LANDTECHNIK 70(6), 2015, 254–261

DOI:10.15150/lt.2015.3115

LANDTECHNIK AGRICULTURAL ENGINEERING

Crop establishment of *Silphium perfoliatum* by precision seeding

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Silphium perfoliatum, a perennial composite from North America, has been found as a promising plant species during the search for alternative biogas substrates. Until now *Silphium perfoliatum* has been established by the time- and cost-intensive transplanting method. The precision sowing of *Silphium perfoliatum* reduces the process costs significantly. However, the bulky seed with mildness germination power complicates a well distributed and adequate plant establishment. In field tests a modified precision seeder was used for sowing *Silphium perfoliatum* which is primarily used for maize sowing.

The hole diameter of the singling disc, the sowing coulter and the roller were modified. In the field tests the modified machinery proved an enhanced and uniform field emergence of *Silphium perfoliatum*.

Keywords

Biogas, bioenergy crop, precision sowing, sowing technique, renewable raw material

Due to the increasing number of biogas plants producing electricity and heat from biomass the requirement for substrates of renewable resources rises (FNR 2013). Currently, corn, cereal (grain and whole-crop silage) and forage are predominantly used as biogas substrates. In addition to the change of the landscape, problems in crop rotation are caused by the expansion of corn acreage. Due to the politically formulated aim to limit the use of corn silage at 60 %, alternatives or additions have to be found. Moreover, the Greening specifications (GAP since 2014) request the cultivation of at least three different crops if more than 30 hectares of arable land are cultivated. Perennial experiments of the Thuringian regional office for Agriculture (TLL) shows that *Silphium perfoliatum* keeps up with corn in biological yield, as well as in matter of gas production (Biertümpfel 2011, Biertümpfel and Conrad 2013). *Silphium perfoliatum* reaches yields of 130–180 dt DM ha^{-1}. Because *Silphium perfoliatum* has no special requirements to climate and soil conditions, it can be cultivated among Central European growing conditions.

received 30 July 2015 | accepted 8 December 2015| published 22 December 2015

Problem and task

Almost all previous crops of *Silphium perfoliatum* have been established through planting of seedlings from specialized companies (Biertümpfel et al. 2012). The planting is done with commercially available vegetable or strawberry planters. For the successful introduction of *Silphium perfoliatum* into agricultural practice it is necessary to develop a precision sowing technique (Biertümpfel and Conrad 2013). Due to the low germination power, 12 to 15 seeds per square meter have to be placed in a seeding depth of 10–15 mm (Biertümpfel 2011, Biertümpfel and Conrad 2013). A uniform distribution of the seeds is crucial for a successful establishment (Biertümpfel and Conrad 2013), because planting stocks develop slowly and are not competitive against weeds. Therefore, precision sowing is recommended for *Silphium perfoliatum*. Existing precision seeders on farms should be used to avoid an acquisition of a new machine. The singling of the seeds is hindered by their shapelessness and low thousand grain weight of 16–20 g (Figure 1 and 2). The sowing of *Silphium perfoliatum* is ambitious due to the low seeding depth in comparison to maize. The machinery has to be adapted precisely to the requirements of *Silphium perfoliatum*.

The aim of the experiments was to modify a common precision seeder, to achieve a uniform field emergence of *Silphium perfoliatum*, without major modifications of the technical system of the machine.

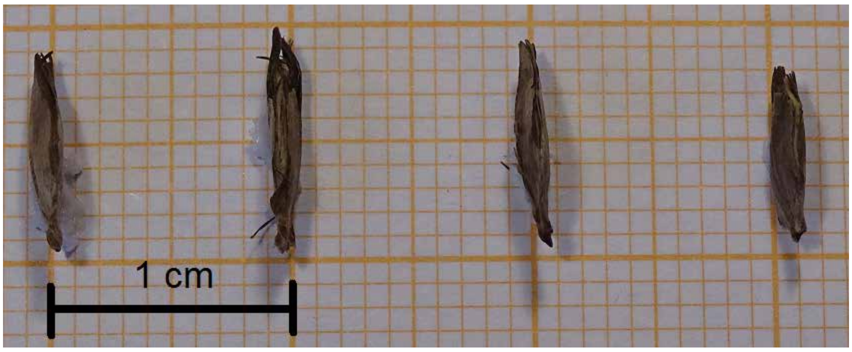
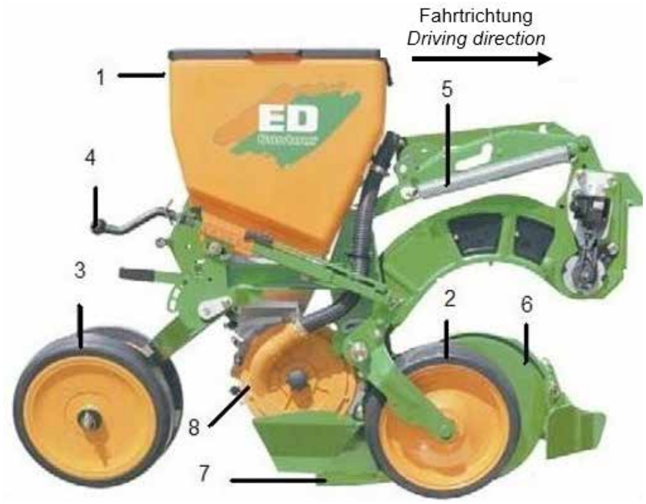


Figure 1: Lateral view on seed of *Silphium perfoliatum* (Photo: A. Schäfer)

Figure 2: Topview on seed of *Silphium perfoliatum* (Photo: A. Schäfer)

Material and methods

For sowing *Silphium perfoliatum* the precision seeder type ED 302 from Amazone was selected. The seeder was equipped with six Contour sowing units (Figure 3) with a row distance of 50 cm. The singling of the seeds are realised by the vacuum at rotating singling discs. The sowing unit is supported on the preparatory and subsequent roller. The rollers are connected to the sowing unit via a spindle and form a cantilever (Figure 3).



Number	Component
1	Seed hopper
2	Preparatory roller
3	Subsequent roller
4	Depth adjustment
5	Adjustment of spring
6	Double disc
7	Seed coulter
8	Seed meter

Figure 3: Precision sowing EKS-M, typ Contour of ED 302 (modified on AMAZONE 2005)

The first field experiment was applied in June 2013 as a non-randomized block design with two replications and long plots on campus Klein-Altendorf, the experimental farm of the faculty of agriculture of the Friedrich-Wilhelms-University of Bonn. The experimental area was ploughed in autumn 2012 and the seedbed was prepared by a rotary harrow and a subsequent tooth packer roller at the day before sowing. The speed of the compressor was varied and also the seeding depths in the steps 5, 10 and 15 mm. For closing and recompaction of the seed furrow a V-shaped roller was used.

In 2014, a further randomized field experiment with four replications on the same location was applied with identical previous tillage. To reduce the multiple assignments and thus the seed demand, singling discs with hole diameters of 2.2 mm, 1.5 mm and 1.2 mm were tested in calibration tests. All singling discs were tested in stripper position 1 (strong attachment of stripper to singling disc) and stripper position 3 (medium attachment of stripper to singling disc). The stripper can be adjusted in five positions. In the calibration tests the seeds were counted and the percentage of multiple assignments of the redundant seeds ascertained. Apart from the V-shaped roller (roller 1), a smooth, about 20 cm wide Farmflex rubber tyre (roller 2, Figure 4) was tested as subsequent roller.

In the field experiment in 2013, was observed that the subsequent roller did not touch the soil at seeding depths of 5 and 10 mm. Since the rollers are at a stop at these seeding depths, the function is not possible. In order to provide the roller contact with the soil at these seeding depths, another kit of sowing coulters was modified and the height of the wedge was reduced by 20 mm (Figure 5). Thus, the contact between subsequent roller and soil surface could be warranted even with seeding depths of 5 and 10 mm.

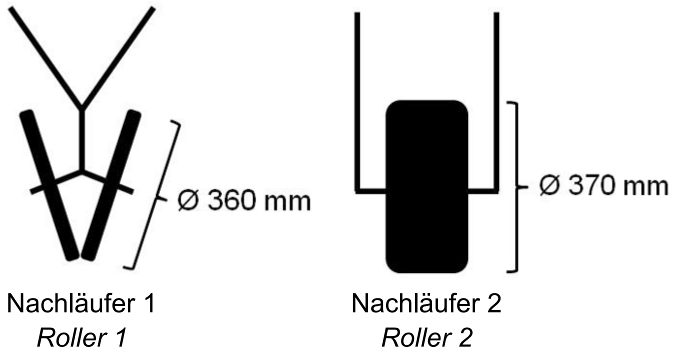


Figure 4: Schematic representation of used roller

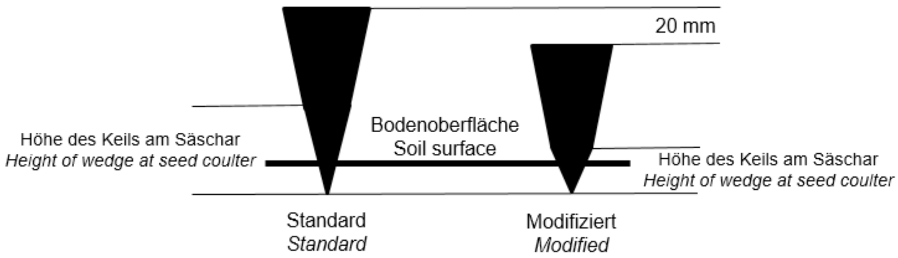


Figure 5: Schematic representation of used seed coulters

To determine the field emergence, the number of plants and number of positions where plants grew up were evaluated in both field experiments. The number of positions where plants grew up is important, because the number of plants does not allow a statement about the distribution of plants per area. If the number of plants is higher than the number of plant positions, it means that there are multiple assignments at separate singling disc positions. That is the reason why in Figure 6 to 8 the measured positions of plants are shown. The normal distribution was tested by the Kolmogoroff-Smirnoff-Test (K-S-Test). To examine significant differences between several variants a unifactorial variance analysis was carried out. With the Tukey test an additional multiple comparison of averages was performed.

For a explicit presentation of the results, the means of the variants and their statistically verified differentiation are listed below the particular boxplots. If the shown means are in different homogeneous subgroups, they differ significantly. The rectangular box of the boxplots represents 50 % of the values. The median is presented by the line in the box. Values outside of the box were represented by the so-called antennas. Bubbles outside a box plot and the antennas represent outliers.

Results and discussion

The pilot test prior to the field experiment in 2013 showed that the necessary number of seeds can be applied with the selected precision seeder. In the field experiment significant differences of field emergence between the variants with different seeding depths occurred. The variants with the seeding depths of 5 mm show significant higher field emergence than the variants with the deeper seeding depths (10 and 15 mm). It is not clear whether the lower field emergence in variants of 10 and 15 mm seeding depth is an effect of the low germination power of the seeds or caused by the irregular seed placement. During the sowing it could be observed that the singling discs were not provided continuously with seeds at low level of the seed hopper. Due to the desiccation of the seeds, Biertümpfel and Conrad (2013) recommend seed placement in depths of 10 and 15 mm.

The different speeds of the compressor had no effect to the field emergence. The field experiment showed that the sowing of *Silphium perfoliatum* with a precision seeder is possible. To optimize the crop establishment modifications at the precision seeder have to be conducted.

Because of the irregular occupancy of singling discs with seeds by low filling of the level seed hoppers, the volume of the seed meter was reduced. To reduce the multiple assignments, calibration tests with three different singling discs were performed prior to the field experiment in 2014. By reducing the hole diameter of the singling discs, the multiple assignments could be reduced. The change of the stripper attachment to singling disc (position 1 or 3) did not separate redundant seeds, and had no effect on multiple assignments (Table 1). Multiple assignments of more than 80 %, which means a higher seed demand of more than 80 % are unacceptable. The economic advantages of sowing are mainly caused by the lower cost for the seeds, as compared to seedlings. Using singling discs with a hole diameter of 1.2 mm is recommended. Nevertheless, singling discs with a hole diameter of 2.2 mm were used for comparison.

Table 1: Results of calibration test ($\bar{x}$ = arithmetic mean, s = standard deviation)

Hole diameter [mm]	Position stripper	Multiple assignment [%]	
		$\bar{x}$	s
2.2	3	80.7	16.5
2.2	1	97.5	3.8
1.5	3	33.8	2.8
1.5	1	28.4	3.1
1.2	3	3.9	3.4
1.2	1	15.3	2.5

In the field experiment 2014, the variants of singling discs with a hole diameter of 1.2 mm showed significantly lower field emergences than the variants where the singling discs with a hole diameter of 2.2 mm were inserted (Figure 6). Despite the missing plants in the variants where singling discs with a hole diameter of 1.2 mm were used, ploughing up the experimental area is not reasonable. Only at less than 4 plants per square meter, ploughing up should be considered (Biertümpfel and Conrad 2013). Because the variants of singling discs with 1.2 mm hole diameter have a field emergence of 75 or 82 %, this plant density, despite the missing plants, is sufficient for crop establishment.

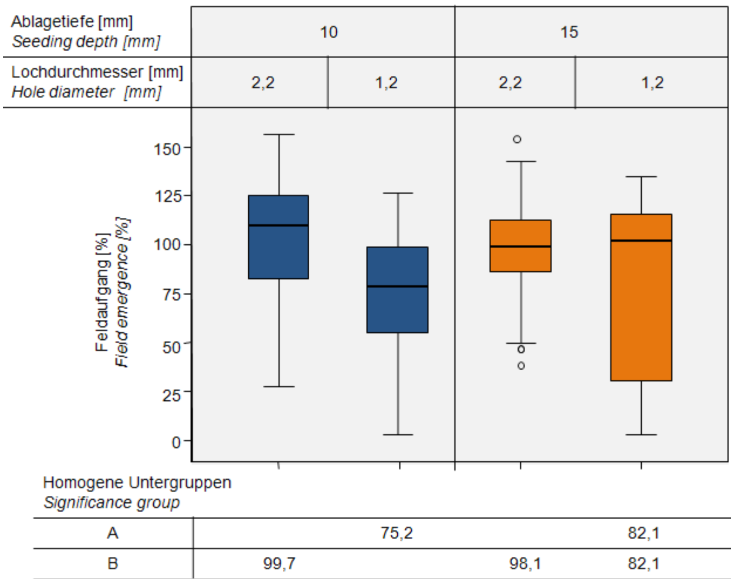


Figure 6: Field emergence versus seeding depth and hole diameter of singling disc

The field experiment in 2014 exhibits, irrespective of the tested roller, higher field emergences in variants with seeding depth of 15 mm than variants with seeding depth of 10 mm (Figure 7 and 8). The germination power of the seeds is sufficient to break through the coverage. Additionally, the field emergence benefited from the advantageous weather conditions (temperatures about 20 °C as well as constant and effective rain). Already Rademacher (1990) manifested the relevance of the roller for the improvement of field emergence.

Roller 1 closed and recompacted the seed furrow. On the other hand roller 2 did not cover the seeds, whereby the seeds remained at the surface and dried up. Keeping that in mind, the lower field emergences of the variants with roller 2 are explainable. Using additional coverers to achieve the seed coverage, roller 2 is suitable for sowing *Silphium perfoliatum* as well.

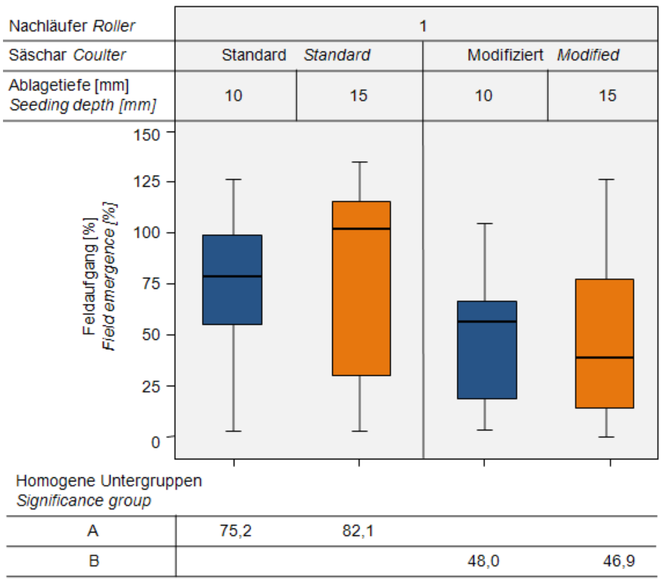


Fig. 7: Field emergence versus seeding depth for roller 1

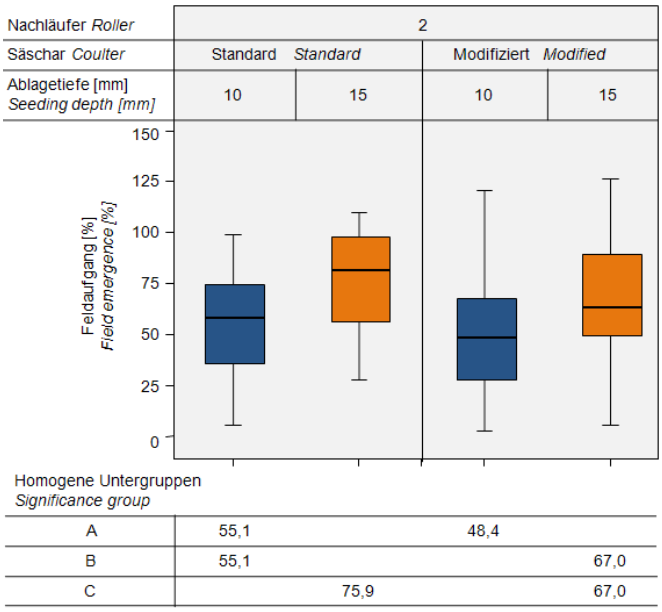


Fig. 8: Field emergence versus seeding depth for roller 2

Using the modified seed coulters, roller 1, as compared to the standard sowing coulter, evenly lay on the seed furrow. These variants reveal lower field emergences although a uniform seed coverage was achieved. Presumably the pressure load on the seeds was too high to break through the seed coverage, due to recompaction of the coverage layer. In the variants of roller 2 the effect of the seed coulter is not as pronounced as in the variants of roller 1 (Figure 7 and 8). A possible reason for this is the fact that roller 2 did not close the seed furrow neither with the standard seed coulters, nor with the modified seed coulters.

Conclusions

Silphium perfoliatum can be established by common precision seeders. By modifying the seeder an improved and uniform field emergence can be achieved. To reduce the multiple assignments and thus the seed demand, the hole diameter of the singling disc needs to be adapted. A change of the stripper position did not separate redundant seeds, and had no effect on multiple assignments. Despite the low germination power of the seeds, it is advisable to deposit the seeds in a seeding depth of 15 mm. In flatter seeding depths there is a risk of drying up. Crucial for a uniform field emergence is the uniform seed coverage. The field experiments show that different rollers can be used. By using rollers that recompact the seed furrow without closing it (roller 2), coverers have to be used. If the seed coverage is too strong, the germination power of the seeds is not sufficient to break through the soil surface. Due to the high requirements for a precise seed embedding mulch sowing is no option. A precondition for the expansion of the cultivated area with *Silphium perfoliatum* for use as biogas substrate, is the optimization of the crop establishment.

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Acknowledgments

Thanks go to AMAZONE company for the allocation of the precision seeder. We also thank the company Chrestensen for providing the seed and the good cooperation. Furthermore we want to thank the team of the Campus Klein-Altendorf for the appropriation of the experiment area and the support during the experiments.