Europ. J. Agronomy 73 (2016) 118–123

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Growth response and active constituents of *Cynara cardunculus* plants to the number of leaves harvests

Hend E. Wahba[a], Atef Z. Sarhan[b], Adel B. Salama[a], Mahmoud A. Sharaf-Eldin[c,a,*], Heba M. Gad[a]

[a] *Department of Medicinal and Aromatic Plants Research, National Research Centre, 12622 Dokki, Egypt*
[b] *Ornamental Horticulture Dept., Faculty of Agriculture, Cairo University, Giza, Egypt*
[c] *Sara Alghonaim Research Chair, Biology Department, College of Science and Humanities, Prince Sattam bin Abdulaziz University (PSAU), 11942 Alkharj, Saudi Arabia*

ARTICLE INFO

Article history:
Received 1 June 2015
Received in revised form 16 October 2015
Accepted 5 November 2015
Available online 17 November 2015

Keywords:
Cynara
Chlorogenic acid
Flavonoids
Number of harvests
Polyphenols

ABSTRACT

Cardoon (*Cynara cardunculus*) is a highly promising medicinal plant that has been used to treat several diseases, but there remains a great need for research into both the agriculture and chemical composition of the plant. For this study, cardoon was cultivated for two successive seasons (2009/2010 and 2010/2011) at the experimental farm of the Faculty of Agriculture, Cairo University. Specifically, the study investigated the effect of numerous harvests of leaves (one, two, three and four harvests/cuts) on both the growth and the active constituents of *C. cardunculus* plants. Both the fresh and the dry weight of the harvested leaves were measured and the active constituents, such as carbohydrate, flavonoid, polyphenol and chlorogenic acid content, were measured. It was found that as the number of harvests increased (up to three harvests) the values of these parameters also increased in both seasons.

1. Introduction

1.1. Cardoon uses

Cynara cardunculus L. is a herbaceous perennial crop belonging to the family Asteraceae (Compositae) and commonly named cardoon. The cardoon plant is a prominent ingredient in worldwide and Mediterranean cuisine (Fratianni et al., 2007), especially in salads and/or soup dishes. Besides the use of flowers for cheese manufacturing, the leaves have different properties in traditional medicine, including as an antidiabetic, antimicrobial, choleretic, cholagogue, and diuretic (Fratianni et al., 2007; Krizkova et al., 2004). In recent years the plant has been commercially grown with a good and stable yield: its stem is used as lignocellulosic biomass for energy (Piscioneri et al., 2000; Raccuia and Melilli, 2007), while its seeds are a source of oil (both edible and for producing biodiesel) (Encinar et al., 2002). Furthermore, once the oil has been extracted from the seeds, the residual flour can be used as a protein rich animal feed (Fernandez and Manzanares, 1990; Foti et al., 1999; Maccarone et al., 1999). Cardoon has also been cultivated as a vegetable crop as the globe artichoke, mainly in Spain, Italy, France and Greece (Portis et al., 2005).

Koubaa and Damak (2003); Pinelli et al. (2007) have each studied the chemical composition of the leaves and seeds of *C. cardunculus*, with saponins, sesquiterpene, lactonens, flavones, sterols, coumarins and lignans all being shown to be present. In respect to pharmacologically active compounds, an inulin compound has been found in the root system of the cardoon plant (Raccuia and Melilli, 2004), while both cynarin and silymarin have been found in cardoon plant leaves (Curt et al., 2002). These latter two compounds are bitter tasting and are known to improve the function of both the liver and gallbladder, stimulating the secretion of digestive juices secretion, particularly bile. They also serve to lower blood cholesterol levels (Grammelis et al., 2008). Leaves rich in polyphenols have been traditionally used in European medicine on account of their known pharmacological properties (Perez-Garcia et al., 2000; Jimenez-Escrig et al., 2003). Recently, however, the cosmetics industry has also made increasing use of these polyphenolic compounds (Lupo, 2001; Peschel et al., 2006), and since the leaves last well in water they are also often used in flower arrangements.

* Corresponding author at: National Research Centre, Department of Medicinal and Aromatic Plants Research, 33 Elbehoth Street, Dokki 12622, Egypt. Fax: +20 1006053070.
E-mail addresses: sharafeldin99@yahoo.com, mahmoud.sharaf-eldin@fulbrightmail.org (M.A. Sharaf-Eldin).

http://dx.doi.org/10.1016/j.eja.2015.11.007
1161-0301/

1.2. The effect of number of leaf harvests (number of cuts) on growth and yield parameters

Mauromicale and Ierna (2000) found that when the harvesting of leaves was delayed from November to April, the head weight of the F_1 artichoke hybrid decreased. Salata and Buczkowska (2007), meanwhile, found that artichoke yields depended on the number of harvests, with clearly higher yields obtained when the leaves were cut twice (0.74 kg m^{-2}) or three times (0.65 kg m^{-2}) in a season rather than just once (0.46 kg m^{-2}). Matthes and Honermeier (2007) also studied the effect of harvest date on the leaf yield of the artichoke plant, finding that dry matter yields increased in line with increases in the growth period to reach a maximum at the fifth harvest, at which point the crop had completed 76 days of growth and sustained 92 days of vegetation. They also, stated that, the minimum yield, however, occurred during the first growth phase, which had the longest growth period (146 days of vegetation). Honermeier and Gottmann (2010), meanwhile, conducted two factorial field experiments with Green Globe artichoke in 2001–2003, harvest in the leaves three times per year. In this case, maximal leaf yield was observed with the first harvest (in 2001) but with the second harvest in 2002 and 2003. Field experiments to investigate the effect of harvest frequency and plant density on leaf yield and caffeoylquinic acids of artichoke were also carried out by Ali and Honermeier between 2006 and 2008, with a mixture of three, five and six harvests per year. The results show that lowest harvest frequency resulted in the highest leaf yield in all years, with these continuing to decrease as the harvest frequency increased (Ali and Honermeier, 2011).

1.3. The effect of number of leaf harvests (number of cuts) on chemical composition of leaves

The main chemical compounds in artichoke (*C. cardunculus* var. *scolymus*) leaves are polyphenolic compounds like caffeoylquinic acids and flavonoids. Constantinescu et al. (1967) showed that the concentration of the active constituents of the Romanian acclimatized *Cynara scolymus* depends on the time of harvesting and position of leaves. Netien and Roulier (1967) found that flavonoid and polyphenol contents in *Cynara scolymus* (Romanian strain) varied with plant age, and those plants 9–10-months-old were most suited for pharmaceutical purposes. Variations in the active constituents in artichoke leaves have also been shown to be dependent on the physiological state of the plant and locality of the sample. Hammouda et al. (1993) suggest that *Cynara scolymus* is best harvested three times in a season to optimise the leaf content of active constituents. Matthes and Honermeier (2007), meanwhile, conducted field experiments to show that an early harvest date has a positive effect on the quality of polyphenolic compounds. Depending on harvest time and location, three to five leaf harvests per year are possible. Their results showed that as the number of harvests increased the concentration of chlorogenic acids decreased but that concentrations of cynarosides showed a more variable trend in respect to the harvest dates, with the maximum concentration occurring at the third harvest (62 days of vegetation), a steady decrease until the thirteenth harvest (118 day of vegetation) and then an increase until the fifteenth harvest (146 days of vegetation). Salata and Buczkowska (2007) added that the content of polyphenolic acids in leaves obtained from a three-fold harvest (in early August, September and October) and from a two-fold harvest (in early of September and October) was over 50% higher than that from a single harvest (in early October). The content of flavonoids in the artichoke leaves varied from 0.23 to 0.36% depending on number of harvests. Honermeier and Gottmann (2010) also found that the concentration of polyphenolic compounds (Coffeoylquinic acids, flavonoids) in the leaves of *C. cardunculus* is significantly influenced by the time of harvest. Also, field experiments to investigate the effect of harvest frequency on leaf yields and coffeoylquinic acids of artichoke were carried out from 2006 to 2008, with results showing higher Coffeoylquinic acid content in the leaves obtained with a lower harvest frequency, associated with longer periods of vegetative growth (Sajid, 2011).

The aim of this study was to investigate the effect of the number of leaf harvests on yield and chemical composition of *C. cardunculus* as a new plant under the local conditions of Egypt.

2. Materials and methods

This work was carried out during two successive seasons in 2009/2010 and 2010/2011 at the Experimental Farm of the Agriculture Faculty, Cairo University, Giza. The main weather information for Giza, Egypt is given in Table 1. *C. cardunculus* seeds were obtained from Dr. Helmut Junge, ABiTEP GmbH, Berlin, Germany. Dr. Junge purchased the seeds from Jelitto GmbH, Germany.

2.1. Nature of soil

Samples were taken from the soil before cultivation, and were subject to physical and chemical analysis in the Soil Science Department, National Research Centre, according to the method of Jackson (1973), with the results being as follows:

Physical properties: clay 22.0% (dry matter), silt 51.0%, sand 26.4%, organic matter 0.6%, soil texture (sandy loam).

Chemical properties: pH 8.0, E.C. (dS/m^{-1}) 1.15, available N 1.40% (dry matter), available P 0.83%, available K 0.27%.

Cations: (Milliequivalent/L) Ca^{2+} 12.2, Mg^{2+} 3.7, Na^{+} 0.27, K^{+} 0.27.

Anions: (Milliequivalent/L) CO_3^{2-}0.0, HCO_3^{-} 1.1, Cl^{-} 1.4, SO_4^{2-} 13.5.

2.2. Soil preparation for cultivation

During both seasons, the soil was mechanically ploughed and planked twice. To prepare the soil for cultivation a mixture of calcium superphosphate (15.5% P_2O_5) at the rate of 476 kg ha^{-1} was added as a source of phosphorus and mixed well manually to the soil.

2.3. Cultivation procedures and maintenance

For propagation, the seeds were sown in plastic bags of 23 × 18 cm in a medium of sand and clay (1 sand: 1 clay) under a sun screen. The uniform healthy cardoon seedlings (60 day old) were transplanted into the field according to a Complete Randomized Block Design (CRBD) with three replicates in the first week of

Table 1
Average values of main weather variables in Giza[a].

Feature	January	February	March	April	May	June	July	August	September	October	November	December	
T (°C)	13.4	14.8	17.4	20.9	24.4	27.0	27.8	27.7	26.0	23.5	19.2	15.2	21.4[1]
SH (h)	212	221	242	278	314	371	358	334	310	298	229	202	3369[2]
RF (mm)	5.1	3.4	2.3	1.1	0.6	0.1	0.0	0.0	0.0	1.1	3.5	6.7	23.9[2]

[a] Source: Meteorological data of Giza (CLAC, Egypt), average values from 2009 to 2011; SH—sunshine hours; RF— rainfall; [1]—average, [2]—total.