Cynara cardunculus L. as a Potential Industry Crop

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Abstract

Fourteen *Cynara cardunculus* L. accessions were compared in order to evaluate fresh total aboveground biomass production as well as its partition into leaves, stalks and capitula at the anthesis stage. For each botanical variety, percentages of dry matter were also calculated. An ANOVA was performed and mean values were compared by Duncan's test. Euclidean distances were calculated and a cluster analysis was performed. Total fresh biomass and all its components showed significant differences among accessions ($p<0.001$). The total fresh biomass ranged between 1188 and 3235 g/plant and its partitioning was strongly affected by the botanical variety. Cluster analysis showed three main groups, one including two cultivated cardoons, a second one, three globe artichoke cultivars, whereas a third one, grouping all wild cardoons together with three cultivated cardoons and two globe artichoke accessions. In both cardoon cultivars, the percentage of dry matter ranged between 30 to 35% for all components of aboveground biomass, whereas in globe artichoke values ranged between 20% for capitula to 40% for leaves. The low inputs management required, adaptability to the local conditions, and the results obtained in the present study suggest the suitability of *C. cardunculus* as a source to be exploited as an industry or energy crop.

INTRODUCTION

Cynara cardunculus L. is a perennial species which comprises three botanical taxa: *C. cardunculus* var. *scolymus* (globe artichoke), *C. cardunculus* var. *altilis* (cultivated cardoon) and *C. cardunculus* var. *sylvestris* (wild cardoon) (Lanteri and Portis, 2008). The adult plants of this species exhibit vigorous development and many studies report on their possible explotability for the production of biomass for energy use. Studies in this way started in the 1980s (Fernández, 1990). The possible use of *C. cardunculus* as an energy and industrial crop requires the evaluation of both the total biomass produced as well as the biomass of the leaves, stalks and capitula because different parts of the plant are characterized by a different efficiency for energy production. Several studies developed in Europe showed that the average annual dry biomass production of *C. cardunculus* cultivars ranges from 15 to 20 t/ha depending on soil and rainfall, with the following biomass partitioning: 40% stalks, 25% leaves and 35% capitula (Dalianis et al., 1996; Fernández, 1993). Due to the fact that *C. cardunculus* is a perennial species and it is able to throw out offshoots for some years without the need to re-sowing, the efficiency value is expected to increase from the second year, as planting initial costs are no longer needed, thus, it can be considered as a renewable source of energy.

The aim of the work was to evaluate the aboveground biomass produced by each botanical variety and its partitioning in leaves, stalks and capitula.

MATERIAL AND METHODS

Fourteen accessions of *Cynara cardunculus* were compared in a randomized design with three replications of 20 plants at the Experimental Field Station of Rosario's National University, Argentina (33°01'S; 60°53'W). The station has a temperate climate and loamy soil and is representative of the major production area of globe artichoke in Argentina. The total annual rainfall was of 950 mm and monthly temperatures ranged between 2°C (July) and 31°C (January).

At the anthesis stage of the second cycle of production, plants of each plot were cut down and weighed to determine leaves, stalks and capitula fresh biomass. An ANOVA was performed for each aboveground fresh biomass fraction and mean values were compared by Duncan's test. Euclidean distances between accessions were calculated and a cluster analysis was performed.

For each fraction (stalks, leaves and capitula), and for each botanical variety, five samples of 100 g were taken and dried in a thermoventilated oven at 60°C, until constant weight. The percentage of dry matter was calculated for each fraction and botanical variety.

RESULTS AND DISCUSSION

Total fresh biomass and its partitioning into leaves, stalks, capitula, showed significant differences among genotypes ($p<0.001$). The total fresh biomass ranged between 1188 and 3235 g/plant (12 to 32 t/ha/year) and the partition of the aboveground biomass was strongly affected by the botanical variety (Table 1). Both wild and cultivated cardoons showed higher leaves weight than globe artichoke, whereas the latter produced heavier capitula. The highest weight of stalks were detected in cultivated cardoons while the lower in wild cardoons.

Significant differences among genotypes for aboveground biomass yield and its partitioning were also observed by Raccuia and Mellili (2007) in a three-year trial performed with wild and cultivated cardoons accessions, globe artichoke accessions were not included. Also, Ierna and Mauromicale (2010), who evaluated six genotypes of their germplasm collection including one cultivated cardoon cultivar, one globe artichoke line, one wild cardoon ecotype, and three progenies between these accessions, demonstrated that the high levels of biomass production and its composition in some *C. cardunculus* genotypes may allow the application of the crop for lignocellulosic biomass production.

Cluster analysis showed three main groups, the first one (GI) included two cultivated cardoons, the second one (GII) comprised three globe artichoke cultivars, whereas the third (GIII) was subdivided into three subgroups (SGI, SGII and SGIII) which included all wild cardoon together with three cultivated cardoons and two globe artichoke accessions (Fig. 1).

In globe artichoke almost all the aboveground biomass was destined to capitula which is commercially the most important part being eaten. Cardoon is cultivated for its succulent leaves, for that reason, domestication derived in forms where leaves and stalks comprised the principal component of biomass weight. In the wild cardoon leaves weight was the most important component of biomass, nevertheless stalks and capitula weights together explained more than 50% of the mean total fresh biomass.

In both cardoon varieties, the percentage of dry matter ranged between 28.2 to 36.5% for all components of aboveground biomass, whereas in globe artichoke values ranged between 20.9% for stalks and 42.1% for leaves (5 to 10 t/ha) (Fig. 2). These values are lower than those reported by Raccuia and Melilli (2007), who obtained an average yield of 50 t/ha of dry biomass acumulated during a 3-years trial carried out in Sicily. Angelini et al. (2009) reported average values between 14-15 t/ha/year in central Italy, and similar values of dry biomass were reported also by Fernández et al. (2006) in the Mediterranean area. The lowest values of dry matter observed in the present work may be due on one hand to the different climatic conditions (Mediterranean vs. South America). In Argentine, summer is rainy, with some rainfalls over 100 mm. The humidity excess right after the end of the productive stage generates the rotting of the aboveground biomass, hampering the biomass harvest at this stage. In order to employ the aboveground biomass for industrial purposes it would be thus necessary to apply desiccant product like paraquat (1,1'-dimethyl-4,4'-bipyridylium dichloride) when plants are still at full growth, for example, at anthesis stage, avoiding the complete development of the reproductive cycle. On the other hand, only one production year was considered in the present work, it is possible that predominant climatic conditions in that year have not been favourable for the expression of a maximum potential vegetative development. Likewise, the fact that, in

globe artichoke, the leaves showed the major dry matter, percentages of importance since they represent harvest residue which are generally discarded.

Although it is necessary to conduct new assays including more evaluation years, the low inputs management required, adaptability to the local conditions, and the results obtained in the present study suggest the suitability of *C. cardunculus* to be grown as an industry or energy crop.

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Tables

Table 1. Mean values for leaves, stalks, capitula and total fresh biomass in the 14 *Cynara cardunculus* accessions.

	Leaves (g)	Stalks (g)	Capitula (g)	Total (g)
		C. cardunculus var. *scolymus*		
Feltrin Roxa	495.00 bcde[1]	873.33 b	1525.00 a	2893.30 ab
Violeta Precocce	361.67 cde	643.33 bc	1473.33 a	2448.30 abcde
Feltrin Verde	565.00 bcde	751.67 bc	1291.67 ab	2608.30 abcd
Imperial Star	248.33 e	441.67 de	915.00 bc	1605.00 fg
Estrella del Sur FCA	311.67 de	520.00 cde	813.33 cde	1645.00 efg
		C. cardunculus var. *altilis*		
Semence	1088.33 a	793.33 bc	903.33 bc	2785.00 abc
Florensa	1138.33 a	1223.33 a	873.33 cd	3235.00 a
Cereseto	695.00 b	785.00 bc	816.67 cde	2296.70 bcdef
Zavalla	508.33 bcde	868.33 b	620.00 cde	1996.70 cdefg
Schiavoni	353.33 cde	366.67 de	468.33 de	1188.30 g
		C. cardunculus var. *sylvestris*		
Route 2	501.67 bcde	408.33 de	593.33 cde	1503.30 fg
Route 9	751.67 b	450.00 de	580.00 cde	1781.70 defg
Entre Rios	603.33 bcd	325.00 e	415.00 e	1346.30 g
Pergamino	665.00 bc	305.00 e	401.67 e	1371.70 g

[1] Values followed by the same letter in the same column are not significantly different at $p<0.05$.

Figures

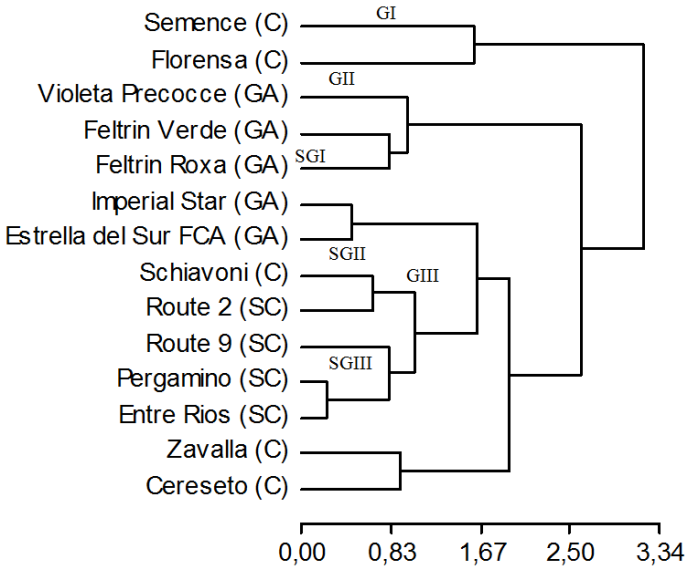

Fig. 1. Dendrogram performed by "Average Linkage" method showing the grouping of 14 *Cynara cardunculus* accessions based on Euclidean distances (C: cultivated cardoon; SC: wild cardoon; GA: globe artichoke)

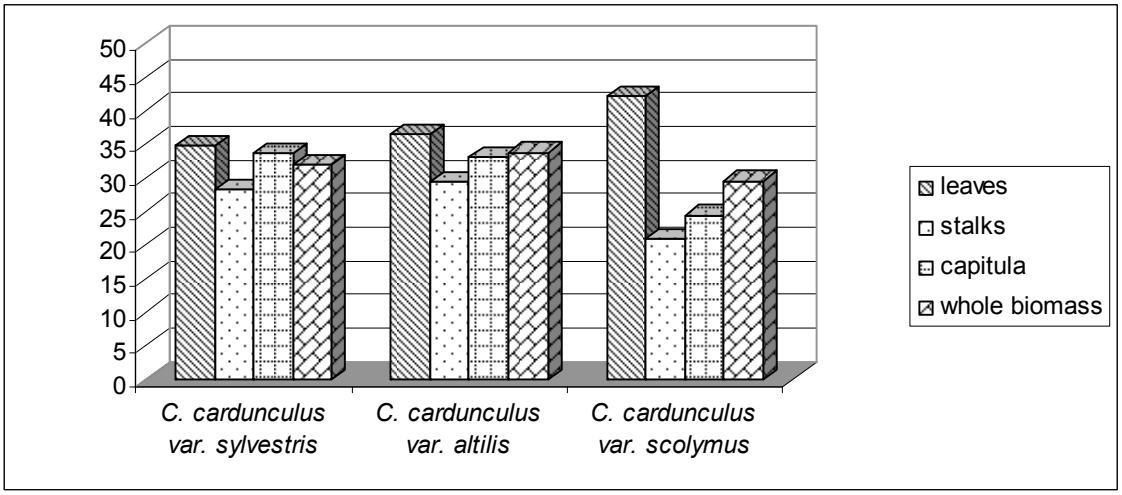

Fig. 2. Percentages of dry matter for each biomass fraction in each botanical variety.