

Silphium perfoliatum

Subjects: Agriculture, Dairy & Animal Science

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Definition

Silphium perfoliatum L. is a perennial crop native to North America that has been the subject of increased scientific interest in recent years, especially in Europe. It is drought and frost-resistant, which makes it suitable for cultivation in Europe on marginal lands that are not used for growing other crops.

1. Introduction

Since climate change is caused mainly due to the wide use of fossil fuels, it is necessary to mitigate their impact and prevent their depletion. Under these conditions, it is very important to replace fossil fuels with renewable energy sources (RES), to stop the increase in greenhouse gases in the atmosphere ^[1] and reduce pollution caused by burning fossil fuels. Researchers are trying to identify different biomass sources that are acceptable for production, cheap, easy to grow and offer high yields that will be suitable for the commonly used conversion technologies. Moreover, there is a need to adapt some of the possible biomass sources to specific climatic conditions of some regions or try to use local sources. Anaerobic digestion can be seen as the most attractive renewable energy pathway to convert organic material into green fuel ^[2]. These complex processes provide several additional environmental benefits, since digestate from biogas production can be used as a biofertilizer and its utilization can reduce the amount of fertilizers needed ^{[1][3]}.

Biomass is considered to be an organic, non-fossil material of biological origin, such as manure, wastewater sludge, food and organic waste, municipal organic waste, animal waste, agricultural residues, and forest and industrial wood waste. The biological wastes are classified as a renewable energy resource due to the possibility of the incorporation of solar energy ^{[4][5]}.

Perennial crops are seen as a promising feedstock for renewable energy technologies ^{[5][6]}, including biogas production, due to the large amount of biomass that can be obtained from a relatively small area compared to annual crops. Moreover, perennial crops offer other benefits for biodiversity and the environment ^{[7][8][9][10]}.

The *Silphium perfoliatum* (cup plant) is considered a promising alternative substrate for biogas production ^{[11][12]} that could replace the current use of maize silage ^{[13][14][15]}. It is characterized by low production costs and can be grown on less productive or polluted soil ^[16]. The crop is resistant to winter frost and summer drought and is less dependent on atmospheric precipitation ^[17]. Moreover, in Central Europe, it is not very susceptible to pests and diseases that affect biomass productivity or yield ^{[11][18]}. Existing pests are unlikely to limit the production of seeds or biomass of *Silphium perfoliatum* ^[19]. In the USA, there have been cases reported of plantation damage caused by larvae, birds and mammals (moths, turkey and deer) ^[20]. In this case, damage was caused by natural biodiversity factors, which are beyond human control and can occur in every country. *Silphium* was studied in different countries, for different purposes: as a potential forage crop in New Zealand ^[21], Ukraine ^[22], USA ^{[23][24]} and Romania ^[25]; and as a forage crop in Belarus ^[26], Chile ^[27], China ^[28] and Russia ^{[29][30][31][32][33]}. In Austria ^[12], Czech Republic ^[15] and Poland ^{[34][35]}, biomass has been investigated for biogas production. It is also being studied for future possible use in Kazakhstan as a forage crop ^[36]. Another use of *Silphium perfoliatum* was proposed as a raw material for particleboards that can successfully replace wood and reduce wood shortages ^[37], which is important for industrial applications. Seeds of *Silphium* L. species, including *S. perfoliatum*, *S. integrifolium* and *S. trifoliatum*, were studied by using different parameters for different purposes ^[35]. *Silphium perfoliatum* was also cultivated as an ornamental plant ^[25] with high nectar productivity

2. Economic Aspects and Energy Efficiency of Biomass Production

Economic factors are very important in the use of *Silphium perfoliatum* as a feedstock for energy and other purposes. Since this plant is tolerant of unfavorable environmental conditions, it offers high biomass yields and the possibility of being planted on poor quality soils where other crops would be unprofitable. However, due to the high price of seedlings and the very high establishment costs for the farmers, *Silphium perfoliatum* cultivation is low and limited to small scale and trial plantations [42]. It was estimated that to be able to obtain reasonable yields, seed processing is necessary, which costs 1,700 Euro per hectare. This operation is considered to be time- and cost-consuming due to the different and unequal seed size and maturity. The seed amount required per hectare is 2.5 kg, whose market price is approximately 680 Euro kg⁻¹. Thus, the cultivation by seedlings can be replaced with sowing. To obtain a high yield level, sowing 1 ha with *Silphium perfoliatum* seeds is estimated to cost about 3,150 Euro. This cost is estimated to be around 60% of the total costs of maintaining a plantation. If the plantation is used for ten years, these costs are divided to this period and total around 400 Euro per hectare per year. Of course, this cost may decrease if the plantation is operated for longer periods, such as 15 years (290 Euro per hectare per year) [43]. The cost of using *Silphium perfoliatum* as a feedstock for biogas production was discussed by Gerstberger et al. [44]. It was estimated that, together with additional compensation, the costs are almost the same as for maize crops [44]. Moreover, compared with maize fields, *Silphium perfoliatum* fields facilitate water infiltration and nutrient circulation [45] and are well-suited for the diversification of bioenergy farming landscapes [44][46]. *Silphium perfoliatum* may contribute to reducing the need for nitrogen fertilizers since its well-developed root system stops the leaching of nutrients from the soil. Thus, in subsequent years of growing, this plant may reduce the amount of fertilizers and prevent the contamination of waters with nitrogen due to reduced erosion [45]. To further reduce the costs, in some cases it was proposed to sow different crops, including forage crop [26][32] between plant rows for the first year of growing, when the *Silphium perfoliatum* biomass yields are significantly lower than in the following years [45].

Another important issue is the energy efficiency of *Silphium perfoliatum* biomass production. The goal is to obtain much higher energy output than energy input level in the biomass production of this species. The energy input depends on the production technology used. The amount of applied mineral fertilizers, mainly nitrogen fertilizers, is of particular importance. In studies conducted in Lithuania [47], the energy input for the cultivation of this species without mineral fertilization was 7.4 GJ ha⁻¹ (Table 1). The use of liming and nitrogen fertilization increased these inputs up to 28 GJ ha⁻¹, depending on the variant and the amount of fertilizers used. It must be stressed that the applied fertilization also increased the energy accumulated in biomass from 187.6 to 361.9 GJ ha⁻¹ both with and without the highest fertilization doses, respectively. Therefore, the energy gain from biomass harvested at the end of September was high and ranged from 180.2 to 333.9 GJ ha⁻¹, respectively. However, the energy ratio of *Silphium perfoliatum* biomass production was the highest (25.3) without fertilization, although this index was only 12.9 in the variant with the highest fertilization dose [47].

Table 1. Energy-efficiency indicators of *Silphium perfoliatum* for different types and rates of fertilization, harvested at the end of September; based on Šiaudinis et al. [47].

Fertilization Rate	Energy Input (GJ ha ⁻¹)	Energy Accumulated in Biomass (GJ ha ⁻¹)	Energy Gain (GJ ha ⁻¹)	Energy Ratio
N0 (not limed)	7.4	187.6	180.2	25.3
N120 (not limed)	17.2	299.4	282.2	17.4
N0 + 0.5 liming rate	12.8	267.1	254.3	20.9

Fertilization Rate	Energy Input (GJ ha ⁻¹)	Energy Accumulated in Biomass (GJ ha ⁻¹)	Energy Gain (GJ ha ⁻¹)	Energy Ratio
N120 + 0.5 liming rate	22.6	290.5	267.9	12.9
N0 + 1.0 liming rate	18.2	332.6	314.4	18.3
N120 + 1.0 liming rate	28.0	361.9	333.9	12.9

N—nitrogen; 0.5 liming rate (3.0 Mg ha⁻¹ CaCO₃); 1.0 liming rate (6.0 Mg ha⁻¹ CaCO₃).

3. Conclusions

It is necessary to investigate the possibility of cultivating *Silphium* on marginal and degraded soils, after extensive agriculture, that cannot be used for other crop plantations. In addition, long-term cultivation of *Silphium perfoliatum* will contribute to improving the soil quality, controlling erosion, improving water infiltration, enriching soil mineral compounds and enhancing biodiversity, especially regarding honeybees and other pollinators.

However, more studies are needed on the costs of maintaining a *Silphium* plantation for future possible large-scale implementation. It is well-known that cultivation by sowing rather than by seedlings can considerably reduce the cost of a *Silphium perfoliatum* plantation. It is very important to improve growing characteristics to obtain sufficient biomass yields to enable the replacement of a maize crop by *Silphium perfoliatum* for biogas production. Although the reviewed studies show that the use of fertilizers can improve biomass yields, these operations can generate other costs which reduce energy efficiency. Therefore, further long-term research is needed to evaluate the use of *Silphium* biomass in comparison with other substrates, taking into account the full cultivation cycle and economic, environmental and energy efficiency. The results of such studies would help to determine whether *Silphium perfoliatum* is competitive to other crops and which ecosystem services are the most important and the most reliable.

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Keywords

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