Effects of plantation establishment on yields and morphological traits of *Sida hermaphrodita* and *Silphium perfoliatum* for sustainable biomass production

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The perennial crops used for biomass production for energy purposes are growing in a sustainable way and they have economic advantages (low cost of cultivation and management) in contrast to annual energy crops, especially to maize.

Particularly the "novel and innovative", more efficient species like **Virginia mallow** or **Pennsylvania fanpetals** (*Sida hermaphrodita* L. Rusby) and **cup plant** (*Silphium perfoliatum* L.), besides their high yield potential, provide additional environmental profits (biodiversity, carbon storage (removing of CO_2 from the atmosphere), protection and benefit for insects and pollinators, e.g. honeybees and bumblebees) and as well as excellent products to biogas plants.

Flower of cup plant

Flowers of Virginia mallow

The aim of the study

Assessment of the impact of plantation establishing methods (generative by seeds vs. vegetative by planting seedlings) and various harvest strategies (one cut vs. two cut strategy during the vegetation season) on morphological traits and biomass production of two Sida phenotypes (from the north and southern Germany) and Silphium, grown on marginal soil in north-western Poland.

Material and methods

Experimental sites

Agricultural Experimental Station in Lipnik **(53°20′35.8" N, 14°58′10.8" E**), which belongs to West Pomeranian University of Technology in Szczecin.

Establishing year - 2016

Experimental Design

Randomized block design with 4 replications

Two provenances of Sida (Sida1 and Sida2) and one of Silphium

Establishment method:

- vegetative by planting of rooted seedlings: 44,000 per 1ha (**planting**)
- generative by sowing seeds (**seed**): ~ 3 kg·ha^{-1}

Management

Fertilization: 100 kg N, 35 kg P and 110 kg K per 1ha before planting (depending on the soil fertility), 100 kg·ha^{-1} N - by start of vegetation next years

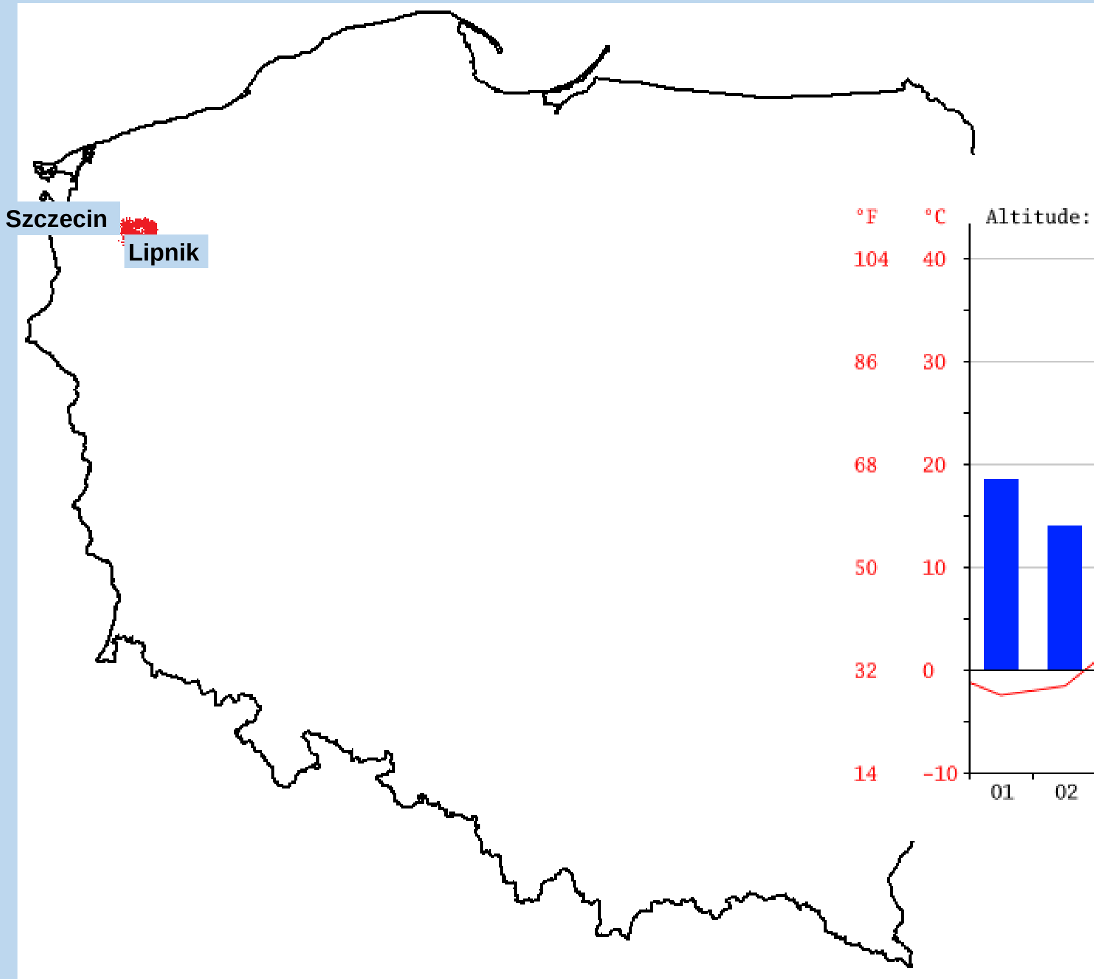
Weeds - Manual hoeing between the rows (only in the first year)

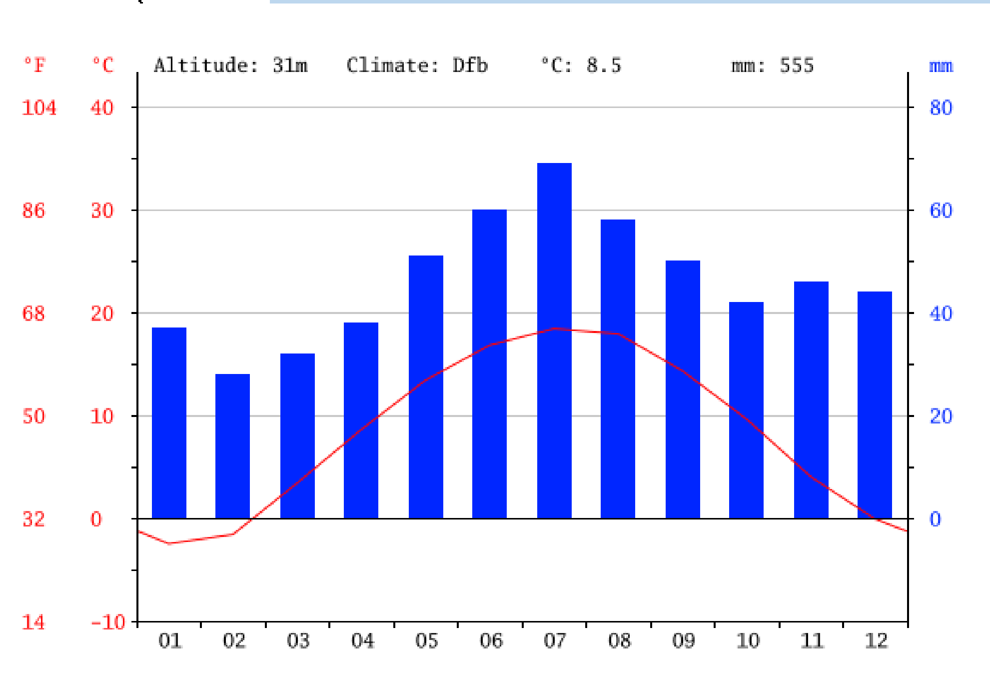
Harvest

One harvest strategy: in October (BBCH 79-81)

Two cutting strategy: in June (BBCH 55-59) and October (BBCH 69-71)

1 - Lipnik (53.20N; 14.58E) near **Szczecin** (North-Western **Poland**), the average annual temperature was 8.5°C, with an annual precipitation of 555 mm, which peaks in summer. The soil texture was sandy with an acid pH (Dystric Brunic Arenosols).





2016 – Establishing year

Sida1 (from South Germany) - planting

Sida1 – sowing (seed)

2016 (Establishing year) - October

Silphium befor sampling

Sida2 plot after harvest

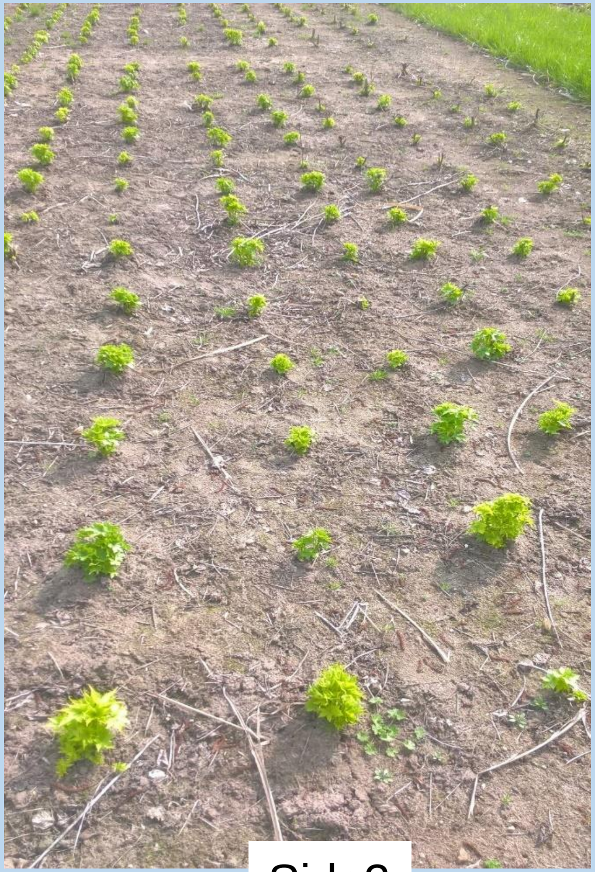
Regrowth of plants in spring 2017

(the second year and the first year of full vegetation

Silphium and Sida plants

Silphium

Sida1



Sida2

The harvest of plants from two-cut strategy plots

June 2017

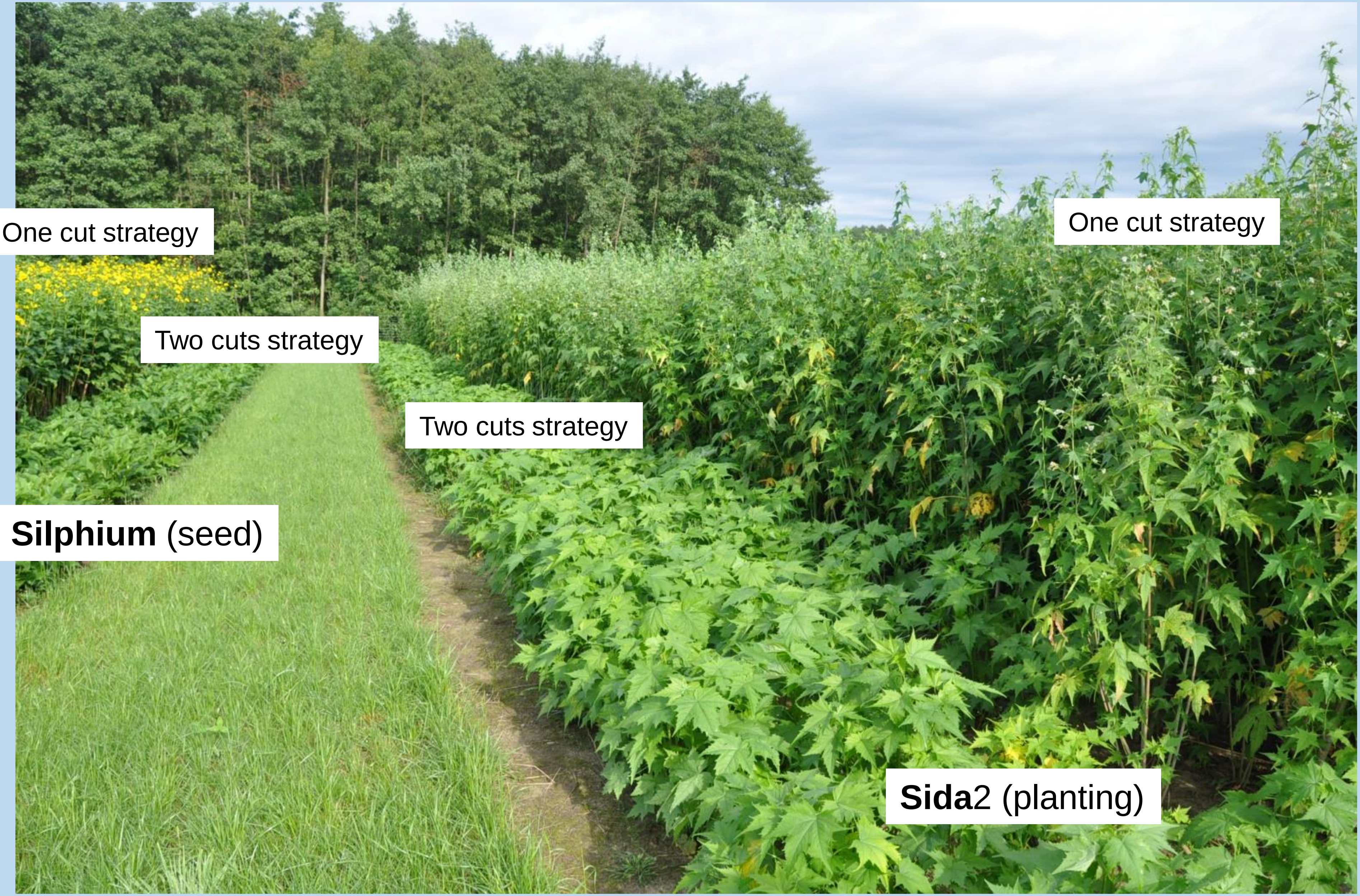
Silphium before harvest

Harvest of Sida1 (seed)

Harvest of Sida1 planting (left) & Sida2 seed (right)

Second **regrowth** of plants in summer 2017

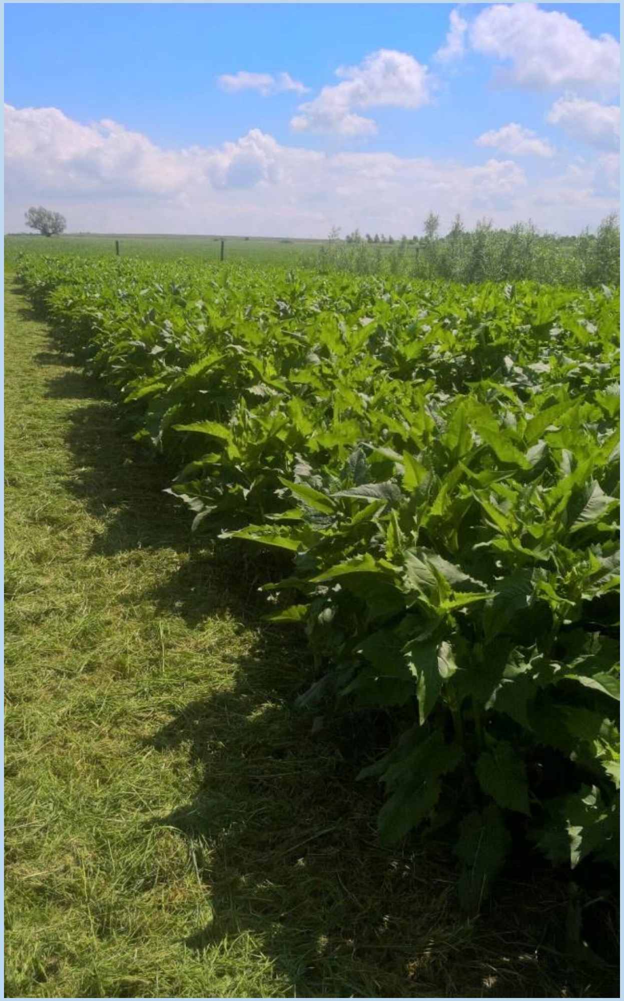
Silphium seeds (left), Sida2 seedlings (right)



October 2017 - before harvest

October 2017 - before harvest

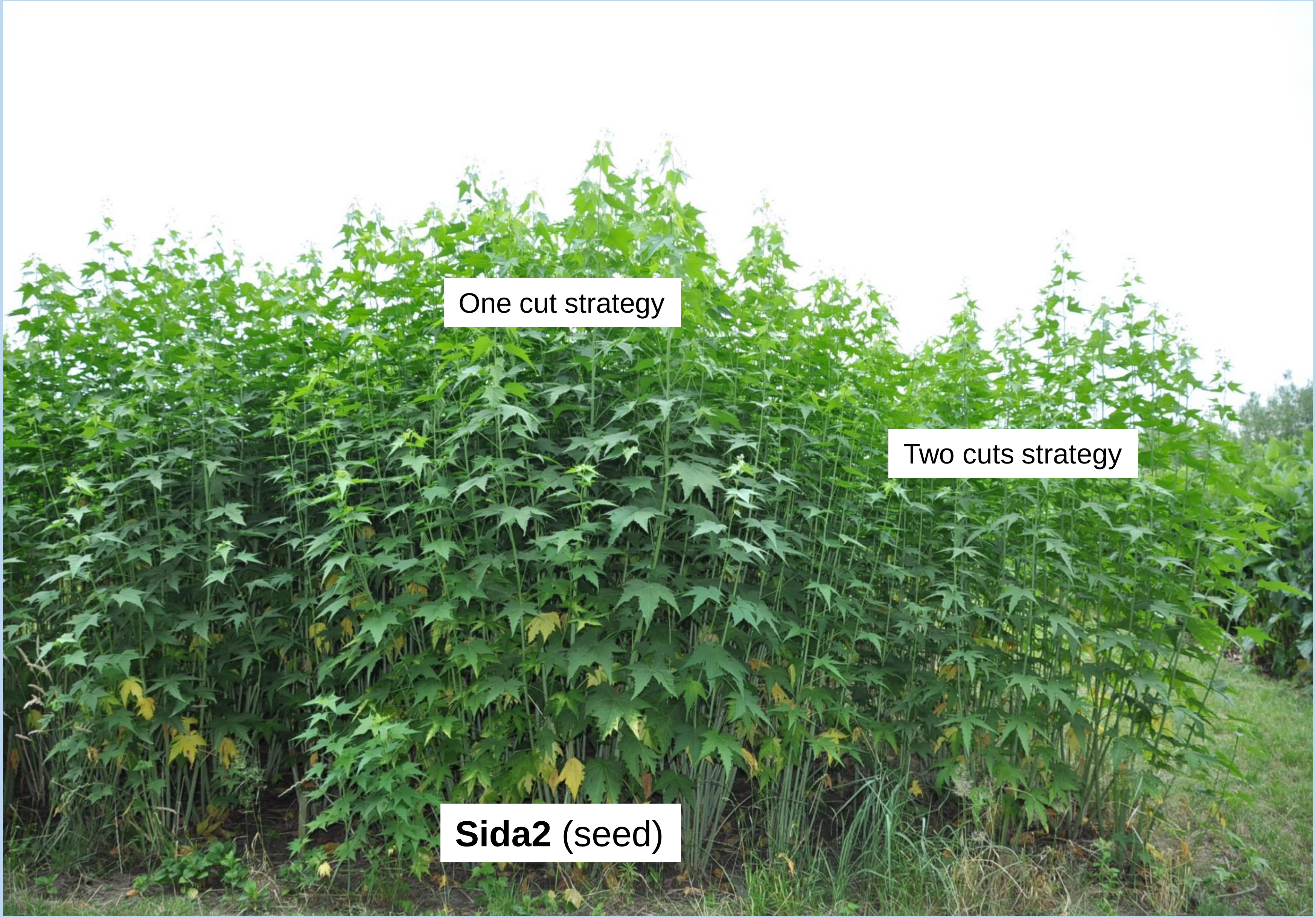
The third year of experiment and the second year of full vegetation
Regrowth of plants - **May 2018**



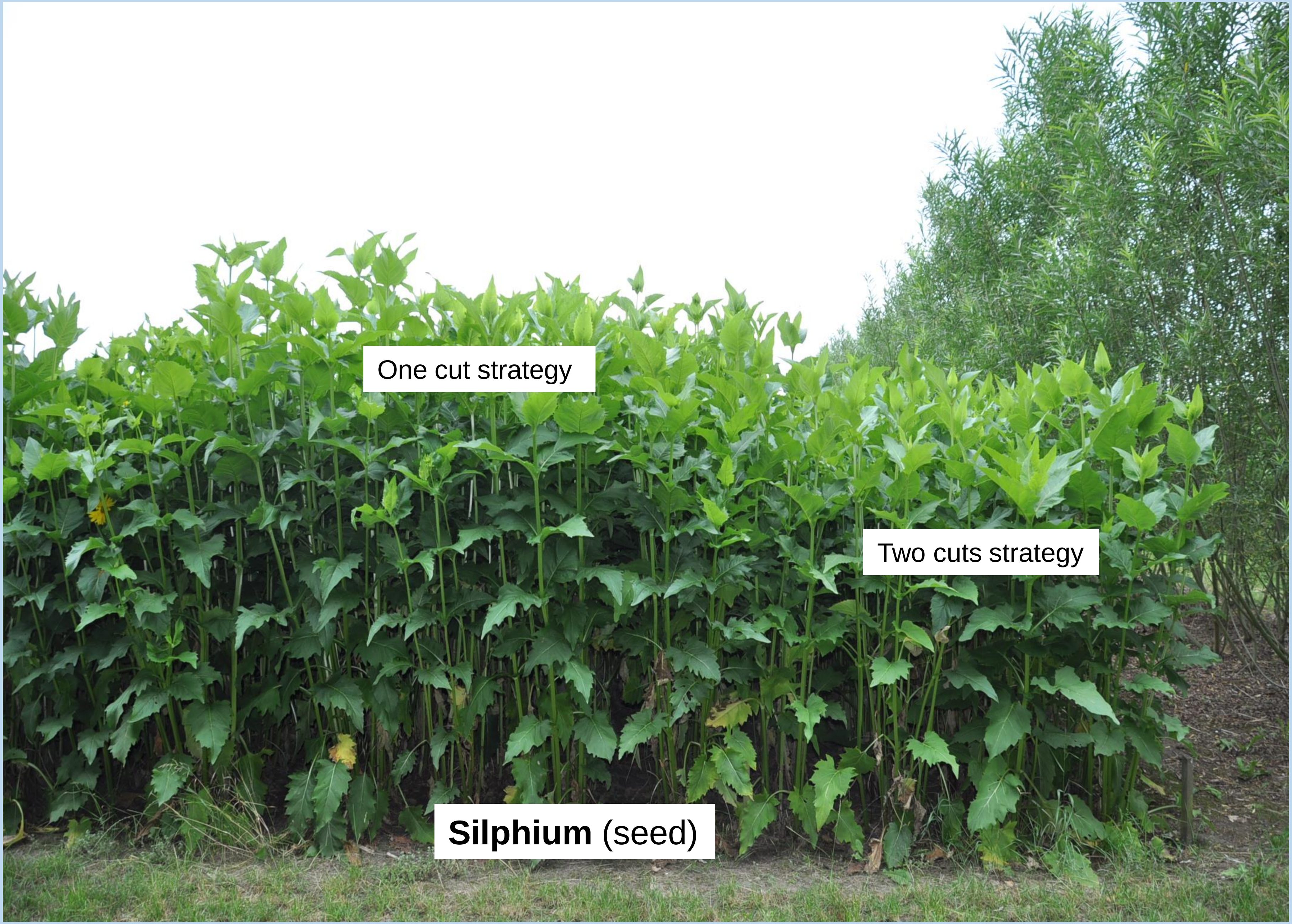
Silphium (seed)

Sida2 (planting)

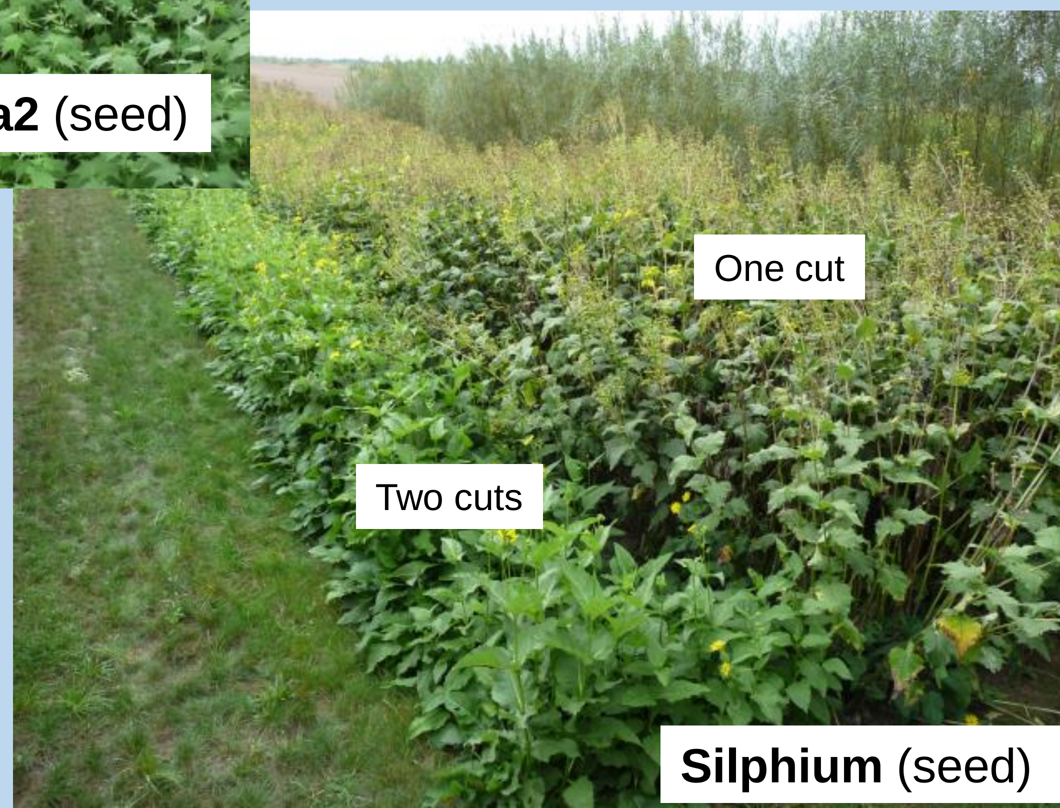
June 2018 before harvest



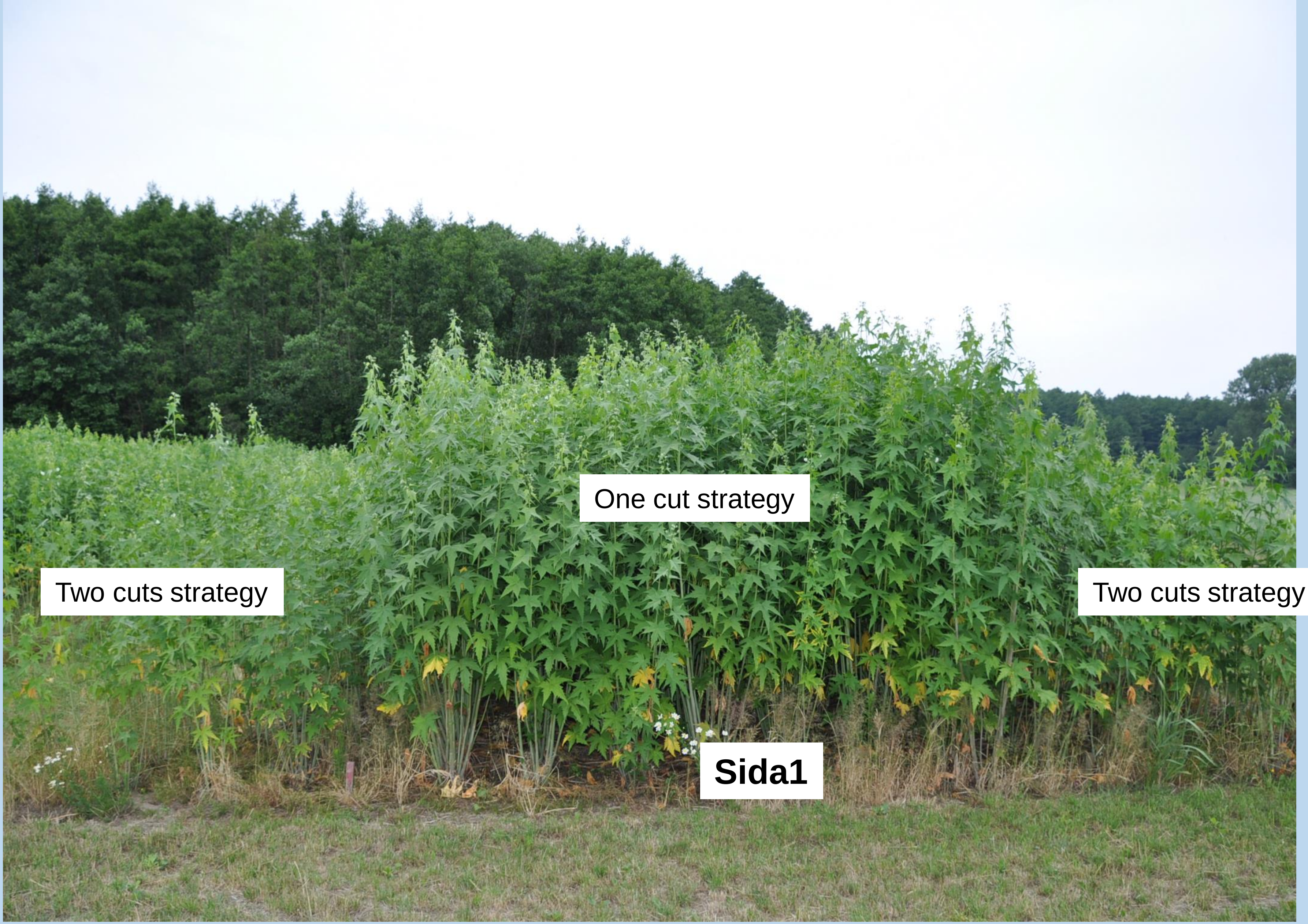
June 2018, before harvest



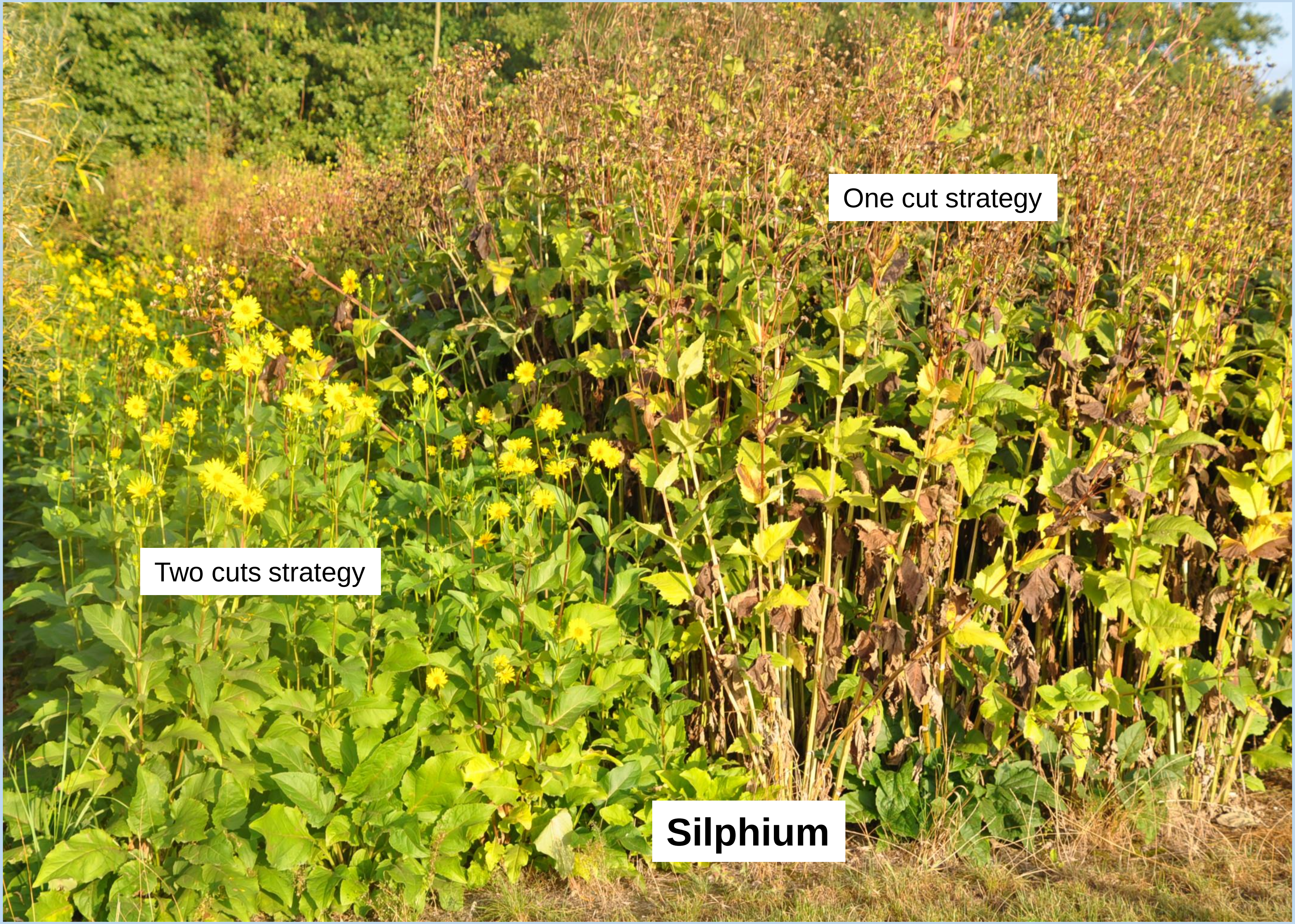
Plants regrowth after the first cut on both Sida phenotypes (left) and on Silphium (bottom) - **7.09.2018**



October 2018 before harvest

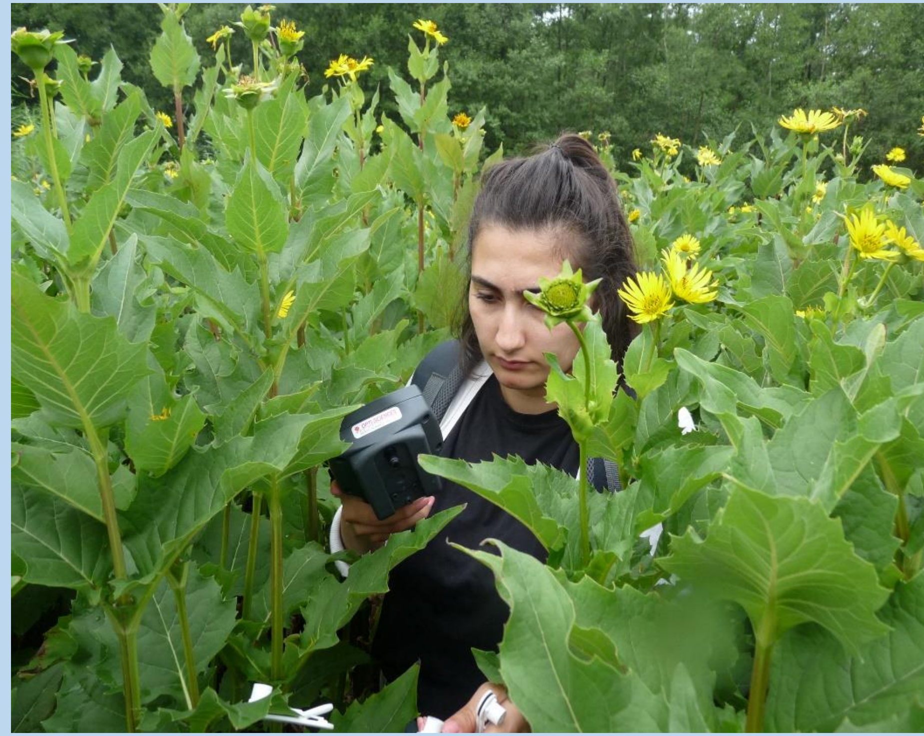


October 2018 before harvest



June 2019 before harvest

October 2019 before harvest



LAI measurement by IAESTE student from Ghana (Sheriff N.) – September 2018

Plant stress measurement by IAESTE student from Turkey (Zeynep K.) – June 2019

Results

The plant density per 1 ha

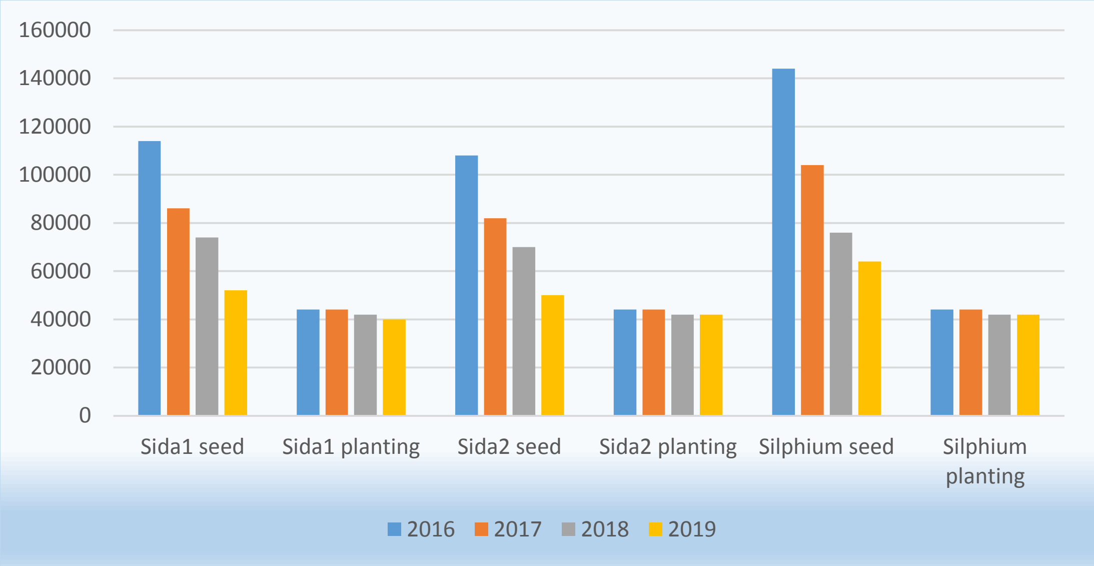


Fig. 1. The number of plants per 1 ha on plots harvested twice a year (June and October)

Table 1. The number of plants per 1 ha on plots harvested once a year (October)

Crop /Establishing method	**Year**			
	2016	2017	2018	2019
Sida1 seed	112000	84000	68000	50000
Sida1 planting	44000	44000	42000	42000
Sida2 seed	108000	80000	64000	49000
Sida2 planting	44000	44000	42800	42000
Silphium seed	140000	110000	72000	62000
Silphium planting	44000	44000	42000	42000

The plant height

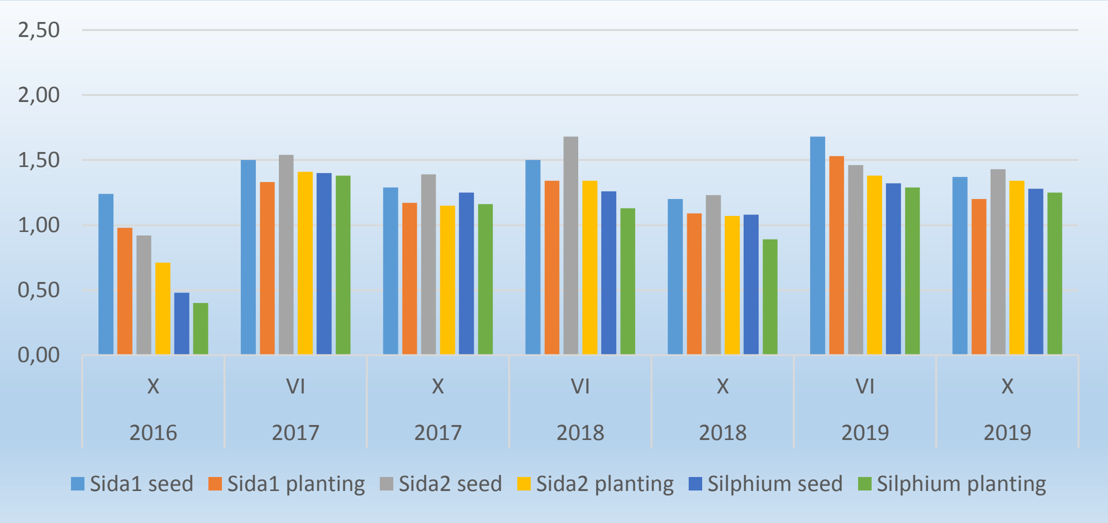


Fig. 2. The plant height [m] of plants harvested twice a year (June and October)

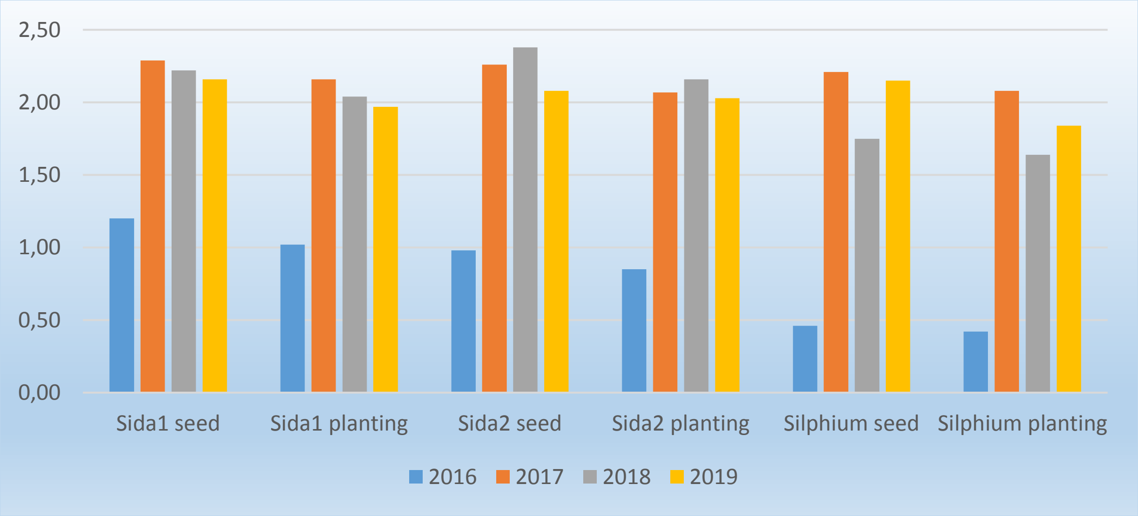


Fig. 3. The plant height [m] of plants harvested once a year (in October)

The shoot diameter

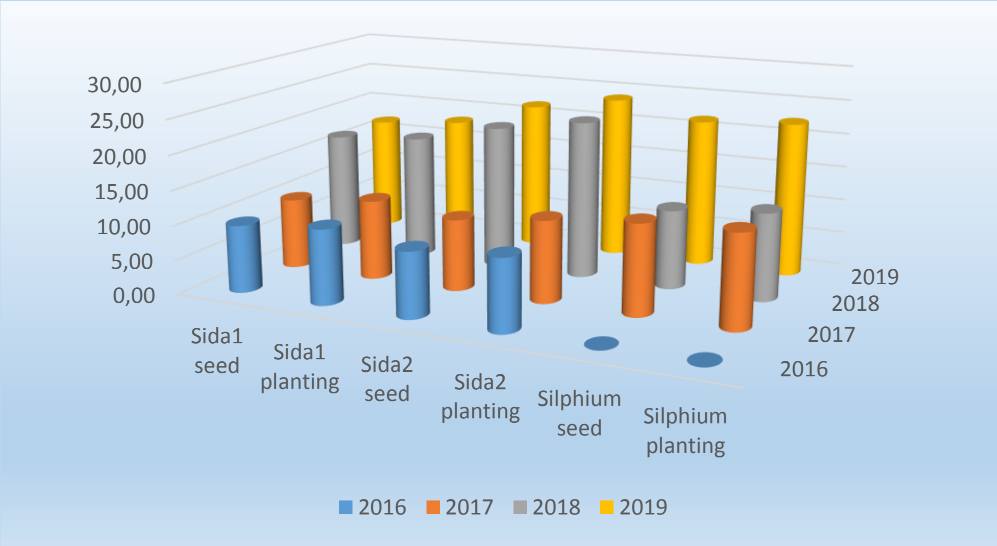


Fig. 4. The shoot diameter [mm] of plants harvested twice a year (June and October)

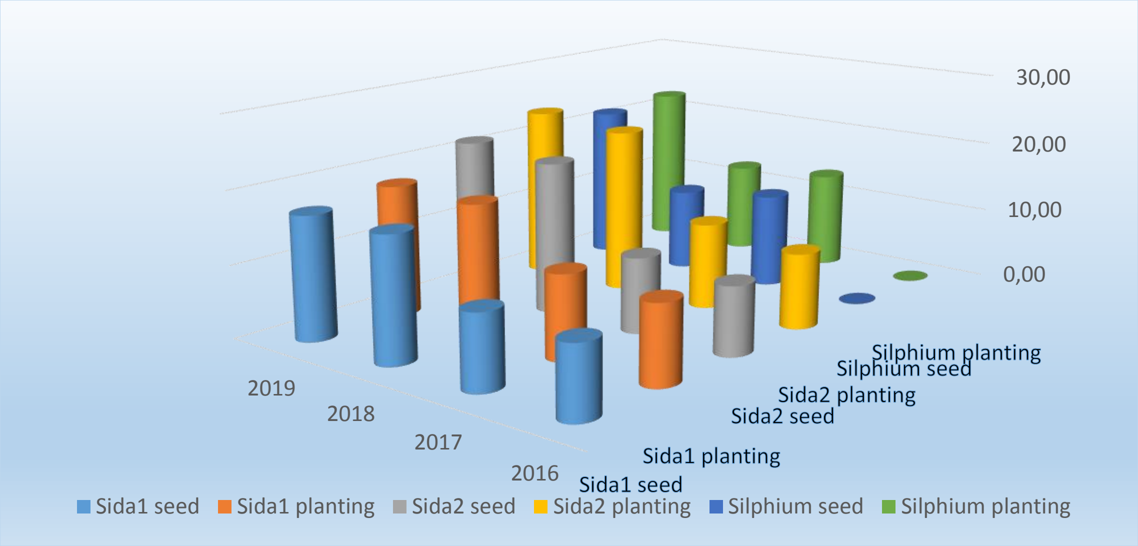


Fig. 5. The shoot diameter [mm] of plants harvested once a year (June and October)

The number of shoots per one plant

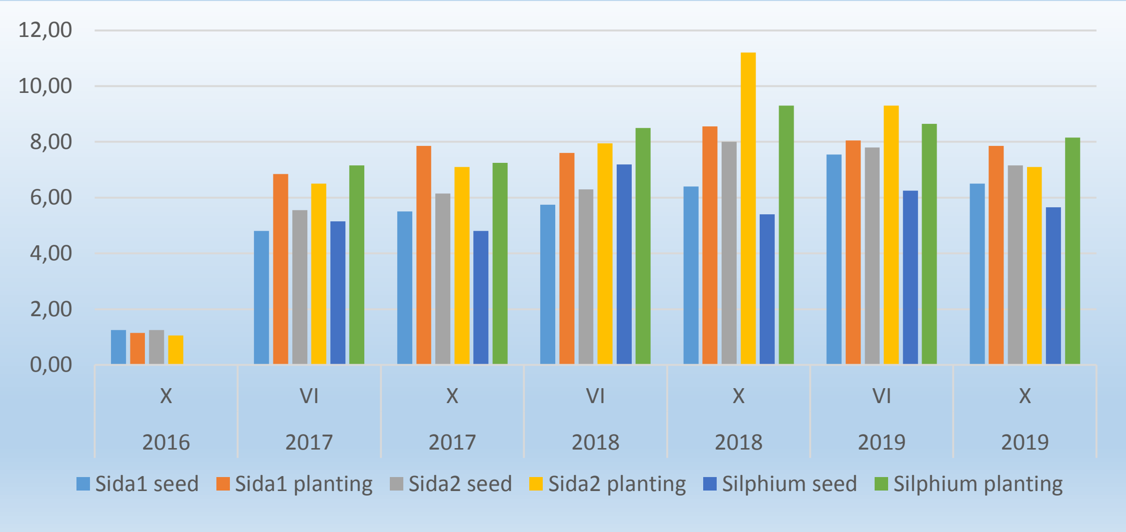


Fig. 6. The shoot number per one plant on plots harvested twice a year (June and October)

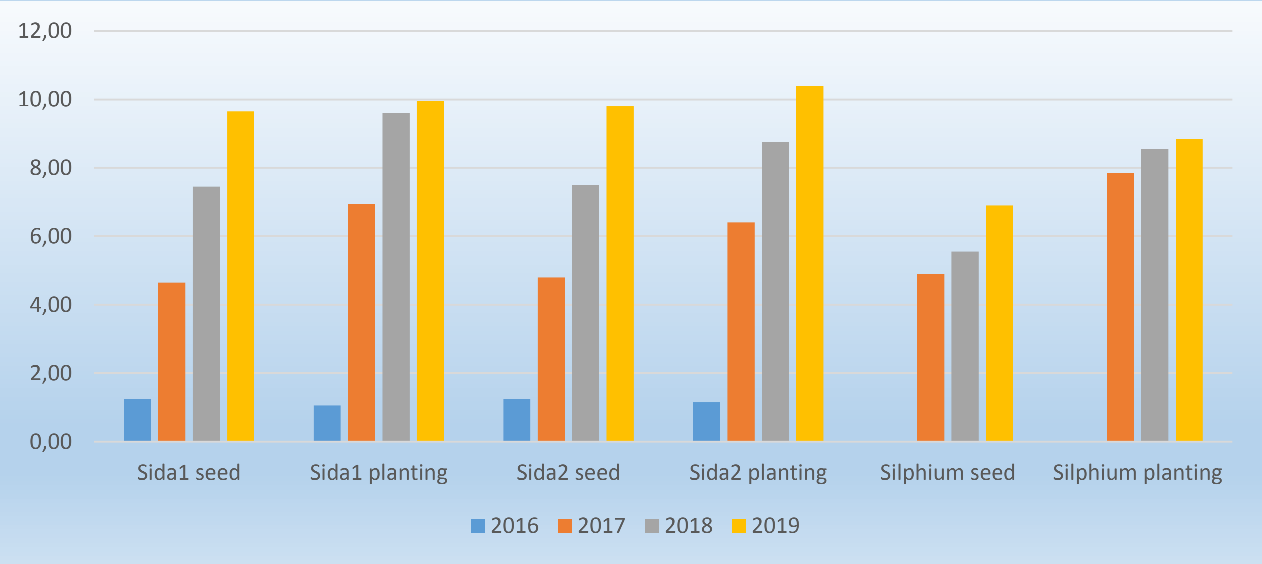


Fig. 7. The shoot number per one plant on plots harvested once a year (October)

The fresh biomass yield

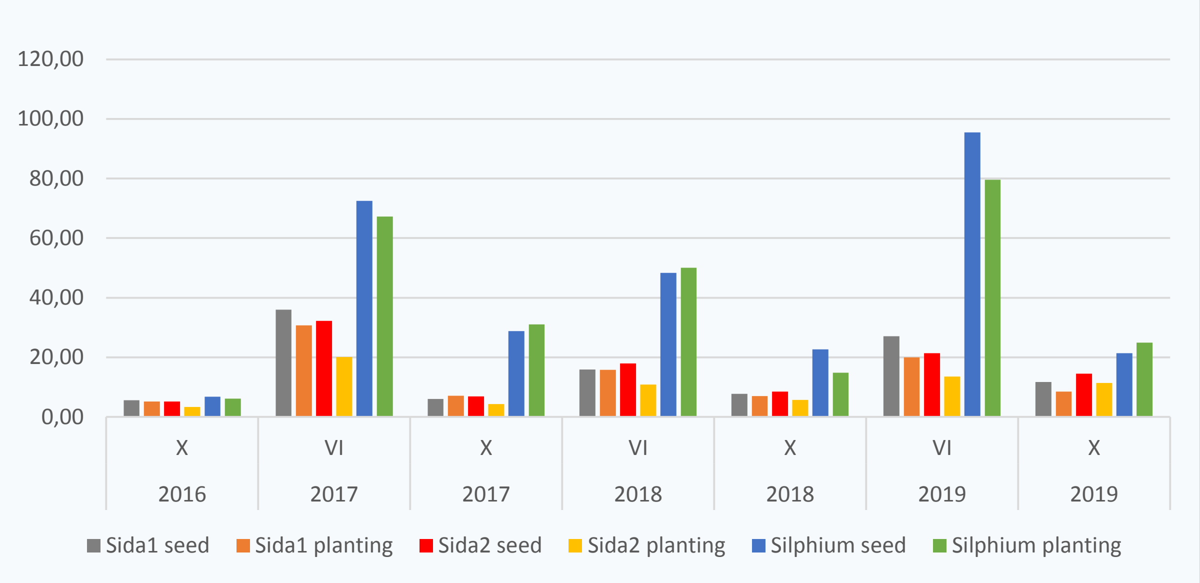


Fig. 8. The fresh biomass yield [$Mg \cdot ha^{-1} \cdot yr^{1}$] of plants harvested twice a year (June and October)

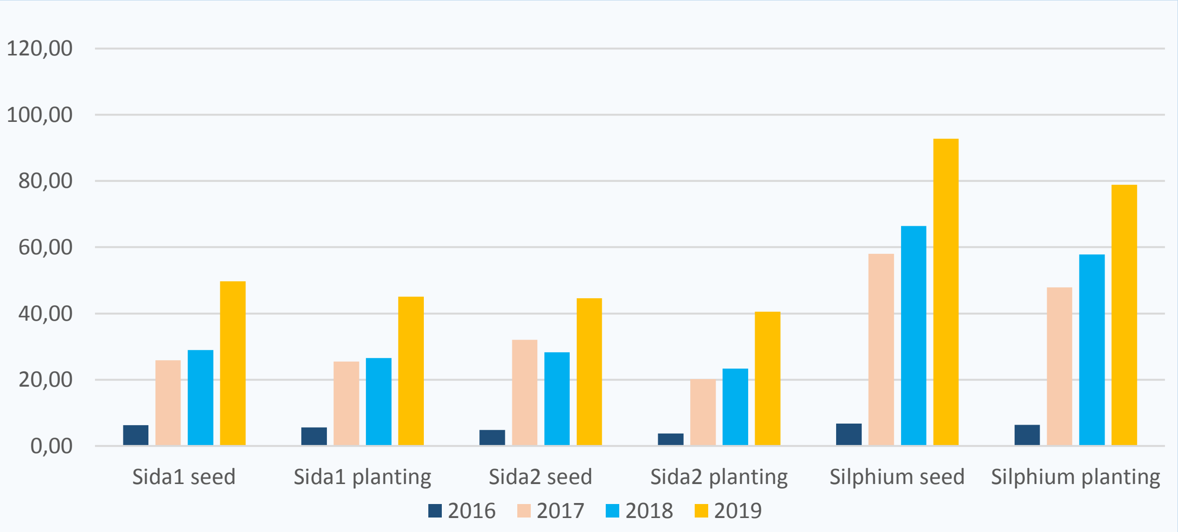


Fig. 9. The fresh biomass yield [$Mg \cdot ha^{-1} \cdot yr^{1}$] of plants harvested once a year (October)

The fresh biomass yield (cumulative)

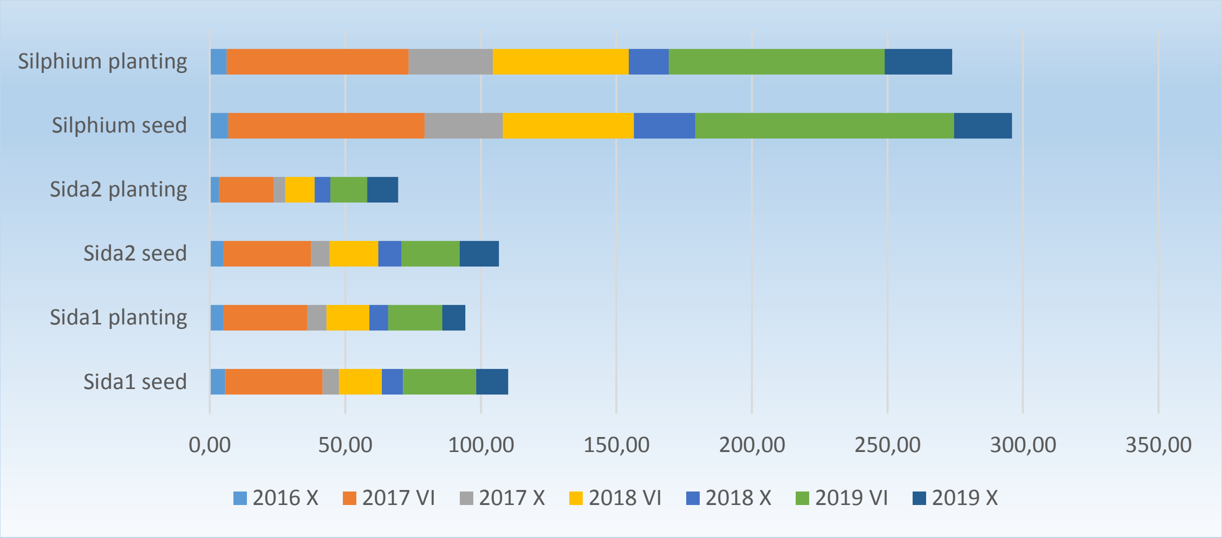


Fig. 10. The total (cumulative) fresh mass yield [Mg·ha^{-1}] of plants harvested twice a year (June and October)

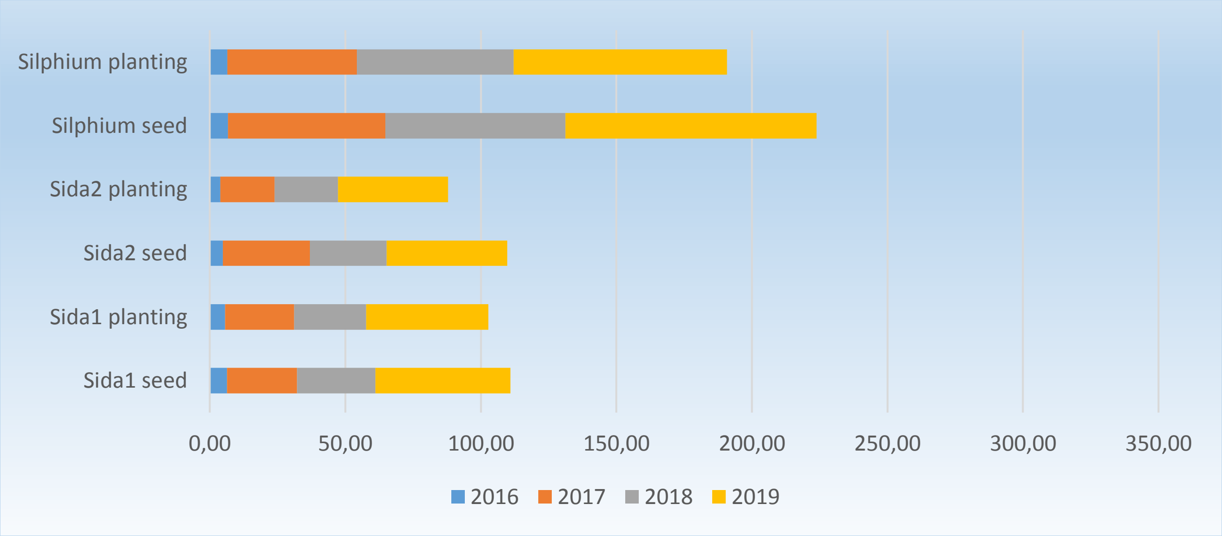


Fig. 11. The total (cumulative) fresh mass yield [Mg·ha^{-1}] of plants harvested once a year (in October)

The dry matter content

Table 2. The dry matter content [%] of plants harvested twice a year (June and October)

Establishing method \Year	2016	2017	2017	2018	2018	2019	2019
Harvest month	X	VI	X	VI	X	VI	X
Sida1 seed	28,30	36,60	32,40	29,00	34,00	30,10	35,00
Sida1 planting	29,23	38,10	29,20	28,00	33,00	30,70	39,00
Sida2 seed	23,13	38,90	32,60	32,00	32,60	34,00	39,50
Sida2 planting	25,79	39,10	30,00	27,50	32,00	30,40	36,00
Silphium seed	16,84	29,90	17,00	16,00	20,00	14,08	20,00
Silphium planting	16,82	28,80	17,20	18,00	21,00	13,56	23,10

Table 3. The dry matter content [%] of plants harvested once during the growing season

Establishing method \Year	2016	2017	2018	2019
Sida1 seed	30,19	39,40	37,00	39,00
Sida1 planting	32,32	37,80	36,00	37,50
Sida2 seed	28,79	39,10	36,50	39,50
Sida2 planting	30,18	38,90	32,60	39,00
Silphium seed	17,13	27,00	31,00	29,00
Silphium planting	15,97	28,00	33,00	25,00

The dry biomass yield

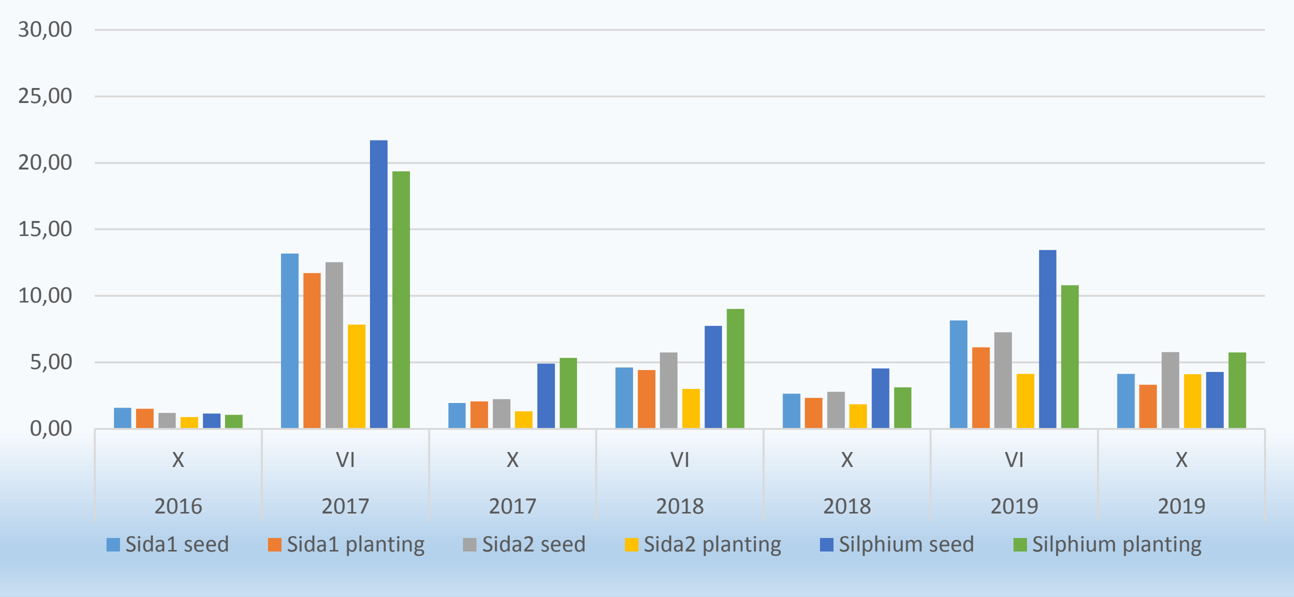


Fig. 12. The dry biomass yield [$Mg \cdot ha^{-1} \cdot yr^{1}$] of plants harvested twice a year (June and October)

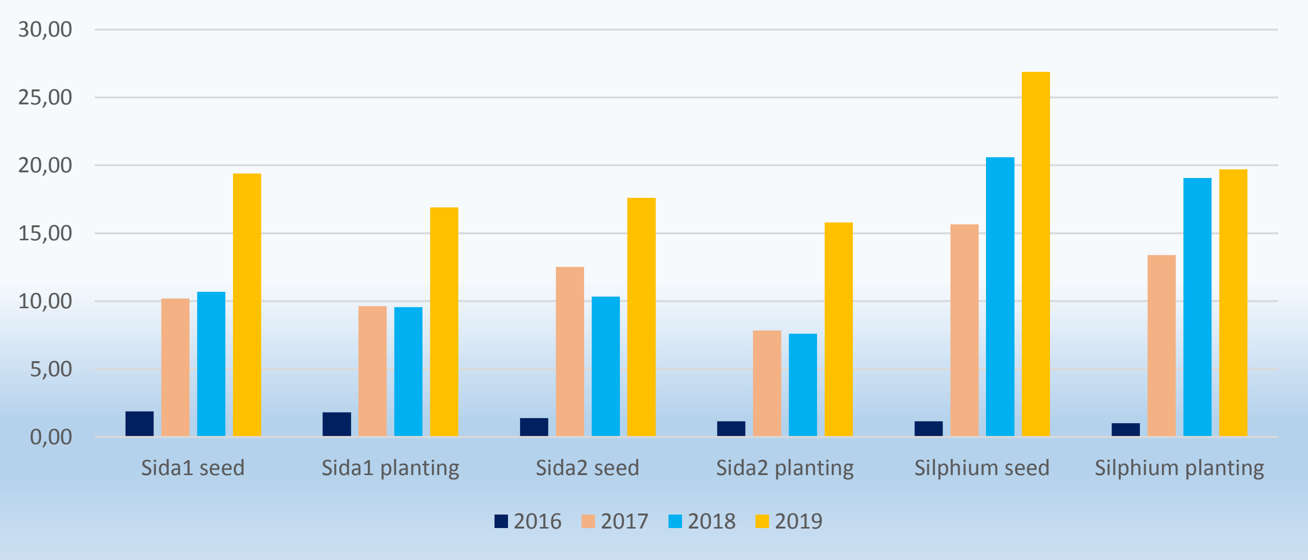


Fig. 13. The dry biomass yield [$Mg \cdot ha^{-1} \cdot yr^{1}$] of plants harvested once a year (October)

The dry biomass yield (cumulative)

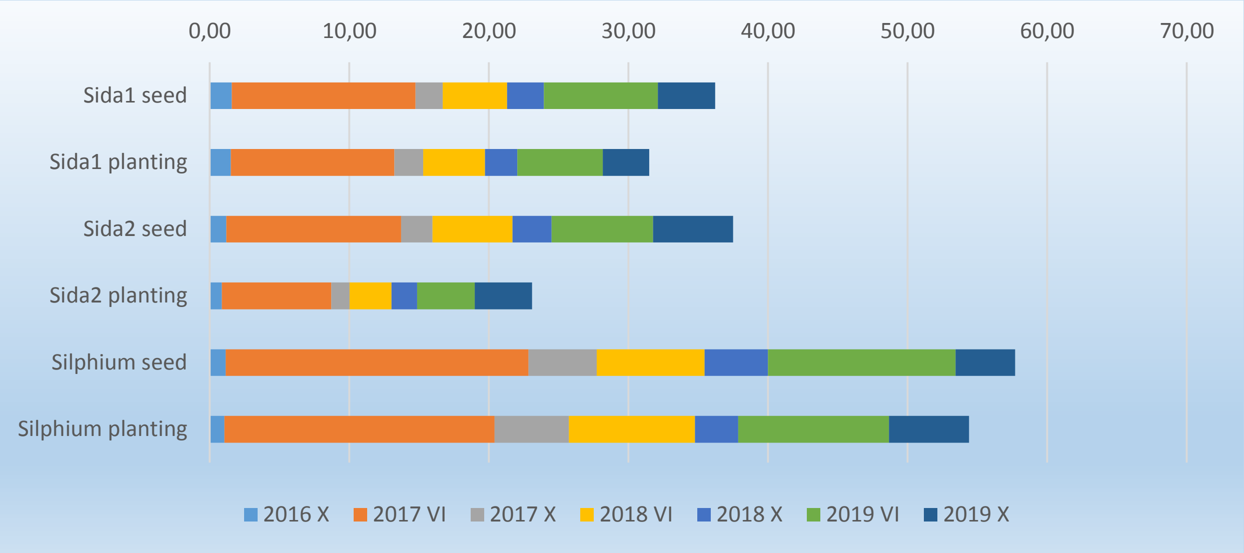


Fig. 14. The total (cumulative) dry mass yield [Mg·ha^{-1}] of plants harvested twice a year (June and October)

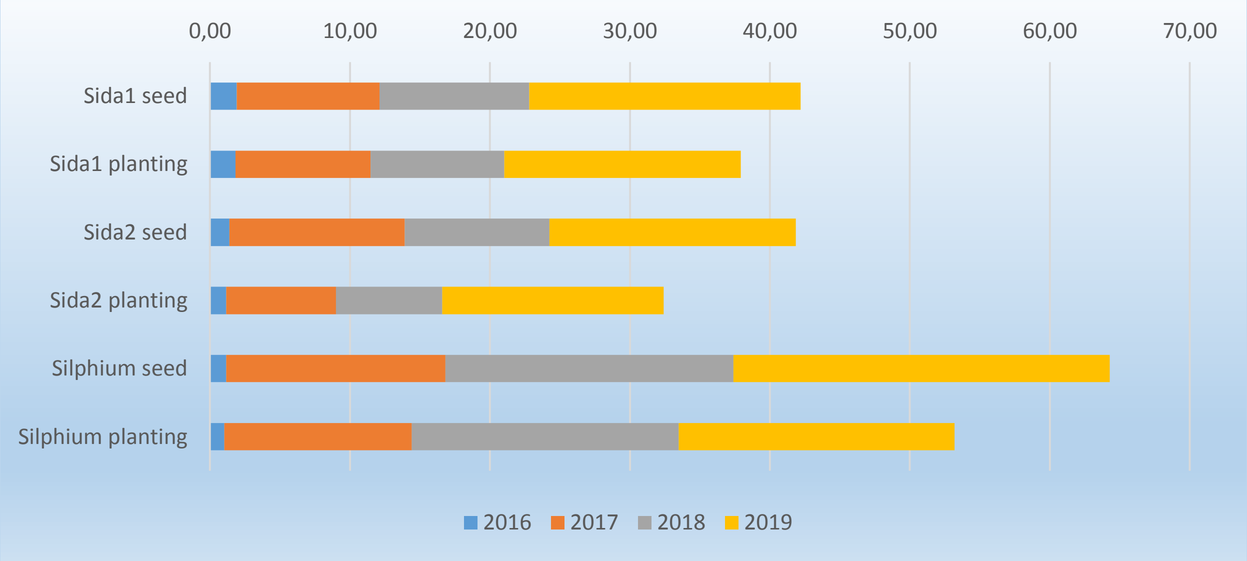


Fig. 15. The total (cumulative) dry ass yield [Mg·ha^{-1}] of plants harvested once a year (October)

Conclusions

•Both investigated perennial plant species: Virginia mallow (*Sida hermaphrodita* (L.) Rusby) and cup plant (*Silphium perfoliatum* L.) established well and provided harvestable yields in full vegetation years.

•The establishing of plantation by sowing seeds resulted in higher biomass yield (ca. 12.0 by Sida and 19.0 $Mg\cdot ha^{1}\cdot yr^{1}$ by Silphium) compared to the planting method (ca. 9.0 and 18.0 $Mg\cdot ha^{1}\cdot yr^{1}$ by Sida and Silphium, respectively), due to the higher plant density obtained after the sowing method compared to the planting method.

•The harvest method had a clearly influence on DMY. In the case of one harvest strategy the DMY increased from 10 (in 2017) to 17 $Mg\cdot ha^{1}\cdot yr^{1}$ (2019) on average for Sida and from 14.5 (2017) to 23 $Mg\cdot ha^{1}\cdot yr^{1}$ (2019) for Silphium. By two harvest strategy the total biomass yield (two cuts in June and October) decreased, in contrast, during investigation period from 13 to 11 $Mg\cdot ha^{1}\cdot yr^{1}$ on average for Sida and from 26 to 17 $Mg\cdot ha^{1}\cdot yr^{1}$ for Silphium

• The cup plant (*Silphium perfoliatum*) produced more biomass as Sida in the same habitat and climatic conditions.

This presentation shows the results of a field study on the growth and yields of two innovative energy crops, Virginia mallow (*Sida hermaphrodita* (L.) Rusby) and cup plant (*Silphium perfoliatum* L.), tested in the frame of **SidaTim** project in Poland, Germany, Italy and UK.

Project: Novel Pathways of Biomass Production: Assessing the Potential of Sida hermaphrodita and Valuable Timber Trees.

Project partners:

This project has received funding from the European Union's **Horizon 2020** Research and Innovation Programme (ERA-NET CO-FUND FACCE SURPLUS). The project was sponsored by:

Thank you very much for your attention

Bumblebee on a flower of *Silphium* – Sept. 2018

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