

Thomas W. Scheidtweiler, Bonn, and Gottfried Eikel, Münster

Punch planting

An ancient principle and a key technology for plant production with low-level mechanization

Minimum tillage is the standard procedure in systems using hand labour or animal traction rather than any special soil-conserving measure. Due to the limited power output of this mechanization level, tillage leaves rough soil surfaces with imperfectly incorporated plant residues. This is good for soil conservation, but most conventional planters are not able to cope with such surface conditions. Therefore, the animal-drawn moldboard plow is often not just the first, but also the only, link in the mechanization chain.

Dr. Thomas W. Scheidtweiler is currently the Head of the Africa Department of the Catholic Academic Exchange Service (KAAD, af1@kaad.de) in Bonn. Between 1994 and 1995 he worked at the Institute of Agricultural Engineering in Bonn under the supervision of Prof. Dr.-Ing. K.-H. Kromer.

Dr. Gottfried Eikel is the deputy editor-in-chief of *profi – magazin für agrartechnik* (eikel@profi.com), Brockhoffstraße 14, 48143 Münster. Between 1988 and 1992 he worked at the Institute of Agricultural Engineering in Bonn under the supervision of Prof. Dr.-Ing. K.-H. Kromer.

Keywords

Animal traction, conservation tillage, punch planting, maize, East Africa

In Africa on average not even one farmer out of 1000 is using a planter. Punch planting with the hand-hoe is the most widespread procedure for maize planting [1]. In order to give the crop a considerable growth lead over weed recurrence, farmers try to complete planting as soon as possible after tillage. For timely planting they tolerate improper seed embedding and low (erosion-susceptible) plant densities, because labor requirements with regard to hand planting increase proportionally to the planting rate. This results in a low productivity per unit area and a poor yield dependability which in turn affects farmers' willingness to adopt innovations – a vicious circle.

Materials and Methods

An animal-drawn revolving spade-punch planter (ADSP, *fig. 1*) has been developed at the Institute of Agricultural Engineering at Bonn University [2 to 9]. It resembles the ancient method of manual punch planting (hand-hoe or planting-stick) in almost every step of the planting process. The principals of gentle seed metering and spot-like soil opening are retained.

The striking feature of the double-row implement is the spade-wheels, arranged in a mirror image. Hollow wedge-shaped spades are mounted on the periphery of these wheels to penetrate the soil. The axis of rotation has a vertical inclination of 23° with an additional yaw angle of 7.5°. These angles

create a combined vertical and lateral movement of the soil-engaging tools, very similar to the way a hand-hoe works. As each seed hole is opened separately, there is no risk that a furrow can induce rill-erosion. Each seed-metering device is equipped with an inclined cup-feed wheel and a star-feed wheel (*Fig. 2*). Single seeds with a wide range of calibers are gently scooped from the reservoirs as if by hand.

Fundamental experiments on the suitability for agricultural practice

After developing and manufacturing the machine [4, 8], many experiments have verified that the spade-punch planter and its seed embedding design are suitable for mechanical planting methods under conditions as they prevail in Germany [5 to 7]. Standard measurement methods were used to examine machine design, crop production and soil conservation in the laboratories of the Bonn Institute of Agricultural Engineering and in several fields under varying conditions. For these experiments a four-row tractor-mounted spade-punch planter with a mechanical metering unit was used. All tests were carried out at working speeds between 3.6 km/h and 7.2 km/h in comparison with a standard pneumatic precision maize planter, which places the seeds into a furrow. The results are as follows:

- Uniformity of horizontal seed placement (seeds at 0.5 to 1.5 times the actual spacing, others are either voids or doubles) and accuracy of lateral seed placement (actual spacing 2.5 cm tolerance) achieved by the spade-punch planter on the test stand are similar or better than the results achieved by

Technical data

weight:	173.5 kg
height (without handle):	720 mm
seed hopper volume:	30 l
planting depth:	20 - 90 mm
theoretical spacing:	136 mm
row width:	600 - 800 mm
draft requirements:	400 - 900 N
labor requirements:	10.4 man-hours ha ⁻¹

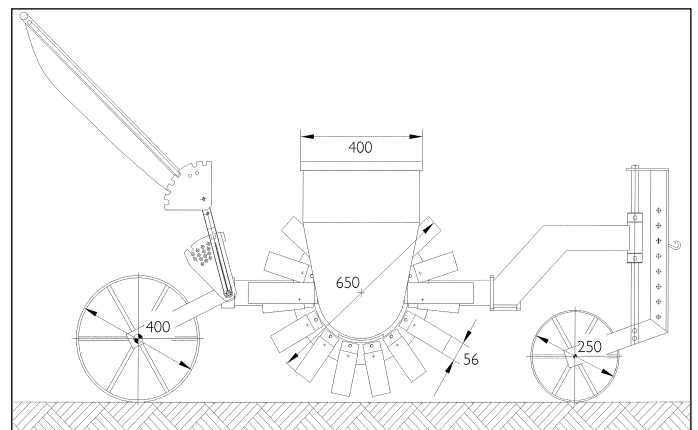


Fig. 1: Animal-Drawn Revolving Spade-Punch Planter (ADSP) with technical data

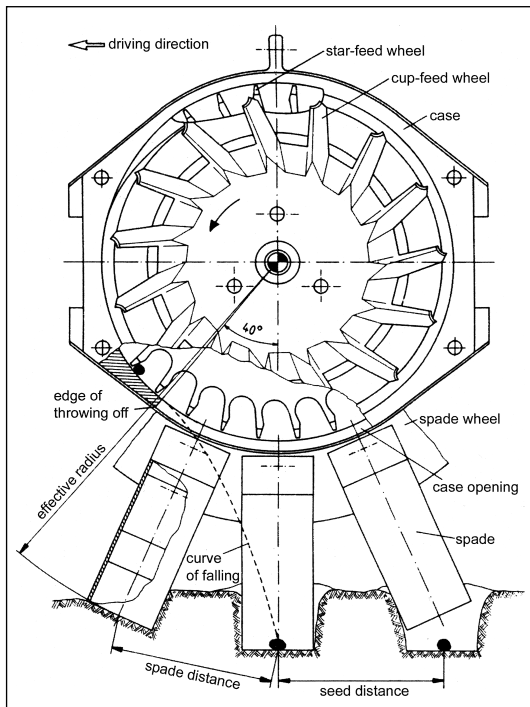


Fig. 2: Principle of seed metering and seed placement with the ADSP

conventional precision planters. There are, however, two exceptions: doubles are insignificantly higher and on slopes seed placement is more irregular.

- Uniformity of plant distribution (plants at 0.5 to 1.5 times the actual spacing) and accuracy of plant distribution (actual spacing \pm 3.5 cm tolerance) achieved by the spade-punch planter in the field are (sometimes significantly) better than the results achieved by the precision planter under varying conditions and types of soil preparation.
- Uniformity of vertical seed placement (planting depth) and covering height are similar with both the spade-punch planter and the precision planter.
- Emergence rates and energy yields of silage maize are similar with both planters. Sometimes the emergence rate was initially lower with the spade-punch planter as compared to the precision planter. This was

the result of a deeper seed placement. In-part lower plant populations and yields of fresh matter were measured after spade-punch planting, but these disadvantages were compensated for by higher contents of dry matter and corn cobs.

- Whether the soil is prepared with a plow (conventional tillage) or with a cultivator (conservation or minimum tillage), punch planting is able to reduce water erosion. The reason is a obstructed flow of water after punch planting as compared to furrow planting. There was no difference in soil erosion between both planting techniques, if maize was planted without prior soil preparation (direct planting).

Due to its high functional reliability when planting maize through organic material like crop residues without additional tools, and reduced water erosion on tilled soils, the spade-punch planter is a good alternative to conventional precision planters. It is, however, complicated to adjust the spade-wheels and metering devices to new varieties where they have completely different exterior seed properties. This is not a major concern in developing countries like Tanzania, where basically the same few maize varieties are used over decades.

Trials in Tanzania

Data are available from farming-systems research, field trials and on-farm tests to compare the ADSP with manual punch planting of maize. This was done in three consecutive years in the Shinyanga region of Tanzania (3°2' S, 33°4' E, 1.143 m). The suitability of both planting methods for direct planting through mulch was also investigated. Another factor was the planting time. The factor complex was repeated on two sites over two years. The Vertisol at site „A“ is a loamy clay soil with a sand content of only 2%,

while the Oxisol at site „B“ is a sandy loam soil with a sand content of 52%. Tilling was carried out with an animal-drawn moldboard plow. Compared to the no-till treatments plowing reduced the degrees of mulch and weed cover from about 60% to between 5 and 20%. The climate in Shinyanga is semi-arid with an average annual precipitation of 820 millimeters. 90% of this rainfall occurs between November and April. The variability in distribution and amount of rainfall is extremely high, with almost every year being abnormal. Figure 3 shows the ADSP during a field test in the Shinyanga region of Tanzania.

Results and Discussion

The main effects of both planting techniques on numerous parameters are summarized in table 1. The ADSP was superior to manual planting with respect to the accuracy of (horizontal) seed placement, initial and final seedling emergence, accuracy of plant spacing and grain yield. As far as uniformity of planting depth and covering height (vertical seed placement) and the uniformity of plant distribution are concerned, the ADSP did not differ significantly from the traditional method.

Depending on the prevailing regime of precipitation, seedling emergence varied considerably at between 26% and 92%. Under favorable rainfall conditions the seedlings emerged within five days after planting, that is, initial and final seedling emergence were equal. A low emergence velocity (low initial seedling emergence rates) always resulted in poor final emergence rates because germinating grains were damaged by insects and draught.

Manually planted maize proved to be highly sensitive to an irregular water supply. This is due to improper seed embedding: Farmers usually move stable soil aggregates over the seed with one foot. Water transition from the soil into the seed can not take place until clods disperse under the impact of rain. Therefore the success of manual planting is governed by weather conditions and planting time. The ADSP established good seed-to-soil contact and made better use of scarce soil water. It compensated a higher percentage of seed voids (the only parameter where hand planting was superior) with better seedling emergence rates, resulting in an overall equal percentage of plants at the required distance between plants.

The analysis of the planting time factor indicates that it is not so much the total amount of rainfall, but rather the frequency of rains which determines the seedling emergence rates. With high evaporation, sufficient soil water in the shallow germination

Table 1: Main effects of the planting method factor

parameter (10, 11)	Hand-hoe (%)	ADSP (%)
accuracy of lateral seed placement (required spacing \pm 2.5 cm)	38.1	74.9
uniformity of horizontal seed placement:		
seeds at 0.5 to 1.5 times the required spacing (other are voids and doubles)	96.8	84.3
uniformity of vertical seed placement:		
coefficient of variance, planting depth*	28.0	29.2
coefficient of variance, covering height*	41.5	44.0
initial seedling emergence rate* (25% of the planting rate)	43.5	57.8
final seedling emergence rate*	55.8	65.2
accuracy of plant distribution (required spacing \pm 3.5 cm)	41.5	80.0
uniformity of plant distribution: plants at 0.5 - 1.5 times the required spacing*	63.8	64.3

within-the-row spacing: hand-hoe (2 seeds/hole) 38.9 cm, ADSP (single seeds/hole) 13.9 cm
* significant interaction with at least one other factor, _ significant main effect (superiority)

zone will only be available if several successive rain showers take place after planting. At the very beginning of the rainy season this usually does not occur. It would be advisable to plant during a high rainfall frequency and not necessarily as early as possible (which is the usual recommendation). Such a strategy, however, requires a higher rate of work than is available with hand planting.

Grain yields were highly dependent on physical soil properties. Particularly at site „A“ the detrimental effects of unabsorbed surface water alternated with the effects of severe water shortage. Plowing improved the hydraulic properties of both soils and defused the weed problem. This resulted in yields which were on average 54% (0.4 t ha⁻¹) higher than those under direct planting. The ADSP plots yielded on average 10% more than the manually planted variants. The yield increase would have been much higher if the plant populations had not been standardized by thinning, because in that process many more plants (40%) had been removed from the ADSP plots than would have been necessary through capacity of the sites. This was confirmed in the on-farm trials. The best factor combination was mechanical planting with previous soil tillage. Here seedling emergence rates of more than 92% (late planting in „Year 1“ at site „A“) and grain yields of up to 2.6 t ha⁻¹ (early planting in „Year 2“ at site „B“) were achieved, which comes up to the highest possible yield expectation for „Katumani Composite“ maize in Shinyanga.

As opposed to the ADSP, labor requirements with regard to hand planting increase

persons could finish off all the maize planting (1.2 ha) on an average-sized farm (3.8 ha) within a single six-hour day. With direct planting the time and energy required for weeding was equivalent to extensive tillage with the hand-hoe. Thus, the intensity of soil tillage and labor was not reduced by not using the plow, but only delayed.

The mean draft requirement to pull the ADSP is 650 N. This is significantly lower than the value for plowing and corresponds to the permanent draft force of two local oxen at the end of the dry season. Farmers assessed the handling of the ADSP using twelve criteria and felt it was easy to operate as a whole. However, it is difficult to keep the machine in straight lines if the oxen are not well trained.

Various grains, such as chick-peas and groundnuts, can be easily planted with the ADSP maize metering devices, which need not be changed for such crops. Simultaneous planting of two different crops (intercropping) and sowing of tree seeds like *Leucaena leucocephala* was also successfully performed in agroforestry trials.

As there is no reliable distribution network for spare parts in Tanzania, a local industrial company was hired to reproduce a planting unit, the most sophisticated part of the tool. The product provided clear evidence that local production of the machine is technically feasible. If produced domestically, the complete machine costs about 1000 US\$. This is a lot by African standards. However, in contrast to a widespread opinion it is not so much the price, but rather the performance and practical value of an innovation which

Summary and conclusions

The traditional method imposes limits on plant densities which are below minimum. Plant densities are 40% higher with the ADSP, which places single seeds in every hole unlike dibbling. This makes better use of the yield capacity of the soils. Also the efficiency of soil water use during the critical germination period was enhanced through the new technology. This was manifested in seedling emergence rates, which were on average 10% above those of hand planting. The traditional method holds out a high uncertainty for cultivation depending on the planting time due to poor seed-to-soil contact.

The planter makes another contribution to reducing the risk of farming through its high work rate and great efficiency. The tolerance of a wide range of seed calibers and seedbed conditions are additional factors where the ADSP distinguishes itself from other planters in Africa, though not from hand planting. Small-scale contractors and machinery pools can get an adequate return on investment with the ADSP. Although investment requirements are quite high, the ADSP has good chances of being accepted, as there is no other implement on the market, that combines all the proved benefits at one time:

- higher planting rates with more uniform seed distribution (increase in output per unit area)
- higher efficiency in exploiting soil water for germination (decrease in farming risk)
- low labor and draft requirements (increase in labor productivity)
- toleration of a wide range of seed calibers (gentle seed metering, versatility)
- suitability for corrugated soil surfaces and for mulch planting (soil and water conservation)

The ADSP increases sustainability of farming. Working on rough soil surfaces and mulch, it provides a fast, uniform and dense plant canopy to protect the soil. This also improves the efficiency of tillage with respect to weed suppression and enables farmers to keep the weed problem under control without herbicides. Last but not least, higher yield expectations encourage the acceptance of further innovations to increase the sustainability of agriculture in developing countries.

Literature

- Books are identified by •
- [1] Scheidtweiler, Th.: Maisanbau in Ostafrika – Möglichkeiten einer Mechanisierung, Entwicklung und ländlicher Raum 23 (1989), H. 6, S. 3-5
 - [2] Scheidtweiler, Th. und K.-H. Kromer: Tillage and Planting Methods to Control Wind Erosion in the Semi-Arid Tropics, Proceedings of the Internatio-



Fig. 3: Animal-Drawn Revolving Spade-Punch Planter (ADSP) in work

proportionally with the planting rate: With the common planting rates of 20000 holes per hectare, the mean labor requirements were 62.3 man-hours ha⁻¹. In the experiments they were 109.6 man-hours with 36630 holes per hectare. Labor requirements for the ADSP, with a row width of 0.7 m, were 10.4 man-hours ha⁻¹. Now two

determines its acceptance. There are numerous medium-scale contractors for animal-traction, who showed great interest in the ADSP. For years the prototype has been employed to plant approximately 50 ha every season.

- nal Symposium „Wind Erosion in West Africa – The Problem and its Control“, University of Hohenheim, Germany, 5 to 7 December 1994 (Weikersheim: Margraf Verlag, 1996), pp. 129-143
- [3] *Kromer, K.-H., L. N. Shaw and W. Brinkmann*: Planter for Hole Imbedding of Seed. ASAE Paper No. 87-1018 for Presentation at the 1987 Summer Meeting of the American Society of Agricultural Engineers, June 28 to July 1, Baltimore Convention Center; St. Joseph/ Michigan: American Society of Agricultural Engineers, 1987
- [4] *Shaw, L. N. and K.-H. Kromer*: „Revolving Spade Planter Soil Opener“, ASAE Paper No. 87-1019 for Presentation at the 1987 Summer Meeting of the American Society of Agricultural Engineers, June 28 to July 1, Baltimore Convention Center (St. Joseph/ Michigan: American Society of Agricultural Engineers, 1987)
- [5] *Eikel, G. und K.-H. Kromer*: Lochsäverfahren bei Mais. *Mais* 2 (1989), S. 30-33
- [6] *Eikel, G. und O. Siebertz*: Technik zur punktuellen Einbettung von Maissaatgut durch organischen Mulch. *LANDTECHNIK* 45 (1990), H. 9, S. 341-344
- [7] • *Eikel, G.*: Bodenschonung und pflanzenbauliche Eignung des Bonner Spaten-Einzelkornsägerätes am Beispiel des Maisanbaus. Forschungsbericht Agrartechnik des Arbeitskreises Forschung und Lehre der Max-Eyth-Gesellschaft (MEG), Nr. 208, Bonn, 1991
- [8] • *Siebertz, O.*: Rechnergestützte Konstruktionsmethodik (CAD) zur Entwicklung von Einzelkornsägeräten am Beispiel eines Maissägerätes mit punktförmiger Saatgutablage. Forschungsbericht Agrartechnik des Arbeitskreises Forschung und Lehre der Max-Eyth-Gesellschaft (MEG), Nr. 209, Bonn, 1991
- [9] • *Scheidtweiler, Th.*: Verfahrensvergleich eines gespanngezogenen Spaten-Einzelkornsägerätes mit der in Ostafrika üblichen Handsaat von Mais. Forschungsbericht Agrartechnik des Arbeitskreises Forschung und Lehre der Max-Eyth-Gesellschaft Agrartechnik im VDI (VDI-MEG), Nr. 295, Bonn, 1996
- [10] Deutsche Landwirtschafts-Gesellschaft: Prüfrahmen für Einzelkornsämaschinen Groß-Umstadt: DLG-Prüfstelle für Landmaschinen, 1989 and 1993
- [11] International Organization for Standardization (ISO): Sowing Equipment, Methods of Test, Part 1 – Single Seed Drills (Precision Drills), Draft International Standard ISO/DIS 7258/1 (1982)