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Innovations in precision seed drilling technology: successes or failures?

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In view of the development of various technological alternatives in precision seed drilling, it has become a matter of research whether there are clear criteria for the success or failure of technological innovations. Around the turn to the 20th century, two very different precision seed drill methods were developed almost at the same time. Band seeding made it possible to achieve nearly perfect single grain sowing. For this purpose, individual, equally spaced seeds were embedded into bands of paper or cotton. In the field, these seed tapes were then unreeled from large drums. The pneumatic system proposed in 1897, by contrast, introduced grain singling using a vacuum for the first time. Although band seeding presented a satisfactory technological solution, it was never widely applied. Pneumatic systems, on the other hand, took long to catch on and only started to be successful in the late 1960s. Up to then, these innovative systems had to be considered as failures. Changing the period under review, however, may completely reverse the assessment of whether an innovation is a success or a failure.

Keywords
Innovations in sowing technology, band seeding, pneumatic grain singling, failed innovations

While reconstruction after World War II had brought tremendous growth rates to several European economies, this growth had perceptibly slowed down by the mid 1970s after the oil price shock and the ensuing energy crisis. This gave rise to increasingly intense discussions on the mechanisms of technological innovations as sources of new growth (Baumol 2002, Dowling and Hüsig 2007). These discussions have not slackened until this day; however, no general consensus has yet been reached as to which factors are indispensable for a successful technological innovation (Spoerer et al. 2007). It is undisputed that the development and first market entry of a new technological variant implies a more or less successful innovation (Kilchenmann 2011). Although Schumpeter (1939) was early to point out that an invention will not necessarily bring about an innovation, the interesting question of how to identify and characterise failed innovations has only recently been explored in more detail (Bauer 2006).

In practice, market penetration by technological innovations is rarely quick and effortless. Long years of uncertainty are more common, usually accompanied by more or less successful endeavours, until an innovation gradually evolves from an invention and is able to establish itself and prevail in the market (Bauer 2006, Dowling and Hüsig 2007). The following explanations are intended to draw attention to the fact that long review cycles may lead to very different and even to diametrically opposite assessments regarding the success of a development. An initially apparent success can still fail in the long run, while a technological innovation with an unfavourable mid- and long-term prognosis can eventually turn out to be both successful and innovative. Selected technological variants for sin-

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gle grain sowing will be used to demonstrate that the assessment of a technological solution as an innovation or as a dead end, as a technology that is outdated or ahead of its time, depends decisively on the specific point in time this assessment is made.

Band seeding—an early technological solution on the way to ideal grain singling?

Countless patent publications dedicated to precision seed drilling (Benninger 2013) serve as an indicator of the extent of technological development in the field of sowing, reflecting the continuous improvement of technological options over time. Much of the development was primarily driven by the agricultural labour shortage increasing with the progress of industrialisation in Central Europe and by the general growth of population (Kriedte 1980). With fewer people working in agriculture, the necessity of higher yields grew along with the need for more efficient methods and method engineering solutions (Krzymowski 1951, Abel 1966, Achilles 1993). The seed drill, which had been introduced as early as the 17th century, was not only labour-saving, but it also contributed to making cultivation more efficient (Fischer 1910, Hupfauer 1969, Troitzsch 1997). On top of that, the seed drill, and later on machines for single grain sowing, offered important improvements for many types of plants; for instance by optimising growing space, by improving the conditions for growth, and, not least, by saving costly seeds (Soucek and Pippig 1990, Rademacher and Heier 1999). Various machines for single grain sowing were already developed in the 19th century, but they only gradually came into use in practice for equal seed spacing in the 1960s (Dencker 1961, Lüdecke 1953). This was not only due to complicated and elaborate mechanical systems, but also to a number of mechanical shortcomings and a lack of precision in grain singling (Hege and Hupfauer 1969, Benninger 2013).

The idea of band seeding dates back to the turn to the 20th century and involves fixing individual seeds at specified spaces on seed tapes, i.e. band-type carriers of fabric or paper, rolling these seed tapes onto drums to later unreel them in the field, and then placing the seeds together with the carrier bands into the soil (Evans 1895, Benninger 2013). Band seeding had the potential to solve nearly all grain singling problems prevailing at the time and to enable almost perfect single grain sowing without any misses or doubles and without the rotating or oscillating singling units becoming jammed, as would otherwise inevitably happen. Within only a few years, further developments followed (Figure 1), and shortly after the turn of the century, this innovation already appeared to be mature (Israel 1900, Fickelscheer 1907, Hege and Hupfauer 1969, Benninger 2013). Essential objectives were to make the large seed tape drums easier to handle and to roll off the seed tape in straight lines on the prepared soil. The machinery for doing so was readily available at the time (Israel 1902, Deming 1908, Rasmussen 1909, Gray 1914a, Gray 1914b, American Seedtape 1918, Sanford 1919, Benninger 2013). This also included ideas and technology for placing the bands sufficiently deep into the soil and for closing the furrows to cover the seed bands (Israel 1902, Deming 1908).

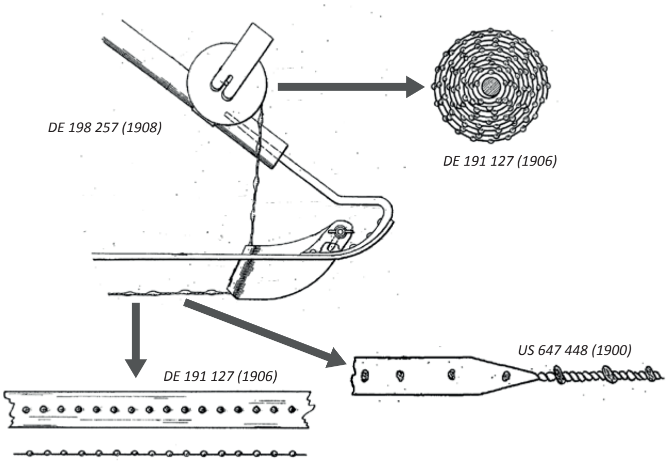

Figure 1: The method of band seeding as described in patent literature around 1900

Over 100 years ago, band seeding thus already met the technological requirements for single grain sowing that still apply today (Rademacher and Heier 1999). A prerequisite for adequate growing space and optimum growth conditions is the precise placement of the individual seeds in the intended spot, at a specified depth, and, as far as possible, without any misses or doubles. Additional aims were to accelerate the process of sowing and at the same time keep the system costs at a manageable level (Soucek and Pippig 1990). The comparison of the process phases of seed singling and embedding in Figure 2 illustrates that precision manufacturing, transporting and accurate unreeling of seed tapes made grain singling and equal grain spacing feasible (Eikel 1991, Rademacher and Heier 1999, Benninger 2013).

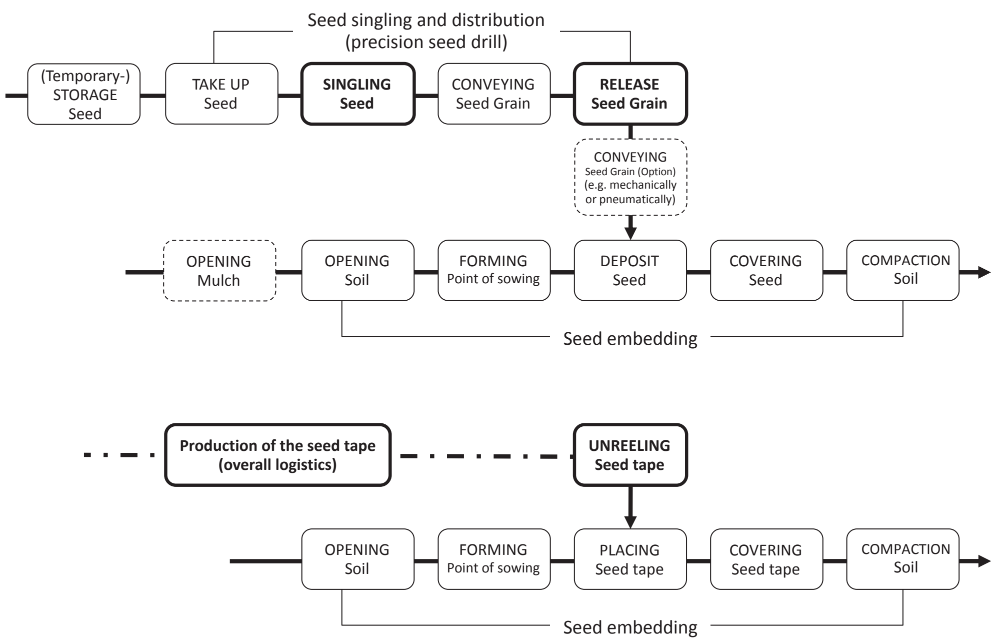

Figure 2: Process phases of single grain sowing and of band seeding

Despite the apparent advantages of band seeding, the method was never able to prevail in practice. A major reason for this was the fact that a central criterion was violated, which was required for the successful introduction of innovations as identified by Bauer (2006). Band seeding required new technological infrastructures in various areas relating to the manufacture of the seed tapes, to the distribution logistics and to the spreading methods, i.e. to unreeling the bands in the field for sowing. In addition, it was never possible to eliminate the risk of the rolled out carrier bands not rotting or dissolving in due time and thus hindering germination and proper growth of the plants (Soucek and Pippig 1990). Nevertheless, band seeding remained useful for particular purposes and is still in use today for experimental cultivation (Soucek and Pippig 1990, Wintersteiger 2008).

Pneumatic grain singling—a failed innovation?

Almost simultaneously with band seeding, the idea to use a pneumatic vacuum in grain singling also emerged shortly before the turn of the century. The suction for taking up the grains and holding them to a drum alternated with overpressure at the precise time and place to release the grains into a seed tube (Mathias 1897, Hege and Hupfauer 1969, Benninger 2013). A further basic invention for pneumatic grain singling (Figure 3) proposed taking up the grains from a hopper by means of a rotating, perforated disc exposed to negative pressure, and then releasing the grains at an intended point of discharge into the seed tube by means of an air pressure blast (Bristow 1920, Benninger 2013).

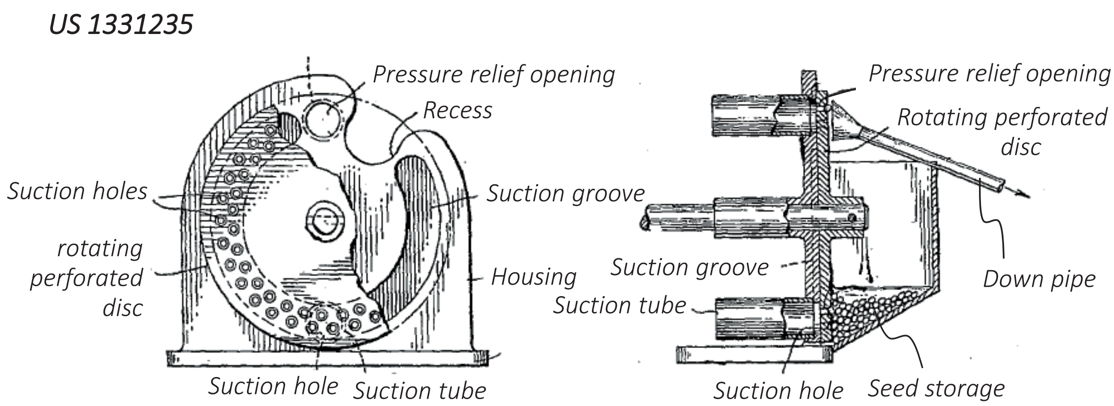

Figure 3: Bristow was the first to describe grain singling by means of a rotating perforated disc under negative pressure in 1920

Even though pneumatic grain singling seemed to be much closer to a prototypical process sequence (Thalmann and Jakob 1987, Eikel 1991, Rademacher and Heier 1999) compared to grain singling by means of band seeding, pneumatic systems nevertheless had no chance of developing beyond concept stage for many decades. Regardless of the growing diversity of pneumatic systems from the 1950s onward and apart from a few exceptions, pneumatic solutions were still far from being applied in practice (Hege 1995, Benninger 2013). In the end, it was not pneumatic grain singling in itself—i.e. taking up grains from a hopper using a perforated disc under vacuum or a drum with precisely positioned reception points—which led the perforated disc systems to practical viability. It was rather the initially apparently insignificant detail of a mechanical wiper for securing and perfecting grain singling that paved the way to success. Figure 4 shows the typical process phases for pneumatic precision seed drilling devices as exemplified by a perforated disc for transporting and singling the seeds (Benninger 2013) and below that a wiper, for which a satisfactory contour was not found before 1971 (Nodet-Gougis et al. 1971).

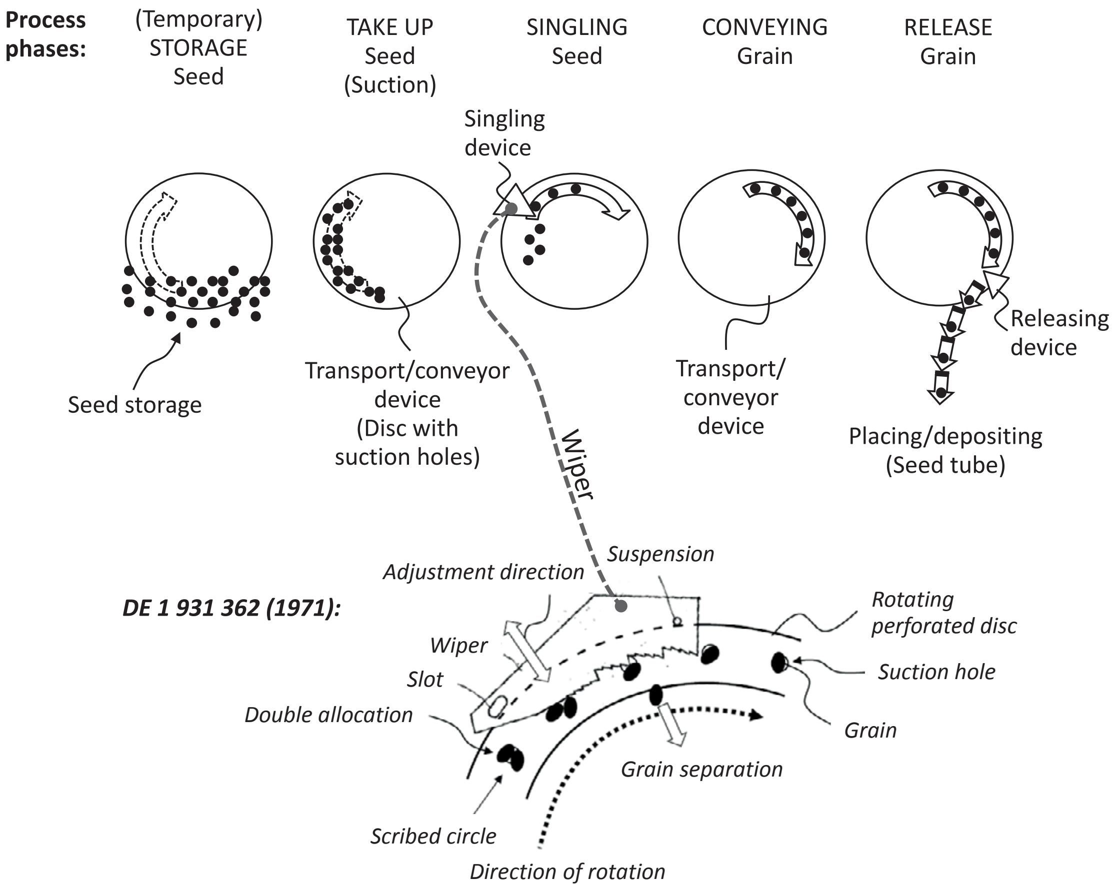

Figure 4: Process phases of pneumatic single grain sowing and saw-toothed wiper

The wiper was originally developed in France as an element for grain singling, and it was improved in numerous variants (Lamazou and Lamazou 1965). Due to its design, it was universally applicable in practice, as it enabled the pneumatic systems equipped with it to handle even non-pelleted and imprecisely calibrated seeds. The wipers helped the pneumatic perforated disc systems to establish themselves in the market and remain widely used to this day, holding their ground against mechanical systems and against competing pneumatic system variants (Soucek and Pippig 1990, Rademacher and Heier 1999, Benninger 2013).

Grain shape: an example of external influences on the development of innovations

The comparison of band seeding methods and vacuum-impinged, rotating, perforated discs for grain singling demonstrates clearly that a long development period in itself is no sufficient indicator for the success of an innovation. Beyond the time factor, other circumstances can become overriding effects for the prospects of technological innovations and decisively influence their success. Calibrating grain sizes and, in particular, pelleting the seeds had such an overriding influence (Dencker 1961, Wenner and Boxberger 1973). Although pelleting was already known in the 1920s (Hege and Hupfauer 1969, Benninger 2013), the method became established only much later, and more so for sowing sugar beets than for sowing maize. While band seeding allowed to achieve the desired precision without any prior treatment of the grain, this was quite different both for mechanically operating systems (Société Civile d'Études 1952) and for pneumatic systems. Pelleting not only supplied problematic seed types with nutrients and plant protection agents, but also with the shape required for the precise and failure-free operation of pneumatic systems (Hempsch 1975). Pelleting has also proven particularly important, however, for mechanical singling systems, where it creates reproducible conditions for precise singling and sowing of sugar beet seeds, rapeseed or chicory seeds.

Current developments based on known mechanisms

Meanwhile, pneumatically operated systems have prevailed. Grain singling in itself has reached a very high degree of precision. Due to collisions and ricocheting in the seed tubes, however, it is frequently impossible to maintain the achieved grain distances up to the position of sowing (Benninger 2013). In order to reduce the negative effects in grain conveyance after releasing the seeds, compressed-air systems have been in use for a few decades (Wenner and Boxberger 1973, Karl Becker GmbH 1981, Martin-Luther-Universität Halle-Wittenberg 1986, Paul 1988, Benninger 2013). Pneumatic conveyance after seed release, however, has only very recently found its way into practice (Amazonen-Werke 2006, Amazonen-Werke 2011, Eikel 2007, Eikel 2011). The precision of grain singling has already been optimised to a great extent. The benefits, however, have been forfeited by increasing the conveying distances between the seed meters and the sowing positions in the soil. These greater conveying distances are due to the increasing spread of precision seed drilling devices that are suited for mulch seeding. The diameter of their cutting discs requires the seed meters to be arranged at a greater height. This results in drop heights of up to more than 30 cm, together with the mentioned ricocheting effects and losses in precision in terms of grain spacing. For the purpose of precise grain placement in the soil, even at high operational speeds, it is therefore clearly beneficial to maintain the precision of grain singling by means of compressed air for grain conveyance between releasing and depositing the seeds in the soil, as indicated in Figure 2, or by means of other measures (Eikel 2007, Eikel 2011). Pneumatic grain conveyance, however, is not the only option. There is a new system that employs mechanical grain conveyance between releasing the seeds from the seed meter and depositing them in the soil. This mechanical system is obviously based on older belt systems (Georgia Tech 1954, Bainer et al. 1955, Precision Planting 2004). The difference is that in the new system the seeds are conveyed in a very precise manner from the seed meter immediately to the sowing position located underneath by means of a brush-studded belt system referred to as “brush belt” (Deere 2013, Deere 2014a, Deere 2014b).

Conclusions

Even if a new technology appears to be suitable for practical application and makes its way into the market, the issue whether it is a success or a failure in terms of innovativeness will be addressed differently according to each case individually and according to different points of time for making this assessment. Well into the 1950s and 1960s, pneumatic grain singling methods appeared at best to have uncertain future prospects, if not to have failed as innovations and to have no chances of wide marketability. Grain singling by way of band seeding, in contrast, could be regarded as a useful development with considerable market and growth potential around the turn of the century and well into the first decades of the 20th century. Over a longer period of time, however, this assessment had to be fundamentally changed. Band seeding could not prevail, while pneumatic grain singling methods represent an exceedingly successful technology and can be considered a successful technological innovation in the field of cereal sowing and single grain sowing.

Similar mechanisms can be identified in pneumatic grain conveyance after the grains are singled and until they are placed in the soil. While this option was still hardly relevant as a practical application in the 1970s, it has been representing a useful supplement to precision singling for the past few years and it contributes to achieving constant grain spacing even with larger interspaces between the seed meter and the seed drill coulter.

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