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Determination of the seed geometry of cup plant as requirement for precision seeding

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In search of economically and ecologically interesting alternatives and additions to maize, currently the predominantly used biogas substrate, cup plant (*Silphium perfoliatum* L.) has been found as a promising plant species. The perennial composite, which is located in North America, can be established by modified conventional seeders. Due to a long flowering period and different geographic origins of the plant material, seeds of different sizes and shapes can be found in the seed batch, which makes a precise singling of the seeds difficult. For the quantification of the geometric parameters the seeds were recorded and measured. The results of these researches were used to optimize the seeding in precision seeders.

Keywords
Cup plant, seed measurement, precision sowing, seed treatment, incrustation

In order to expand the crop rotation for biogas production systems, alternatives or additions to the predominantly used substrate maize are needed to supply biogas plants with substrates of renewable resources. Silphium perfoliatum (*Silphium perfoliatum* L., below called cup plant), a perennial composite from North America, has been found as a promising plant species for biogas substrate. In addition to a gas yield at the level of the maize, cup plant has a number of ecological advantages. These arise due to the perennial cultivation through the whole year's soil coverage and the long flowering period from July to September (Biertümpfel et al. 2012). For the successful introduction of cup plant into agricultural practice, it is necessary to optimize the cultivation. Due to the currently realized time- and cost intensive transplanting method, the development of a sowing technique has become more important (Biertümpfel and Conrad 2013). The aim of sowing is an equal distribution of 12 seeds per square meter. For the equal distribution of the seeds the precision sowing method is suitable. By modifying the precision seeder, an equal singling of the seeds as well as a homogenous field emergence was achieved (Schäfer et al. 2015).

Since the seed costs of 1 700 € ha^{-1} (about 62 %) are the largest part of the cultivation costs, a precise singling is a possibility of seed and cost saving (Biertümpfel and Conrad 2013). The precise singling of the seeds is hindered by the shape and the inhomogeneity of the seeds in the seed batches. Two reasons for the inhomogeneity of the seeds can be pointed out. On the one hand there are, despite the ongoing breeding processing of cup plant, no varieties available. Commercially available seed is composed of seeds of different geographic origins with a high genetic variation (Biertümpfel et al. 2012, Gansberger et al. 2015). On the other hand, the seeds mature unevenly after flowering, which results in different sizes of seeds. If the inflorescences are not harvested at the ideal state of maturity and thus in multiple passages, but in all inflorescences in one passage, the seed batches contains mature and immature seeds (Gansberger 2016). The mature seeds with the trailed palea at the seed-coat are shown in Figure 1 (left). In the following this state of the seed is called „natural form".

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Because these seeds have a strong germination inhibition, they are considered dormant and are not suitable for sowing (Scheithauer 2012, Trölenberg et al. 2012). In addition it is possible that the palea get caught, which leads to bridging in the sowing heart.

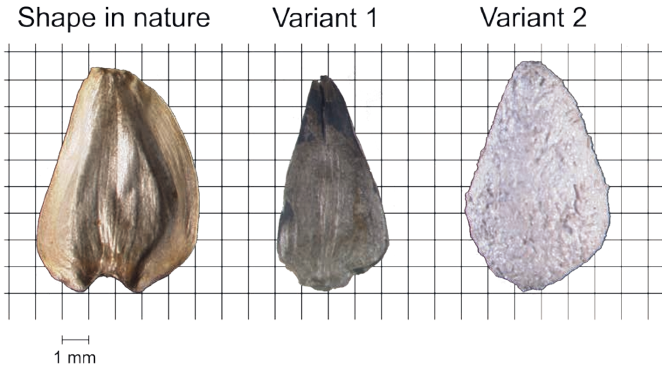

Figure 1: Overview of different types of cup plant seeds

For the above reasons, the commercially available seed has to be processed. During the processing, the palea is rubbed off mechanically and the dormancy is partly broken. The dimensions of the seeds in the natural form vary between 9–15 mm in length, 6–9 mm in width and can be 1 mm thick at the maximum (Niqueux 1981). The thousand grain weight of the seeds varies from about 14 g (Neumerkel and Märtin 1982) to 21.5 g (Kowalski and Wierciński 2004). In the middle of Figure 1, a treated, commercially available seed (below called variant 1) is depicted. Figure 2 shows different seeds of variant 1 with the corresponding dimensions.

Figure 2: Overview of the different shapes and sizes of variant 1 within a seed batch

For a more precise singling in the precision seeder the seeds were coated with a hygroscopic material. Due to the geometry of cup plant seeds a coating, as usually used for sugar beet seeds, is not possible. For commercial purposes, the commercially available seeds grains were incrusted (Figure 1, right).

Problem and task

Due to the unequal maturity of the seeds as well as associated time-consuming and cost-intensive harvesting and the processing of the seed, the seed costs of 1 700 € ha^{-1} are classified as high for biogas production compared to other crops. To increase the attractiveness of cup plant for biogas plant operators, the reduction of cultivation costs as well as the safeguarding of the establishment are necessary. Since the uniform distribution of the seeds is the basic prerequisite for an efficient plant stock, the singling of the seeds play an elementary role in safeguarding of plant establishment. Moreover, with a precise singling, the seed costs and also the cultivation costs were reduced. However, the quality of singling strongly depends on the singled seed and its geometric form. In conclusion the singling of flat seeds, including cup plant, is difficult (Stieger and Brinkmann 1975). Within a seed batch there are seeds of different sizes, which also has a negative effect on the singling.

Due to homogeneous seeds the singling can be more precise. This experiment was aimed to determine the seed sizes within a seed batch. Seeds of variant 1, as well as seeds of variant 2 were recorded and measured. The results indicate whether a fractionation of the seeds is useful for increasing the homogeneity within a seed batch.

Material and methods

The investigated seeds derive from the company N.L. Chrestensen Erfurter Samen- und Pflanzenzucht GmbH and were processed after customary method by the breeder. The seeds of variant 2 derived from the identical seed batch and were incrusted by Kwizda agro GmbH in Austria. In this process, the seeds were completely coated with a hygroscopic cover. More detailed information about the incrustation is protected know-how of the company. For the exact measurement of seeds length, width and area, 300 seeds of variants 1 and 2 were recorded by using a binocular from Leica company (Type MZ-16-F; Leica, Wetzlar, software „DISKUS“). The measurement of maximum length and maximum width of the seeds was occurred with the measurement software „DISKUS“. A digital dial gauge, which was locked on a tripod, was used to measure the thickness of the seeds. The feeler pin was spring loaded and pressed with a force of 0.92 N onto the seeds. The measurement of the seed area was based on the captured images using the program „IfL Blob Analysis“ of the Institute of Agricultural Engineering at the University of Bonn. The spreadsheet Excel 2015 (Microsoft Corporation, Redmond, USA) was used for data preparation and descriptive statistics. The statistics program SPSS Statistics (IBM Corporation, Armonk, USA) was used for complex data analysis.

Results and discussion

The shapes of the seeds of variant 1 can basically be described as elliptical. There is a pronounced symmetry to the longitudinal axis of the seeds. Nevertheless, differences are noted through the progress of the longitudinal sides. In the majority of the investigated seeds (about 70 %), these sides converge conically towards one another and end in a pronounced tip. A less percentage of about 30 % assume these seeds, whose tapered side is ovoid. Differences are also noted in the characteristics of the lengthening at the bottom of the seeds. Through the lengthening, the seeds were fixed in the flower (Figure 2, at the lower end of the seeds). The expression underlies no discernible pattern in this sample. This effect can be explained by the processing or by the mechanical rubbing of the paleas. The shapes of the seeds of variant 2 differ only slightly from those of variant 1. The stamping of the lengthening on the underside of the seeds is not comprehensible after the incrustation, since the undersurface is rounded off by the incrustation mass.

The measured seeds of variant 1 have an average length of 8.39 mm. These are about 0.6 mm shorter than the seeds length of variant 2. However, the standard deviation (σ = 0.80) is identical for both tested variants. By the incrustation the maximum width of the seeds is increased by about

0.5 mm to 5.19 mm. The standard deviation is also almost identical here. The largest change due to the incrustation is to document at the seed thickness. So the seeds of variant 2, with an average thickness 2.57 mm, were almost twice high as the seeds of variant 1. However, the larger standard deviation of variant 2 occupies a higher variance of the seed thicknesses. This can be attributed to the fact that five measured seeds of variant 2 are double incrustations. Overall, the seeds of variant 2 were longer, wider and thicker than the non incrustated seeds, with the greatest increase in seed thickness. By the seed geometry there is also the largest possible area for an incrustation available. The seeds of variant 2 have with 34.47 mm^2 a 30 % superior area than variant 1 (Table 1, Figure 3).

Table 1: Results of the length, width, thickness and area measurement of the seeds of variants 1 and 2 (n = 300)

Seeds		Average	Standard deviation	Minimum	Maximum
Variant 1	length in mm	8,39	0,8	6,05	10,39
	width in mm	4,71	0,54	3,47	6,06
	thickness in mm	1,3	0,15	0,67	1,97
	area in mm²	26,74	5,7	18	35
Variant 2	length in mm	8,96	0,8	7,18	11,35
	width in mm	5,19	0,56	4,15	7,18
	thickness in mm	2,57	0,3	1,42	4,45
	area in mm²	34,47	4,65	25	45

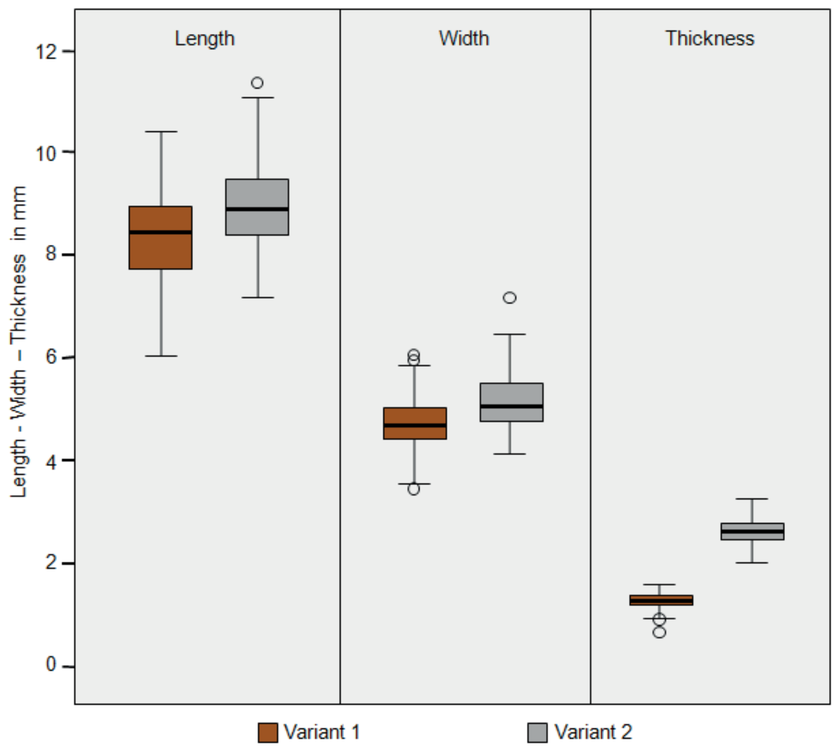

Figure 3: Spread- and layer dimensions of the length, width and thickness of variants 1 and 2 in mm

The dimensions of the seeds described by Niqueux (1981) can only be partially confirmed. The investigated seeds of variant 1 are shorter and narrower. However, in comparison with the seeds described by Niqueux, the paleas have already been separated from these seeds. If this were not the case, the measured values would probably be in the range indicated by Niqueux. The variation of the length and width of the seeds of several millimeters could be detected in the examined sample. The maximum thickness of 1 mm indicated by Niqueux was not occupied. The seed thickness of the examined seeds of variant 1 is 1.30 mm on average. A maximum thickness of 1.97 mm was recorded in variant 1. The small thickness compared to the length and width of the cup plant seeds is a cause for the occurrence of miss assignment in precision seeder (Stieger and Brinkmann 1975).

The percentage distribution of maximum seed length with a class width of 0.25 mm for variant 1 and 2 is shown in Figure 4. For the seeds of variant 1, a smaller, advanced peak between 6.75 and 8.00 mm can be observed. The seeds of these lengths have a length/width ratio of 1.58. These are the ovoid shaped seeds, which were outlined above. The seeds of the main peak, indicating a length of 8.00 to 10.00 mm, have a length/width ratio of 1.91. An even larger length/width ratio of 2.35 show the seeds of seed length higher than 10.00 mm. These are the seeds that converge conically to a pronounced tip. These seeds incline to double assignments at the tested precision seeder with rotating singling discs. In this case, two to three seeds are primed into the drill hole, what restricted the singling of the seeds. Overall, the length/width ratio indicates that the width decreases by increasing length of the seeds. The area of the seeds increases despite the length of the seeds increases only slightly. An explanation for the different length/width ratios of the seeds (variant 1) is the high genetic variability of the plant material.

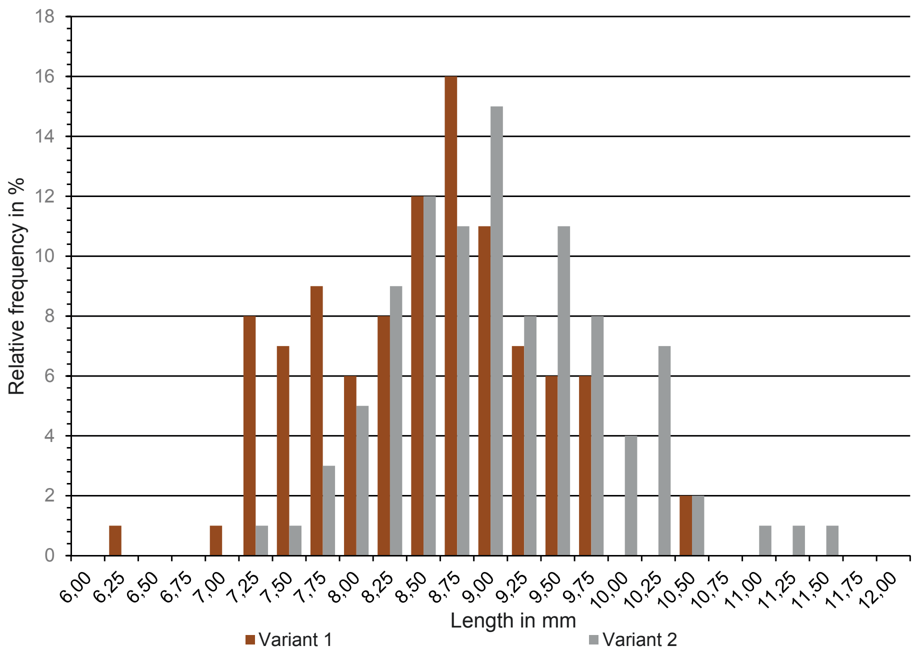

Figure 4: Percentage distribution of maximum lengths of the seeds in variants 1 and 2 in mm

The seeds, having a length to 8.00 mm account for a percentage of 25 % of the seed batch. In order to increase the homogeneity and thus to precise the singling, the screening of this fraction should be considered. Another argument for the screening of this fraction is the insignificant minor thickness of these seeds. On the basis of the results of Stieger and Brinkmann (1975) a smaller percentage of misassignments is possible. Klüver (1991)proved that uniform seed in shape and size is advantageous for the precise singling of seeds in a precision seeder. As typical for composites, Assefa et al. (2015) show also a positive correlation between size and weight of the seed with the germination rate for cup plant. Thus, by screening small seeds, the quality of the seeds and the germination rate could be increased.

In the case of the seeds of variant 2, the above-described front peak of the seed lengths does not occur (Figure 4). However, in variant 2, as in variant 1, the above-described different seed shapes are present. As a result of the incrustation, the thousand corn weight is tripled to about 60 grams. Studies with a test machine showed better flow properties in the seeding meter due to the larger thousand corn weight. By the incrustation the tips of the seeds were rounded off, which reduces or prohibits the above-described effect of the double assignment at the holes of the singling discs. In a greenhouse experiment, a faster field emergence of these seeds could be documented. A field experiment also showed a significantly higher field emergence in comparison to the seeds of variant 1. The fast field emergence of the incrusted seeds can be explained by the hydrophilic characteristic of the incrustation mass. In this case there is more water available at the seedling for germination. This is advantageous because the young seedling can quickly dry out due to the low seeding depth of 15 mm. At this juncture the agronomic advantages of incrustation are more important than the technical advantages. Although the costs of the incrustation are comparatively high at 200 € kg^{-1}, nevertheless they can be compensated by higher and safer field emergence. It can be assumed, that the incrustation becomes more economic in the case of rising quantity ordered.

Conclusions

The measurement of seed variants 1 and 2 gave information about the various seed shapes and sizes. It was shown that a fractionation would particularly homogenize the examined variant 1. So it is to be expected, that the singling is more precise which results in a reduction in the seed effort and thus in the seed costs. An incrustation has only a small effect on the homogenization of the seed batch. Due to procedural and agronomic advantages, the incrustation should be considered for the sowing of cup plant. Besides the genetic spread of the plant material, the long flowering period and maturation are the reasons for the inhomogeneity of the seeds. In ongoing experiments, the causes were analyzed in different seed batches and crop years. The results show the prerequisites for the precision sowing process to increase the attractiveness of cup plant for farmers.

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