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Single-seed sowing of cereals

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Seeding technology for practising single seed sowing of cereals is available on the market. Many trials have been carried out by agricultural machinery manufacturers, advisory institutions, scientific institutions and practitioners. This publication aims to provide an overview of the topic.

1. Conventional drill sowing

Since the beginning of agriculture, humans have been concerned with the even distribution of seeds across the area to be cultivated. Currently, grain is mainly sown using seed drills, which is not the optimal method for crop cultivation. For technical reasons, conventional drill sowing results in random seed placement, which leads to very different distances between the seeds. When several seeds are placed in one spot, the plants that grow from them compete for water, light and nutrients.

The more intense competition between plants in conventional drill sowing can lead to longer, unevenly thick stalks, with more uneven tillering and poorer crop aeration, which can also promote leaf and stalk diseases as well as ear fusarium.

According to textbooks, the optimum sowing depth for cereals is 2 to 3 centimetres. Seeds sown too deep or too shallow result in a lower yield per ear. If seeds are sown too deep, tillers form, and a higher auxin level in the plant leads to the formation of long leaves and poorer tillering. This can also result in poorer development of fine roots and thus poorer water and nutrient uptake, the development of stem base diseases, and losses due to black frost when the plants break off. If seeds are placed too shallowly, field emergence decreases when soil moisture is low, and bird damage and herbicide damage can also occur.

2. Objectives of single-seed sowing

The objectives of single-seed sowing have been described since the 1940s: better distribution of growing space should minimise all the disadvantages listed above. Targeted and precise seed placement must replace random seed placement. To ensure that all seeds have optimal germination and growth conditions, single seed sowing must also ensure uniform depth [Hege, 1949; Heege, 1967].

With evenly distributed seeds, the seed quantity can be significantly reduced. For example, with a sowing density of 200 seeds per square metre and 15 cm row spacing, there is one seed every 3.3 cm on average.

2.1 Test results for single-seed sowing of cereals

The literature describes the following advantages of single-seed sowing of cereals compared to conventional drill sowing:

Higher yields with the same use of resources [Ohe et al., 2016]: The trial mentioned was conducted over three consecutive years from 2012 to 2014 with winter rye and winter wheat in Germany. Wheat was grown at nine locations and rye at five locations. Drill sowing was compared directly with single-seed sowing at the same sowing densities. In 2013, the yield advantage for rye was 4%, in 2014 it was 5% and in 2015 it was 2% (average sowing density 120 to 200 grains/m²). In wheat, 2014 saw a 5% yield advantage for single-seed sowing, significantly ahead of the other two years, which only saw a 2% advantage (sowing density: 200 grains/m²). Furthermore, the effects of single-seed sowing on lighter soils were not uniformly higher than on better soils. However, individual locations did not show a significantly positive yield effect from single-seed sowing in any year.

Furthermore, the literature cites the following positive effects of single-seed sowing of cereals:

- Higher yields with lower resource use [Große-Hokamp, 1984].
- Higher and more uniform leaf area index and less self-shading [Olsen and Weiner, 2007].

More uniform and rapid ground cover also resulted in greater weed suppression with single-seed sowing than with drill sowing [Olsen et al., 2005; Kristensen et al., 2008; Olsen et al., 2012].

However, the question arises as to whether single-seed sowing in cereals has other positive effects in addition to increasing yields. Does the optimal distribution of growing space create a better microclimate in the crop with improved ventilation? Could this result in more cost-effective crop management with fewer diseases and, accordingly, lower use of pesticides and growth regulators? Is it possible to reduce nitrogen use through better utilisation of nutrients and water, for example [Ohe et al., 2016]? The answers to these questions are still pending.

2.2 Going one step further: equal-height sowing in a triangular

Compared to pure single-seed sowing, uniform sowing in a triangular pattern allows for the most even spacing between individual plants. Here, the spacing between individual plants is also optimised across the direction of travel, i. e. across rows. Composite sowing is technically possible for crops with low sowing densities (e. g. maize, beet, rapeseed). With higher sowing densities in cereals, composite sowing is much more demanding and cannot yet be implemented technically. New techniques in the field of crop production robotics may offer further possibilities here. In a project on uniform sowing, the Julius Kühn Institute achieved the following results in 2017/2018 in plots of winter wheat that were planted/sown by hand [Kottmann et al., 2019]:

The crops in uniform sowing generally developed more homogeneously than the drilled crops. Compared to drill sowing, complete ground cover was achieved earlier in uniform sowing. The leaf area index of the broadcast sowing plots with 150 grains per m² was higher than in the drill sowing with 150 grains per m², but not as high as the leaf area index of the drill sowing with 350 grains per m². The grain yield was slightly higher in uniform sowing than in both drill sowing variants, but the differences were not significant. However, the differences in the yield components of the two genotypes were striking.

Both the ‘Faustus’ and ‘Kopernikus’ varieties are grain density types and showed no differences in yield components in either drill variant. In uniform sowing, however, “Faustus” was characterised by a significantly higher number of ears per m². “Kopernikus” compensated for its lower number of ears with a higher number of grains per ear. This showed different reaction patterns of the genotypes in equal sowing. It should be noted here that all currently approved varieties were selected in drill sowing and therefore the potential of an even sowing pattern cannot be fully exploited [Kottmann et al., 2019].

According to Herrmann et al., 2024, the georeferenced placement of sugar beet pellets, for example by field robots, enables individual plants to be treated with pesticides and fertilisers. The accuracy of today’s RTK GPS systems in field use is 2 to 3 cm. For sugar beets with a planting distance of 20 to 25 cm, this accuracy is sufficient to accurately determine the individual plant. For cereals with sowing densities above 200 grains per m², georeferenced sowing is currently not possible – so it remains a vision for the future. According to the authors’ experience, sowing densities of only 100 grains per m² in uniform sowing can already yield the same yield as 350 grains per m² in drill sowing. A further reduction in sowing density is realistic, especially when using hybrid seeds. When reducing seed rates, the risk of poor field emergence or winterkill must be taken into account, which often cannot be compensated for in very thin stands and can therefore lead to yield losses or weed infestation. According to the above-mentioned authors from the Julius Kühn Institute, future developments in the field of autonomous field robotics will improve the accuracy of georeferenced grain placement during cereal sowing and the processes of individual plant treatment with plant protection products and fertilisers.

3. Definition of drill and single-seed sowing from a statistical perspective

The distribution of seed spacing in drill sowing corresponds to an exponential distribution (asymmetrical): small seed spacings occur more frequently than larger seed spacings. With single-seed drills, seed spacing is normally distributed, but often has multiple peaks due to the influence of cell occupancy and field emergence.

The coefficient of variation (CV) [%] is a suitable statistical measure for describing the uniformity of seed spacing. The more uniform the seed spacing, the lower its value. A CV of significantly less than 70 % can only be achieved with sowing technology that includes seed separation [Große-Hokamp, 2017]. A longitudinal distribution with exactly consistent seed spacing, so-called uniform sowing, can be characterised by a normal distribution, which ideally has no or only very little dispersion and thus has a low CV (Figure 1). According to Griepentrog, 1991, the coefficient of variation is not suitable for describing the grain spacing in drill sowing, as this is not normally distributed, as mentioned above. The author recommends describing the quality of the longitudinal distribution in drill sowing using the variation factor (Vf) (Vf = variance of the sample/theoretical Poisson mean).

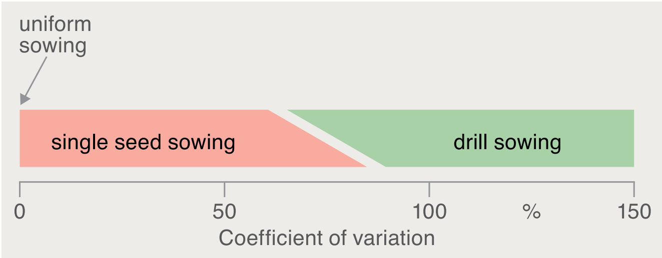

Figure 1: Coefficient of variation as an indicator of the uniformity of longitudinal distribution [Griepentrog, 1995 modified by Reckleben]

In addition to the coefficient of variation and the variation factor, the characterisation of specific stand areas is also suitable for the statistical description of grain distribution and competition. This parameter allows the distribution to be described in both the longitudinal and transverse directions. According to the literature, circles and polygons (multi- angles) are suitable for this purpose.

Heege, 1970 describes seed distribution using circles, whereby the distance from one seed to the nearest seed corresponds to the radius of this circle (Figure 2).

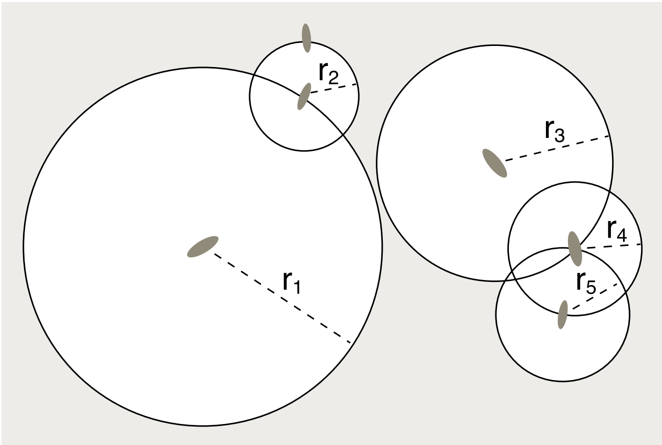

Figure 2: Distance r to the nearest possible grain [Heege, 1970]

Competition situations in plant populations due to stand area are already described in plant ecology using polygon models. Griepentrog, 1999 describes how this methodological approach can be applied to problems of establishment in agricultural plant production. To calculate the polygon areas, it is crucial to determine which plants in the vicinity of a reference plant are to be considered neighbours and are relevant for the formation of the polygon or stand area. Among other things, Voronoi polygon decomposition is suitable for this purpose. According to Griepentrog, 1999, a total of three characteristics are of particular importance for the stand area of a plant described by a polygon: the size and shape of the area, but also the position of the plant in the polygon (the so-called eccentricity). Figure 3 shows an example of a polygon decomposition. The different base areas, shapes and positions of the seeds in the polygon are clearly visible.

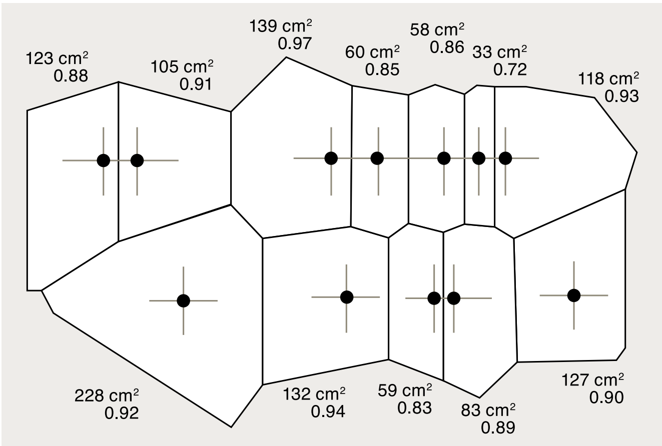

Figure 3: Example of a polygon decomposition (for rapeseed) with indication of polygon size and shape factor [Griepentrog, 1999]

4. Available technology with current relevance for the German market

The greatest technical challenge in precision seeding of cereals is to achieve precision in seed separation in the seed unit, including extremely accurate seed placement in the soil with uniform embedding of the seeds in the seed furrow at practicable driving speeds. This process is made more difficult by the fact that seed sizes can vary greatly even within a single cereal species.

The current series of precision seed drills from Väderstad and Monosem work like conventional maize and beet seed drills with electrically driven separating discs. The aim when sowing is to achieve uniform seed spacing with a minimum of double seeds and gaps. The test results published by the DLG Test Centre for Technology and Farm Inputs in Groß-Umstadt on established maize and beet precision seed drills show that the separation quality in the precision seed drill decreases as the driving speed increases. According to the manufacturer's specifications, driving speeds of up to 13 km/h are possible when sowing individual grain seeds with the Väderstad Proceed.

Due to their design, the singling units have a certain width. In order to still be able to achieve approximately conventional row spacing with single-seed grain sowing technology, the singling units on the Väderstad Proceed are arranged on two individual sowing rails at a distance of 1.39 metres. This results in a row spacing of 22.5 cm. On the Monosem precision seed drill, all coulters are arranged in a row. The row spacing is 25 cm. With Monosem sowing technology, a seed hopper is mounted above each coulter. In comparison, Väderstad has a central seed hopper, from which the singling units are supplied with seed as required. A small amount of seed is stored in a storage chamber. From there, the seed is fed into the singling mechanism. Calibrated seed is not necessary for either of the two models mentioned. The machines mentioned have parallelogram-guided sowing units to achieve a uniform seed placement depth. The precision seed drills, which place wheat, barley, rapeseed, sugar beet, peas, maize, sunflowers and other seeds precisely in the soil, are also technically equipped to vary the sowing rate and thus to work on a site-specific basis.

In 2015, Horsch began selling the Funck metering unit (product name: Horsch SingularSystem) for the Express, Focus and Pronto seed drill models. This component works like a centrifuge, is installed in the seed flow above the double disc coulter and standardises the seed spacing. In the following years, the Solus single-seed drill was developed. Horsch is currently focusing clearly on the further development of seed drilling technology and thus the perfection of seed placement, but the further development of seed separation for cereals has been scaled back and, at the time of going to press, neither of the two technologies mentioned above was actively offered on the market.

The Belgian manufacturer Herriau is regarded by experts as a pioneer in single-seed sowing technology. At the authors' request, Herriau stated that it continues to produce single-seed sowing technology for cereals in working widths of between three and six metres in mounted or trailed versions. Depending on conditions and sowing density, working speeds of 8 km/h are possible.

Based on the above-mentioned sowing techniques, the following classification can be made: On the one hand, there are designs that use a so-called sowing heart with perforated discs to separate the seeds (Väderstad, Monosem). They work on the same principle as conventional maize and beet seed drills. Herriau uses special separation and distribution heads. On the other hand, there are components that have been installed in the coulters or above the coulters. These include, for example, centrifuges, rotating rollers or cascades, which even out the seed spacing. The authors are not aware of these latter components being installed in current series of seed drills.

For many sowing technology manufacturers, optimising seed placement is currently the top development goal. To this end, coulter technologies (including coulter pressure control) are being developed and offered for different applications in order to achieve optimal contact with the soil water. The perfect creation of the seed furrow also has a high priority in order to optimise placement depth, seed coverage and embedding (also by means of catch rollers and furrow formers).

Practical research is needed to determine whether the complex and cost-intensive process of grain separation or components for optimising placement depth has a greater influence on plant development.

5. Experience report by farmer Wilfried Mißlbeck

Wilfried Mißlbeck runs an arable farm in Saxony-Anhalt, south of Magdeburg. Since spring 2020, he has been practising single-seed sowing of wheat with a Horsch Pronto 6DC with integrated Funck metering units (working width: 6 metres, 40 coulters, 15 cm row spacing). Sowing is usually carried out at a driving speed of 9 to 10 km/h, depending on soil conditions. (Faster speeds are also possible, but the best results are achieved at 9 to 10 km/h). The Funck metering device is not currently actively marketed by Horsch.

Mißlbeck obtains calibrated and dust-free wheat seed from a nearby service provider. The farm manager reports that such service providers with sieve cleaning systems and integrated dust extraction equipment are rather rare in Germany. In the past, the provision of the desired seed quality has always worked perfectly. Before sowing begins, the shake box and a seed sample are used to determine the optimal choice of metering discs with the shoes in the Funck metering units. All 40 Funck metering units are then adjusted one after the other. Mißlbeck is satisfied with the reliability and fail-safety of the singulation. The farmer also notes that the precision seeder used requires more maintenance than a conventional drill. From time to time, jammed seeds in the metering discs cause blockages, which are displayed to the driver on the control terminal and then have to be removed. During blockages, however, the seed flow to the seed coulter is maintained at all times via a bypass and there are no gaps in the placement. The farm manager reports that the calibration process is somewhat more time-consuming. When switching to a different crop type, the so-called shoes on the discs in the 40 Funck metering units have to be replaced.

For earlier sowing dates for winter wheat at the end of September (after rapeseed and peas), the sowing rate is reduced to 120 grains per square metre in some cases. In his opinion, such reduced seed quantities only make sense if the soil is well prepared and the external conditions are optimal. Uniform depth placement is essential, and the catch rollers on the seed coulter do a good job here. For later sowing dates in October (after beet and grain maize), the sowing rate is usually more than 200 grains per square metre, and according to Mißlbeck, single-seed sowing no longer has the desired effect here. However, the technology prevents multiple grains from being deposited in one place (clumping).

The farm manager reports that the higher machine costs, lower daily output during sowing and increased seed preparation costs are offset by many positive synergies: according to Mißlbeck, the seed is distributed more evenly in the row. After sowing, uniform field emergence can be observed, and the homogeneous crops are more evenly aerated in spring and dry faster (more favourable microclimate). Since the introduction of single-seed sowing, he has noticed less infestation of mildew and stem base diseases. Due to the lower seed densities, the plants do not compete with each other so intensively for height. The plants thus have more resistant stalks and the risk of lodging is reduced, for example in spring when there is a lot of rainfall and little sun. According to Mißlbeck, the plants are also more resistant during dry periods. The farm manager is certain that savings in fungicides and growth regulators are guaranteed, even if the effect is only small. The farm manager cannot say definitively whether wheat single-seed sowing generally results in higher yields. However, he believes that in years with pronounced spring drought, higher yields can be observed for the reasons mentioned above.

6. Hanse-Agro GmbH trials on single-seed sowing of grain

Between 2015 and 2020, Hanse-Agro GmbH conducted trials on grain singulation to varying degrees in collaboration with Horsch GmbH and Saaten-Union.

The technology used was a 3 m Horsch Pronto with Funck metering units for singulation. Wheat and rye were sown in varying quantities and years, with two hybrid varieties of rye and one line and one hybrid variety of wheat. The comparison with wheat is particularly interesting, as the lower seed density of hybrid varieties and the associated higher seed costs necessitate more precise placement in terms of depth and spacing between grains. The seed was specially sieved to ensure the functionality of the Funck metering units. This worked well for wheat, but caused problems with rye due to the shape of the grain. Other researchers have also reported this.

The question was investigated as a precise experiment in the Lüneburg Heath over the first three years in wheat. For this purpose, a strip experiment was set up at four locations over the last three years:

- Grünholz near Eckernförde (Schleswig-Holstein) → loamy sand, 37 – 47 agricultural value points
- Fahrenwalde near Pasewalk (eastern Mecklenburg-Western Pomerania) → variable loamy sand, 35 – 40 agricultural value points
- Wulfsode (Lüneburg Heath) → sand, around 30 – 35 agricultural value points
- Bahrdorf (near Wolfsburg) → loamy sand, around 40 agricultural value points

Seeding densities in drill seeding (drill) and single seeding (ss)

- 210 grains/m² (line, drill)
- 140 grains/m² (line + hybrid, drill + ss)
- 105 grains/m² (hybrid, drill + ss)

In contrast to many other trials, the same sowing technique was used here with and without singulation. This means that any differences are not due to different sowing techniques or coulter settings, but solely to the different seed rates.

The most significant difference in wheat yield occurred between the varieties in favour of the hybrid variety at all locations in all years. In the precision trial, however, only in the first trial year, a 10 % increase in yield in favour of singulation sowing was also observed. In subsequent years, however, this difference was no longer detectable.

Differences in seed density were determined by location and sowing time. This means that with early sowing and warm weather afterwards, the lower seed density of 105 seeds/m² was at least equivalent.

Otherwise, the differences remained isolated cases that were only found in individual years or at individual locations.

The rye trial was only conducted at the two locations Wulfsode and Fahrenwalde in 2016 and 2017 in a precise trial. Due to technical problems with separation caused by the grain shape (see above), a tendency towards higher yields was even observed in drill sowing.

What can be concluded? The differences found were in the variety type, and only in isolated cases were slight differences in wheat found in favour of singulation. Fundamentally, it is questionable whether uniform sowing is really desirable, as is often claimed. Unlike maize and sugar beet, each plant has several yield organs (shoots).

It is interesting to compare this with rapeseed. In rapeseed, it is the branches that compensate for deficiencies in plant distribution. In addition, it can be observed that free-standing individual plants have prolonged vegetative development, resulting in partially unproductive shoot formation. Interestingly, single-seed sowing only shows advantages over drill sowing in winter rapeseed if there is a significant difference in field emergence. Other options such as underfoot fertilisation make the difference in single-seed sowing in rapeseed.

Competition between plants in the row promotes development and slows down excessive shoot formation. As climatic changes mean that early-maturing varieties are increasingly coming into focus, delayed development and (too) late shoot reduction would not promote yield security.

Based on consulting experience and other trials, it can be concluded that the precision of the planting depth is more important for yield security than the uniform spacing of the plants.

It remains to be seen what other effects, such as weed or grass suppression, reduced disease incidence, response to lower N fertilisation (e.g. red areas), etc., are influenced by improved plant spacing. This is because the mechanical effort and fractionation of the seed incur costs that must be offset by additional yields. More complicated and usually heavy technology also limits operational reliability and operating time.

7. Additional comments from the DLG Technical Committee "Soil cultivation technology and sowing technology"

Single-seed sowing is suitable for early sowing of winter cereals under good conditions. However, wide rows, especially in early sowing, can increase weed pressure. When sowing later in the year, for example after maize and sugar beet with higher sowing densities, single-seed sowing can no longer play to its strengths. Summer cereal crops can have low tillering capacity in dry years. In such years, it may be advisable to use a high sowing density with narrow row spacing from the outset, in which case single seed sowing technology is not necessary and the additional provision of conventional drilling technology would be rather cost-intensive. In the case of cover crop mixtures and mixtures in crop rotation, it should be determined before investing in single seed sowing technology whether these can be sown with the appropriate machine.

The high row widths mentioned above (22.5 cm and 25 cm) have an impact on solar radiation and thus on the temperature and microclimate in the crops. Reduced shading by the grain has disadvantages in terms of suppressing weeds and grasses. On the other hand, the reduced shading also leads to more intense evaporation and thus to increased withdrawal of valuable soil water. On the other hand, the crops can dry out more quickly, which inhibits the development and spread of plant diseases. According to the DLG committee, further research should be conducted on these issues. Farmers who want to start single-seed sowing of cereals are interested in which row widths are suitable for which locations. Furthermore, it should be investigated how contact or underfoot fertilisation during sowing can give cereals a growth advantage over weeds and grass weeds. Further fundamental research is also needed to determine the extent to which single-seed sowing or even combined sowing generally has a positive influence on plant development and whether, in comparison, precise adherence to the sowing depth and/or high embedding quality may even be more important. Future practical research must also determine the extent to which active ingredient quantities can be reduced (e.g. fungicides through more intensive crop aeration) without causing resistance. The industry is dependent on facts in this regard.

8. Conclusion

An overall assessment of single-seed sowing of cereals, taking into account all technical, agronomic and economic factors, is still pending. Capital-intensive, complex and therefore maintenance-intensive sowing technology is required. Higher yields and reduced use of seed and plant protection products are possible.

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