root collar diameters of 360 individual plants as 25.95 mm and the root collar diameter of 170 individual plants as 28.11 mm. In this study, the means of two years were 26.18 mm and 25.78 mm which are similar to the study of Sari et al. (2011). Cicek et al. (2013) stated the root collar diameter of individual plants as 21.1 mm. This value was a little lower than our mean values of first and second years (26.18 mm and 25.78 mm) (Table 5.).

The highest root xylem diameter values were obtained in April harvest as 20.68 mm and 20.79 mm. The lowest mean were for the November harvest as 7.68 mm and 7.98 mm. The means of harvests were 15.50 mm and 15.02 mm, in the first and second years respectively. When we examined the two years together, the average root xylem diameter of the two years were the lowest in November harvest (7.83 mm) and the highest in April harvest (20.73 mm) (Table 5.). Since the cortex of the plant is used as drug raw material and as food a higher root xylem diameter is undesired. Therefore, the low root xylem diameter values of early harvests shows that the plant is more suitable to fresh consumption.

The cortex diameter was the highest in February harvest in both years as 8.29 mm ve 8.55 mm and lowest as 4.03 mm and 4.25 mm in August harvest. The cortex diameter is desired, in this study cortex diameter was higher in January, February and March harvest. The average cortex diameter of the two years were the lowest in Augustharvest (4.14 mm) and the highest in January, February and March harvest as follows (7.64 mm, 8.42 mm and 8.17 mm) (Table 5.).

CONCLUSIONS

In our study, as a result of an evaluation according to the harvest periods the highest root length has been obtained in July in both harvest years. The highest yield of wet root, wet cortex and dry cortex have been obtained in July. In the averages of taraxasterol acetate and taraxasterol which are the components used as raw material of drugs for the plant, the highest values were obtained in May. In the evaluation done in terms of the weight of single plant; wet root, wet cortex and dry cortex weight of single plant have been observed as the highest in the harvest of July. In the single plants, the highest root collar diameter has been observed in March, the highest root xylem diameter in April, the highest cortex thickness in February harvests. If it is prone to be used as the raw material for the drugs, then the harvest should be done during May when the active ingredients are at the highest point.

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