26th European Biomass Conference and Exhibition Proceedings,
14-18 May 2018, Copenhagen, Denmark. pp350-352
DOI:10.5071/26thEUBCE2018-1DV.5.4

# PERFORMANCE OF SIDA HERMAPHRODITA AND SILPHIUM PERFOLIATUM IN EUROPE: PRELIMINARY RESULTS

Gianni Facciotto[1]*, Marek Bury[2], Francesca Chiocchini[3], Laura Cumplido Marín[4], Henryk Czyż[2], Anil Graves[4], Teodor Kitczak[2], Reent Martens[5], Christopher Morhart[6], Pierluigi Paris[3], Michael Nahm[6]
[1]Consiglio per la ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA) – Centro di ricerca Foreste e Legno, Strada Frassineto Po – 15033 Casale Monferrato (AL), Italy; phone:+39 0142330900, fax: +39 014255580;
*e-mail: gianni.facciotto@crea.gov.it;
[2]West Pomeranian University of Technology, Szczecin (PL);
[3]Institute of Agro-Environmental and Forestry Biology, Porano (I);
[4]Cranfield University, Cranfield (UK);
[5]3N Centre of Experts, Werlte (D);
[6]Albert-Ludwigs-University, Freiburg (D)

ABSTRACT: Sida hermaphrodita (Virginia mallow) and Silphium perfoliatum (cup plant), are two perennial herbs that can be used for energy production, or, particularly in the case of the first species, as a basic compound for various materials, such as fibre products or particle boards. Silphium can be used as an alternative to maize for biogas production. The flowers of both species provide abundant pollen and nectar for pollinating insects. These new crops are currently being tested on the SidaTim project (FACCE-SURPLUS) in Germany, Italy, Poland, and the UK. The biomass (dry matter) produced by Sida during the first year ranged from 0.8 $Mg \cdot ha^{-1}$ in Poland and 1.4 $Mg \cdot ha^{-1}$ in Germany, to 6.6 $Mg \cdot ha^{-1}$ in Northern Italy. During the second year, it ranged from 7.0 $Mg \cdot ha^{-1}$ in Italy to 14.0 $Mg \cdot ha^{-1}$ in Poland. The yield of Silphium during the second year ranged from 14.5 $Mg \cdot ha^{-1}$ when harvested once at the end of the vegetative period to 25.7 $Mg \cdot ha^{-1}$ when harvested twice per year (in June and October) in Poland.
Keywords: Perennial energy crops, *Sida hermaphrodita*, *Silphium perfoliatum*, biomass yield.

## 1 INTRODUCTION

The use of renewable energy has increased significantly in the EU from 8.5% in 2005 to almost 17% in 2015 of gross final energy consumption. The global primary energy supply from biomass reached about 60 EJ in 2015, representing 10% of the total global primary energy consumption and 14% of the final energy consumption. Traditional use of biomass, primarily for cooking and heating, is substantial, accounting for about 9% of the global final energy consumption [1]. Forest biomass, agricultural residues, and energy crops constitute the three major sources of biomass for energy. Dedicated energy crops grown on liberated agricultural land or marginal lands are expected to be able to meet the major part of the increasing biomass demand over the 21st century [2], [3]. The bio-based economy plays a key role in the green economy, not only in energy production, but also in chemical and material applications [1].

Expanding biomass feedstock production from cultivated energy crops can imply substantial land use change, with direct and indirect impacts on environment (GHG balance, soil, water and biodiversity impacts) [4]. Sustainable strategies require the use of renewable resources and mitigation of climate change. The research project 'Novel Pathways of Biomass Production: Assessing the Potential of *Sida hermaphrodita* and Valuable Timber Trees'(SidaTim) [5] was funded under FACCE SURPLUS (Sustainable and Resilient agriculture for food and non-food systems) in order to strengthen the European bio-based economy through research and promotion of new land uses comprising innovative multipurpose plant species and novel agricultural management approaches.

This work reports preliminary results of the SidaTim project on the growth and biomass production of two perennial plants, *Sida hermaphrodita* (Virginia mallow) and *Silphium perfoliatum* (cup plant), which are currently being tested in Germany, Italy, Poland and the UK. Sida can be used for energy production, and as a basic compound for various material products, such as fibre products or particle boards [6]. Silphium can be used as an alternative to maize for biogas production [7]. The flowers of both species provide abundant pollen and nectar for pollinating insects.

## 2 MATERIALS AND METHOD

The experimental site plans, cultivation and harvesting protocols were coordinated and circulated amongst the project partners for development.

### 2.1 Experimental sites

In the late spring/early summer of 2016, three experimental plots were established by the project in Poland (Lipnik: 53.20 N; 14.58 E), Germany (Werlte: 52.85 N; 7.67 E), and northern Italy (Casale Monferrato: 45.13N; 8.51E); two other two plots were established in spring 2017 in the UK (Silsoe: 52.07N; 0.63 W) and in central Italy (Montenero di Bisacce: 41.95N; 14,78E).

In Lipnik, (PL) the average annual temperature was 8.5 °C, with an annual precipitation of 555mm, which peaks in summer. The soil texture was sandy with an acid pH. The reference crop was Salix SRC planted at 44,000 plants $ha^{-1}$.

In Werlte (D), the average annual temperature was 9°C, with an annual precipitation of 768 mm and a summer peak in rainfall. Soil texture was sandy with an acid pH of 5.6. The reference crop was Silphium planted in 2010 (the oldest Silphium test field in Germany with an annual average yield of 13.1 Mg dm $ha^{-1}$).

In Silsoe (UK), the average temperature was 9.9°C, with an annual precipitation of 657 mm. Soil texture was loam to clay, freely draining and slightly acid.

In Casale Monferrato (I), the average annual temperature was 12.5°C, with an annual precipitation of 784 mm and a dry period in July. The soil texture was sandy loam with a pH of 7.8 - 8.0. The reference bioenergy crop was poplar SRC (10,000 cuttings ha$^{-1}$), with two different harvesting cycles (one and two years).

In Montenero di Bisacce (I) the average annual temperature was 17.5°C, with an annual precipitation of 364mm and a dry period from May to September (monthly Eto varied between 110-150 mm and precipitation was about 23 mm per month). Soil texture was clayey (44% of clay) with an alkaline pH. The reference bioenergy crop was maize silage, sown at a density of 84,000 seeds ha$^{-1}$.

2.2 Experimental design

The experimental layouts were a randomized complete block or a Latin square design with four replications depending on the location; the experimental units had a surface area of about 100 m$^2$. Planting density was about 44,000 plants per hectare for Sida and Silphium. Two Sida provenances (Sida 1 and 2, from southern and northern Germany, respectively) and one Silphium provenance (from Chrestensen, Erfurth Germany) were compared. The plots were split into two subplots, in which one (subplot a) was sown, and the other (subplot b), seedlings were transplanted. Each sub-plot was split into two equal parts. One was harvested for biogas production and the second for direct combustion of biomass. In Montenero, the sowing treatment was not used for Sida and Silphium, as during preliminary testing, the inefficacy of sowing for local site and seasonal conditions had become evident.

2.3 Cultivation

The soil was prepared with a plough to a depth of 30 cm. After establishment and in spring of the second year, chemical weeding was applied in Lower Saxony, whilst in the other sites, manual weeding was undertaken. During the summer of the first year, three or four harrowing operations were performed between the rows in most of the sites. Fertilizer was applied only in some northern Europe sites at a rate of 60 kg N ha$^{-1}$ and 25 kg K ha$^{-1}$ in the first year and 80 kg N ha$^{-1}$ for BBCH 11. In Italy and the UK, the plots were irrigated during the summer of the first year by sprinkler or drip irrigation.

2.4 Growth and biomass production

The evaluation of the plant growth of two Sida provenances and Silphium was conducted during the growing season using the BBCH-code [8]. In July (2017) and October (2016, 2017), a sample per plot of Sida and Silphium was harvested to estimate biogas yield, and data on fresh weight and oven dry weight were collected. Final harvesting of the Sida plots was conducted during the dormant season (February) when the shoots had a moisture content of less 30%. Silphium was only harvested in the second year, because during the first year, it forms only a rosette of leaves at ground level.

The biomass yield for combustion was estimated by weighing all the plants harvested on each subplot (excluding border rows and rows harvested for biogas). The dry matter content was estimated gravimetrically from a fresh weight biomass subsample from each subplot weighting 1 kg. This was dried to constant weight in an oven at 103±1°C.

2.5 Statistical analysis

Analysis of variance (ANOVA) of biomass production was carried out for species/provenance, planting material and post-harvest utilization. The means of the treatments were compared using the Tukey test.

3 RESULTS AND DISCUSSION

In the first year, the height of Sida plants varied from 100 to 230 cm in Italy and from 80 to 170 cm in Germany and Poland, while Silphium plots reached a good ground coverage ratio (89-90%) at all the sites. The Sida plants derived from seedlings flowered in late summer, but only 10% from plants grown from seeds started to blossom. In year 2, the tallest Sida and Silphium plants reached 460 and 360 cm, respectively.

The yields of biomass for combustion after the first year of growth (Table I) were modest, and ranged from between 1.0 – 2.0 Mg dm ha$^{-1}$ in Werlte and Casale up to 4.0 Mg dm ha$^{-1}$ in Poland. This is typical for the biology of this species, because Sida hermaphrodita grows slowly in its first year usually with fewer stems than in subsequent years. The results showed that Sida 1 yielded higher quantities of biomass than Sida 2 in Lipnik and Casale. But at all sites, biomass production varied significantly depending on the establishment method (sowing or planting). Plants that were planted as seedlings (sl) developed more quickly and produced about twice the yield of plants sown from seed (s).

**Table I:** Average yields and Tukey tests of Sida aboveground dry biomass grown for combustion in Mg ha$^{-1}$. The yields refer to plots with plants grown from seed (s) or seedlings (sl). They were harvested at the end of the first year of growth in Lipnik (Lip), Werlte (Wer), Casale (Cas), Montenero (Mon), and Silsoe (Sil).

| Species | Lip | | Wer | | Cas | | Mon | | Sil | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sida1 s | 4.6 | A | 0.6 | B | 0.4 | C | 0.0 | A | 0.0 | A |
| Sida1 sl | 4.5 | A | 1.3 | A | 4.3 | A | 0.0 | A | 0.0 | A |
| Sida2 s | 2.9 | B | 0.5 | C | 0.7 | C | 0.0 | A | 0.0 | A |
| Sida2 sl | 4.2 | B | 1.4 | A | 2.0 | B | 0.0 | A | 0.0 | A |
| Average | 4.0 | | 1.0 | | 1.9 | | 0.0 | | 0.0 | |
| Test F$^{(2)}$ | ** | | ** | | ** | | | | | |

See notes for explanation of letters

On average, on the three sites planted in 2016, biomass yield measured at the end of the year of establishment (Table I) was lower than that achieved in second year (Table II).

**Table II:** Average yields and Tukey tests of aboveground Sida and Silphium dry biomass grown for combustion in Mg ha$^{-1}$. The yields refer to plots with plants grown from seed (s) or seedlings (sl). They were harvested at the end of the second year of growth in Lipnik (Lip), Werlte (Wer), and Casale (Cas).

| Species | Lip | | Wer | | Cas | |
|---|---|---|---|---|---|---|
| Sida1 s | 9.6 | ab | 6.4 | ab | 2.9 | c |
| Sida1 sl | 10.2 | ab | 7.8 | ab | 7.1 | b |
| Sida2 s | 7.8 | c | 8.3 | c | 6.0 | b |
| Sida2 sl | 9.3 | b | 9.5 | b | 8.2 | ab |
| Silphium s | 15.7 | a | 15.7 | a | 10.6 | a |
| Silphium sl | 13.4 | a | 13.4 | a | 10.7 | a |
| Average | | | | | | |
| Test F$^{(2)}$ | * | | * | | * | |

See notes for explanation of letters

In general, Silphium showed the highest biomass production. It was often significantly higher than either provenance of Sida, irrespective of whether it was established by sowing seeds or plantings seedlings.

Silphium produced more biomass in northern Europe (Lipnik and Werlte) than in Italy (Casale) in southern Europe.

The yield for biogas production (Table III) was determined in October 2016 in Lipnik, Werlte and Casale. This ranged from 2.9 Mg dm $ha^{-1}$ for Sida 2 seeds to 4.6 Mg $ha^{-1}$ dry matter for the other treatments, while in Casale, it ranged from 2.8 Mg $ha^{-1}$ for Sida 2 seedlings to 6.6 Mg $ha^{-1}$ for Sida 1 seedlings.

During the second year, it was found that the largest total yield was achieved by Silphium on all the three sites. The highest yield, about 25.6 Mg dm $ha^{-1}$ was produced in Lipnik. Sida produced less than half this quantity of biomass (between 12.0 and 14.5 t dm $ha^{-1}$). Overall, Sida 1 yielded greater quantities of biomass than Sida 2.

**Table III:** Average yield and Tukey tests of aboveground Sida and Silphium dry biomass grown for biogas in Mg $ha^{-1}$. The yields refer to plots with plants grown from seed (s) or seedlings (sl). They were during the first and second year of growth in Lipnik (Lip), Werlte (Wer) and Casale (Cas).

| **Species** | **Year** | **Lip** | | **Wer** | | **Cas** |
|---|---|---|---|---|---|---|
| Sida1 s | 1st | 4.6 | c | 4.5 | c | - |
| Sida1 s | 2nd | 13.8 | b | 7.8 | b | 2.9 |
| Sida1 sl | 1st | 4.5 | c | 4.5 | c | 6.6 |
| Sida1 sl | 2nd | 15.1 | b | 9.2 | b | 11.2 |
| Sida2 s | 1st | 2.9 | c | 2.9 | c | - |
| Sida2 s | 2nd | 9.2 | b | 9.0 | b | 3.8 |
| Sida2 sl | 1st | 4.2 | b | 4.2 | b | 2.8 |
| Sida2 sl | 2nd | 14.8 | b | 9.0 | b | 7.2 |
| Silphium s | 2nd | 24.7 | a | 13.7 | a | 9.5 |
| Silphium sl | 2nd | 26.6 | a | 14.6 | a | 14.4 |
| Average | | 4.0 | | 1.0 | | 1.9 |
| Test F(2) | | ** | | ** | | ** |

See notes for explanation of letters

## 4 CONCLUSION

- Plants grown from seedlings in an open field produced significantly more biomass than plants grown from seeds, especially in the case of Sida.
- During the first two years of the study, Silphium produced significantly more biomass than Sida.
- Two harvests for biogas production are possible for both crops, the first in early summer and the second in early autumn.
- Biomass harvested in winter, particularly Sida biomass, can be used for combustion in heating plants.

## 5 NOTES

(1) Crops sharing the same lowercase letter are not significantly different at p=0.05, or the same capital letter are not significant at p=0.01.

(2) *: $p\leq 0.05$ **: $p\leq 0.01$

## 6 REFERENCES


[1] N. Scarlat, J.F. Dallemand, F.Fahl, Biogas: developments and perspectives in Europe, Renewable Energy (2018), doi: 10.1016/j.renene.2018.03.006.

[2] N. S. Bentsen, C. Felby, Biomass for energy in the European Union – a review of bioenergy resource assessments, Biotechnology for Biofuels (2012), 5: 25

[3] COM(2014)15 final, A policy framework for climate and energy in the period from 2020 to 2030. Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions, 2014.

[4] EEA, EU bioenergy potential from a resource efficiency perspective, Report N6/2013, pag. 64.

[5] SidaTim - Novel Pathways of Biomass Production: Assessing the Potential of *Sida hermaphrodita* and Valuable Timber Trees. URL: http://faccesurplus.org/ research-projects/sidatim/

[6] M. Nahm, C. Morhart. Virginia mallow (Sida hermaphrodita (L.) Rusby) as perennial multipurpose crop: Biomass yields, energetic valorization, utilization potentials, and management perspectives. Global Change Biology Bioenergy (2018), doi: 10.1111/gcbb.12501.

[7] M. Gansberger, L.F.R. Montgomery, P. Liebhard. Botanical characteristics, crop management and potential of Silphium perfoliatum L. as a renewable resource for biogas production: A review. Industrial Crops and Products (2015), 63: 362–372.

[8] N. D. Jablonowski, T. Kollmann, M. Nabel, T. Damm, H. Klose, M. Müller, M. Bläsing, S. Seebold, S. Krafft, I. Kuperjans, M. Dahmen, and U. Schurr, U., Valorization of Sida (*Sida hermaphrodita*) biomass for multiple energy purposes. GCB Bioenergy (2016), 9: 202–214.


## 7 PROJECT LOGO, SPONSOR AND PARTNERS


SidaTim

FACCE SURPLUS
SUSTAINABLE AND RESILIENT AGRICULTURE FOR FOOD AND NON-FOOD SYSTEMS

The project is sponsored by:

Bundesministerium für Ernährung und Landwirtschaft

ptble
Projektträger Bundesanstalt für Landwirtschaft und Ernährung

Narodowe Centrum Badań i Rozwoju

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 652615.

Project partners:

# Performance of Sida hermaphrodita and silphium perfoliatum in Europe: Preliminary results

Facciotto, Gianni

2018-12-31

Gianni Facciotto, Marek Bury, Francesca Chiocchini, et al., Performance of Sida hermaphrodita and silphium perfoliatum in Europe: Preliminary results. 26th European Biomass Conference and Exhibition Proceedings, 14-18 May 2018, Copenhagen, Denmark. pp. 350-352

https://doi.org/10.5071/26thEUBCE2018-1DV.5.4