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# Phytomass production from *Silybum marianum* for bioenergy

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**SUMMARY –** *Silybum marianum* Gaertner is a herbaceous thorny member of the Compositae family, common in the native flora of the Mediterranean basin. *Silybum marianum* seeds contain a complex substance called silymarin, well appreciated for treating human liver diseases and animal wellbeing. Because of its extremely aggressive vegetative growth, causing stress on adjacent plants, it is known as a dangerous weed in cropping areas. On the other hand, the rusticity and the high growth rates of *S. marianum* make it interesting for bioenergy purposes in rainfed Mediterranean environments. A research work was started in Sardinia in order to evaluate the performance of this species in terms of biomass production under low input conditions. Data on undisturbed dry matter accumulation, yield, and phytomass partitioning into its components (leaves, stems and heads) were collected. The heating value and the energy balance of the crop were also assessed. The first year results are reported in this paper.

**Key words:** Milk thistle, biomass, calorific value, energetic balance, bioenergy.

***RESUME*** *– "Production de phytomasse de* Silybum marianum *pour la production de bioénergie".* Silybum marianum *Gaertner est une espèce herbacée et épineuse de la famille des Compositae, commune dans la flore du bassin méditerranéen. Les graines de* S. marianum *contiennent un complexe de substances appelées silimarina qui sont très utiles pour les maladies du foie pour l'homme et pour le bien-être animal. Elle est considérée comme une plante mauvaise pour les cultures. D'un autre côté, la rusticité et les rythmes de croissance élevés rendent le chardon Marie intéressant pour une finalité bioénergétique en milieux méditerranéens sans irrigation. Une recherche a été conduite en Sardaigne pour estimer les performances de cette espèce pour la production de biomasse. La production de matière sèche et sa répartition (feuilles, tiges, fruits), le pouvoir calorifique et le bilan énergique de cette culture ont été évalués. Les premiers résultats ont été illustrés dans cet article.*

***Mots-clés :*** *Chardon Marie, biomasse, pouvoir calorifique, bilan énergique, bioénergie.*

## Introduction

Several high productive species are currently being recognized as energy crops but very few lignocellulosic herbaceous plants can be grown, without irrigation, under rainfed conditions of Mediterranean environments such as *Cynara cardunculus* L. It is grown as a permanent crop and the whole aerial biomass produced over the annual growth cycle is harvested every year (Curt *et al.*, 2002).

*Silybum marianum* Gaertner (milk thistle) is a herbaceous thorny species of the same Compositae family with large, green coloured and white veined leaves. It is related to human habitats and it is common in the native flora of the Mediterranean basin; for its high competition ability (aggressive vegetative growth causing depression of adjacent plants) it is reputed as a dangerous weed (Gabay *et al.*, 1994) in cropping areas and in particular in grass-legume mixtures. Nevertheless, *S. marianum* seeds contain a complex substance called silymarin well studied and appreciated for the treatment of human liver diseases and animal wellbeing (Morazzoni and Bombardelli, 1995; Leng-Peschlow, 1996; Tedesco *et al.*, 2004.). In addition, the rusticity and the high growth rates of *S. marianum* make this plant very interesting for bioenergy purposes under rainfed Mediterranean conditions, in those areas where traditional cropping surface has recently decreased. After a seed collection of Sardinian populations of milk thistle, plots of this species were established in autumn 2006, to evaluate its performances in terms of biomass production under low input conditions and annual cropping. The first year results are reported in this paper.

## Materials and methods

The experiment was carried out in North-Sardinia (Italy) on flat clay-loam calcareous soil, pH 7.5 with low N and $P_2O_5$ content and adequate $K_2O$ content, during 2006-2007. The climate of the area is semi-arid Mediterranean, with a mild winter and an average annual rainfall of 547 mm. In Autumn 2006, plots of a Sardinian populations of milk thistle were established with a seeding rate of 2 kg $ha^{-1}$ of viable seed and row spacing of 50 cm. Each plot was 60 $m^2$ in size and a complete randomized design was adopted. At sowing fertilization was applied at a rate of 100 kg $ha^{-1}$ of $P_2O_5$ and 35 kg $ha^{-1}$ of N. No fertilizer, pesticide applications or agricultural interventions and irrigation were supplied after sowing.

The following measurements were made on three sampling areas per plot: plant density, dry matter (DM) percentage and its accumulation, DM yield (t $ha^{-1}$), phytomass partitioning into stems, leaves and heads. Harvesting of whole plots was performed in June, when plant above ground organs were died, by using a cutter forage harvester equipped with hay loader.

The higher heating value (HHV, i.e. the amount of energy released by complete combustion of a mass unit of sample, at constant volume in an oxygen atmosphere, expressed as MJ $Kg^{-1}$ of dry weight) was determined using an oxygen bomb calorimeter (model 1425 Semimicro, Parr Instrument Company, Moline, Il, USA) for each phytomass component of the plant.

Energy analysis of biomass production was carried out applying the methodology of Gross Energy Requirement (IFIAS, 1974). All factors involved into the cultivation process were recorded and converted in quotas of direct (fuels) and indirect energy (machinery, seeds, fertilizers) by mean of coefficients reported in literature by several authors (Jarach, 1985; Riva, 1996). The energy yield of milk thistle was obtained by multiplying the HHV per unit of biomass by the above ground dry matter yield. Total energy consumptions and gross energy output were calculated to identify the net energy gain (difference between energy outputs and inputs), the energy ratio (ratio between outputs and inputs) and the energy productivity (amount of biomass produced per unit of input energy).

## Results and discussion

### Meteorological trend

The total annual rainfall from September 2006 to August 2007 was about 520 mm and its distribution was similar to climatic values, but from sowing to biomass harvesting date only 420 mm were recorded. Winter temperature was unusually higher than climatic values and this has probably favoured the winter plant growth

### Dry matter composition and yield

Emergence was regular and seedling vigour and development were remarkable since early growth stages compared to not sowed species, probably due to the high seed mass (20 mg each).

DM matter progressively increased from March to May (Fig. 1); in June about 20 t $ha^{-1}$ of dry biomass were harvested. DM percentage was very low in winter and early spring, it ranged from 10 to 30% in February and May respectively. Only in June it reached about 80%.

Relevant changes within phytomass components were observed: only leaves in February whereas at harvest, in June, leaves, stems and heads represented respectively 34, 55.7 and 10.3% of the total dry biomass. During the season the occurrence of not sowed species was negligible as these plants were smothered by the high competition ability of the milk thistle.

Taking into account the low level of inputs applied to the crop and the amount of effective rainfall during the season, it is evident that *S. marianum* has an interesting potential for biomass production and its yields proved to be superior than those of cereal and forage crops in the same environment. These results confirm previous production data reported by Carruba and La Torre (2003) at single plant level in Sicily.

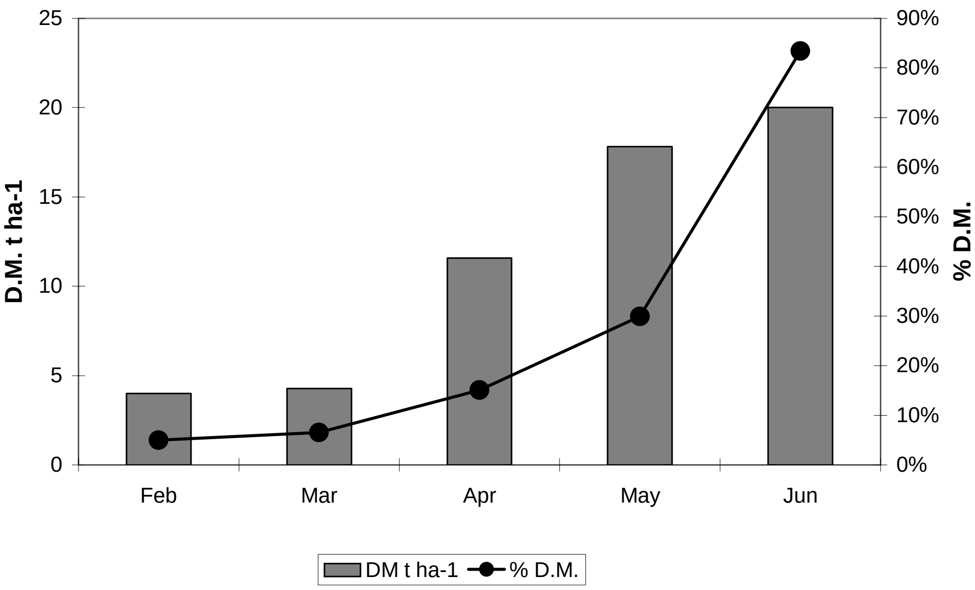


Fig. 1. Seasonal undisturbed biomass accumulation and DM percentage from February to June 2007.

## High heating value and energy balance

HHV was on average 14.8 MJ $kg^{-1}$ of DM, very similar to that of *C. cardunculus* (González *et al.*, 2004) and it decreased between components in the following order: heads, stems and leaves. Total energy requirements (Table 1) for the cultivation of milk thistle were 8.0 GJ $ha^{-1}$, of which 55% was represented by indirect energy and the remaining part by direct-use energy.

Table 1. Energy balance of milk thistle crop (mean ± se)

| Factor | | Unit | Direct MJ $ha^{-1}$ | Indirect MJ $ha^{-1}$ | Total MJ $ha^{-1}$ |
|---|---|---|---|---|---|
| Input | Plowing | | 1938.4 | 110.4 | 2048.8 |
| | Rototilling | | 651.1 | 45.1 | 696.2 |
| | Fertilizing | | 42.5 | 3773.2 | 3815.7 |
| | Planting | | 407.0 | 67.2 | 474.2 |
| | Harvesting | | 552.9 | 459.5 | 1012.3 |
| Total Energy Input | | GJ $ha^{-1}$ | | 8.0 | |
| Output | Dry biomass yield | t $ha^{-1}$ | 20.4 ± 0.64 | | |
| | Higher heating value | MJ kg | 14.8 ± 0.15 | | |
| Total Energy Output | | GJ $ha^{-1}$ | | 301.3 | |
| Net Energy Gain | | GJ $ha^{-1}$ | | 293.3 | |
| Energy Ratio | | % | | 37.4 | |
| Energy Productivity | | t $GJ^{-1}$ | | 2.5 | |

This low level of energy input is mainly due to the absence of pesticide treatments and irrigation. The largest energy input was represented by the diesel fuel used by farm machinery, followed by nitrogen and phosphorus fertilizers. Among the different agricultural operations, fertilizing represents more than 47% of the total energy consumptions, while soil and seed bed preparation together account for 34%.

Considering an average calorific value of the whole dry biomass of 14.8 GJ $t^{-1}$, the gross energy output was 301.3 GJ $ha^{-1}$, which results in a net energy gain of 293.3 GJ $ha^{-1}$. This value compared to the results reported for other type of biomass crops in Mediterranean area (Bonari and Picchi, 2004) shows that milk thistle leads to a better energy balance than *Miscanthus sinensis*. Although the energy outputs of other species as *Arundo donax*, and *Sorghum bicolor* were higher than *S. marianum* (598 and 458 *vs* 301 GJ $ha^{-1}$), the output to input energy ratios of 34.4 and 14.9 *vs* 37.4 indicates that milk thistle has a better efficiency in energy conversion as well as the energy productivity (2.5 GJ per each ton of biomass produced).

## Conclusions

*S. marianum* has an interesting potential for biomass production into rainfed Mediterranean environments where it can be grown under low inputs; it should be exploited also for bioenergy purposes and as a substitute for species requiring irrigation water so avoiding competition with other important crop destinations. Moreover its annual cycle can allow a high degree of flexibility, compared to perennial species, within current crop systems and including marginal areas.

## References


Bonari, E. and Picchi, G. (2004). *Biomasse agroforestali da energia: le possibilità offerte dalle colture dedicate*. Convegno Terra futura, Firenze (Italy) 2-4 aprile 2004.

Carruba, A. and La Torre, R. (2003). Cultivation trials of milk thistle (*Silybum marianum* Gaertner) into the semiarid Mediterranean environment. *Agr. Med*., 133: 14-19.

Curt, M.D., Sánchez, G. and Fernández, J. (2002). The potential of *Cynara cardunculus* for seed oil production in a perennial cultivation system. *Biomass Bioenergy*, 23: 23-46.

Gabay, R., Plitmann U. and Danin A. (1994). Factors affecting the dominance of *Silybum marianum* L. (*Asteraceae*) in its specific habitats. *Flora*, 189: 201-206.

González, J.F., Gónzalez-García, C.M., Ramiro, A., González, J., Sabio, E., Gañán, J. and Rodríguez, M.A. (2004). Combustion optimisation of biomass residue pellets for domestic heating with a mural boiler. *Biomass Bioenergy* , 27: 145-154.

IFIAS (1974). *Energy analysis workshop*. Report n. 6, Stockholm.

Jarach, M. (1985). Sui valori di equivalenza per l'analisi e il bilancio energetico in agricoltura. *Riv. Ing. Agraria*, 1: 2-114.

Leng-Peschlow, E. (1996). Properties and medical use of favolignans (silymarin) from *Silybum marianum*. *Phytotherap. Res.,* 10: 25-26.

Morazzoni, P. and Bombardelli, E. (1995). *Silybum marianum* (*Carduus marianus*). *Fitoterapia,* 66: 3-42.

Riva, G. (1996). I bilanci energetici. Indicatori di processi industriali eco-compatibili. *La Termotecnica*, Gen-feb, 33-45.

Tedesco, D., Tava, A., Galletti, S., Tameni, M., Varisco, G., Costa, A. and Steidler, S. (2004). Effect of Silymarin, a natural Hepatoprotector in periparturient Dairy Cows. *J. Dairy Sci*., 87: 2239-2247.