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Strip-till seeder for sugar beets

Strip-till save costs by reducing tillage on the area of sugar beet rows only. The seeding system is characterized by a deep loosening of soil with a tine combined with a share and by following tools generating fine-grained soil as seed bed. In cooperation with the Kverneland company group Soest/Germany a strip tiller combined with precision seeder was designed and tested in field experiments. Tilling and seeding was performed in one path on fields with straw and mustard mulch. Even the plant development was slower as compared to conventional sawn sugar beets the yield was on equivalent level. Further field experiments are planned to attest constant yield, cost and energy efficiency of the seeding system.

received 17 Februar 2014
accepted 23 April 2014

Keywords
Strip tillage, seeding systems, mulch seeding, zone tillage, seed emergence

Abstract
Landtechnik 69(3), 2014, pp. 139–142, 4 figures, 8 references

Slit-drilling is a form of strip-tillage with deep loosening of the soil (up to 25 cm) within the cultivated strip which is particularly beneficial for root crop development, e.g. tubers or sugar beet. The depth of loosening is the important characteristic. As compared to conventional tilling operations applied for sugar beets, the strip till reduces machine operations and as a consequence costs are expected to be lower mainly by reducing the fuel consumption for field work. Strip till generates a rough surface of the soil which helps to reduce erosion by run-off water and the implement employed in this study is applicable for mulch seeding which avoids erosions as well.

In the last years cultivation methods with strip till were applied for maize and sugar beet in one and two phase operations, the latter is tilling of strips with a deep slot in autumn (25 cm) and seeding in springtime into the strip without additional tilling operations. Demmel et al. [1] used different tool combinations for the two phase strip till. Two implements were employed with a mass per row of 150 to 300 kg. The consolidated sugar yield was 7 % lower in two test years as the reference which was the conventional cultivation of sugar beets with full till operations. The implements of American provenience with a row width of 75 cm had been adjusted to 45 and 50 cm row width, which may have had a yield impact. Multiple experiments in several years were conducted by the university of Hohenheim. Herrmann [2] reported on faster temperature rise in the two phase strip till operation. He used a six row implement with 8 km/h operation speed and a power demand of 117 kW, when the tine was adjusted for a slot depth of 18–20 cm.

Licht [3] reported on faster soil temperature rise in springtime as compared to no-till cultivation by 1.2 to 1.4 °C causing a better plant development when strip till was applied. An expected increase in water content of the soil in the 30 cm layer did occur only when compared to test plot tilled with a tine cultivator.

Divers shares on two field locations have been studied by Morris [4]. As compared to the plough variant the emergence of sugar beets sawn with a strip till implement equipped with shares having lateral wings was equivalent. The tine without shares and wings working in a depth from 11 to 18 cm was worse. There was no impact by operational speed and it was concluded that the speed should be adjusted to the required field operation capacity.

Generating slots into the soil admits subsoil fertilization, which is required for successful maize cultivation. Sander [5] applied subsoil fertilization for sugar beets but did not found a continuous increase in yield. Subsoil fertilization is affected by annual and climate conditions and depends on depth of deposition as well as kind of fertilizer. So far non-leaching fertilizers, e.g. Diammonium phosphate (DAP), were recommended but as well Calcium ammonium nitrate (CAN) and compound fertilizer with rates of 30 to 70 kg/ha were applied.

Design of strip till seed drill

By preliminary tests [6] the effect of different tool combinations was studied aiming at loosening of the soil by a tine up to 30 cm depth, at uniform re-compaction in all layers of the tilled soil and at a fine grained seed bed in one path. **Figure 1** displays the implement as a prototype which was the result of the previous soil physical tests of different tools. The implement is distinct from other strip till implements by its light weight and coupling of the seeding unit at the rear of the tilling tools. The working speed is in the range of 7–8 km/h.

The tines are equipped with triangle shares at bottom with inclined position to generate downwards forces which avoids heavy design of the implement to keep it in the soil. This position of the shares contemporaneously results in a loosing of soil, which becomes visible when the soil surface is lifted up by the share inclination.

Profile wheels (d = 40 cm) act as soil re-compaction tools. The large diameter pretends the wheels from slipping and they form the seed groove into which the seeds are deposited. The profile wheels are followed by crumble discs positioned with an offset, moving fine grained soil into the seed groove. When mulch seeding is required cutting discs are employed ahead of the tines to cut the soil and the organic material laying on the soil surface.

The strip till implement was designed for one phase operation by direct coupling of the seed units at the end of the till tool carrier. The entire implement has a weight of less than 3 t, and the total length is 3 m which demands only low hydraulic lifting power. The independent suspension of the coulter discs results in a good adjustment to the soil surface preparing a shallow seed bed. The company of Kverneland supported the prototype assembly by components, this was the carrier frame with three point linkage and carrier wheels, all were taken from the maize seeder program. The company as well provided the precision seeder units with mulch option which are electrically driven (Product range: Monopill SE).

Implement in action and field experiments

In the years 2012 and 2013 field experiments were conducted on the Klein Altendorf experimental farm (50°37'51″ N 6°59'32″ E; luvisol, loamy silt) with deep layered loess soil after two mulch tillage operations. Preceding crop was barley. After harvest in one variant (straw mulch) the soil was tilled once with a tine cultivator. In the second variant, field mustard mulch was grown as intermediate crop. The mustard was superficially chopped and incorporated by a tine cultivator with spring tines. As reference a regular farmed sugar beet adjacent field was used, which was tilled by plough and seed bed preparation. Fertilization and plant protection has been uniformly done for the reference field and the strip till experimental plots.

Each of the four plots (250 m²) was tested by 4 replications. For determination of plant population plant rows of 10 m was marked, yield was measured on plots of 10 m² and for morphological data 15 beets per sample were taken. The results given in **Figures 2**, **3** and **4** homogenous subgroups were calculated by Tuckey test to reveal significant results. Prior the Gaussian distribution was checked by Kolmogorow-Smirnow test and the variance homogeneity by Levene test.

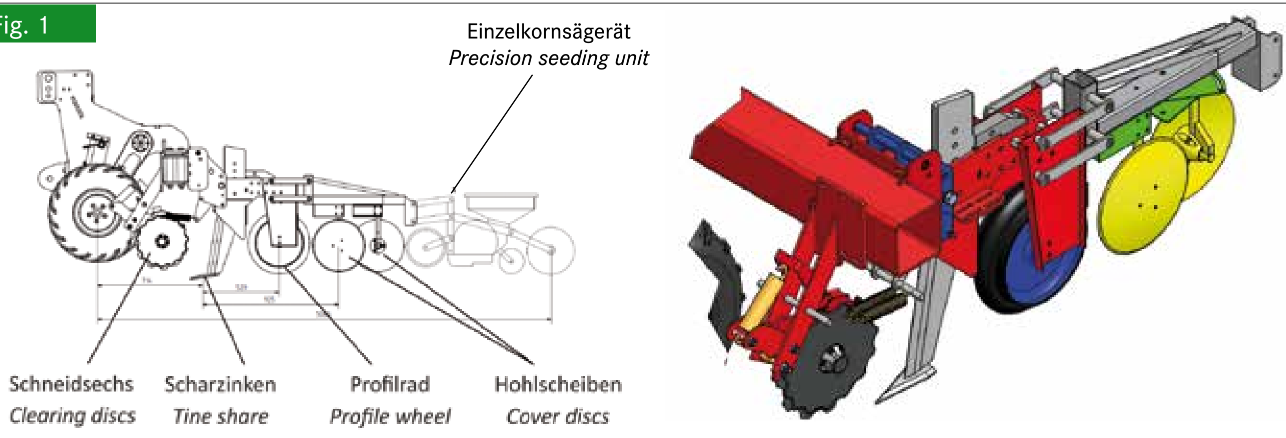
Results and discussion

A slower emergence of the beets from strip till variants was observed accompanied by late emergence of beets in row gaps. In the final assessment significant evidence was however only for the field mustard variant with 88.1 % emergence rate. The final emergence in the reference plot was 95.8 % and in the straw mulch plot 91 % of the planted seeds were counted as beet plants (**Figure 2**).

Worse field emergence of the strip till variants is explained by the contemporaneous tilling and seeding (one phase cultivation), which does not comply with optimal soil conditions. As a consequence the soil seed contact is worse than in conventional tilled fields and the germination is initiated by a larger part through weather conditions.

The yield originates from the number and magnitude of the plants. There is a significant relation between beet maximum diameter ($R^2 > 0.9$), root length ($R^2 > 0.1$) and plants mass [7]. The beets from strip till cultivation were significantly longer, the mustard plots contained beets which were 5 % longer as compared to the conventional cultivated beets. Regarding the maximum diameter the expected increase of the strip till variants did not appear. The beets from straw mulch increased and in mustard mulch the maximum diameter decreased. Single beet mass was increased for the strip till variants (**Figure 3**), for the straw mulch variant (12.7 %) even with statistical significance. The explanation for the increase in beet in beet mass is that lower field population appeared in the strip till variants, which was compensated by the beets capability to increase growth of the single plants [8].

Fig. 1



Single phase strip-till implement connected to wheel-based carrier and coupled with precision seeder for sugar beets (Kverneland Monopill SE)

In **Figure 4** the beet mass and sugar yield for the three variants are outlined. To compare the results of the two years experiments the relative yield data were calculated based on the data of the reference plot (100 % = 64.7 t/ha average mass yield). The yield of strip till variant straw mulch was 3.3 % lower and of mustard variant 7.1 % lower. As the scatter of the yield data is high there is no statistical significance of differences between the yields of all variants. The experiments of Demmel [1] confirm that cultivation with higher efforts in tillage result in higher yield. Sander [5] stated mass and sugar yield on the same level for strip tilled beets in 3 years field experiments at 5 sites.

The reference sugar yield was 12.2 t/ha, for the strip till variant 5.6 % lower and mustard variant 6.4 % lower with no statistical significance however.

Resumee

The results of 2 years field experiments demonstrate that with low input tillage as realized with the introduced strip till seed drill the yield of sugar beet is on the approximately same level as of the conventional cultivated beets. Additional improvements and tests on other field sites with different soil and climate conditions are needed and aim at securing yield stability of the strip till cultivation variant. The one phase seeding of sugar beets by strip till implement may contribute to cost and energy savings and thus being an alternative under environmental aspects.

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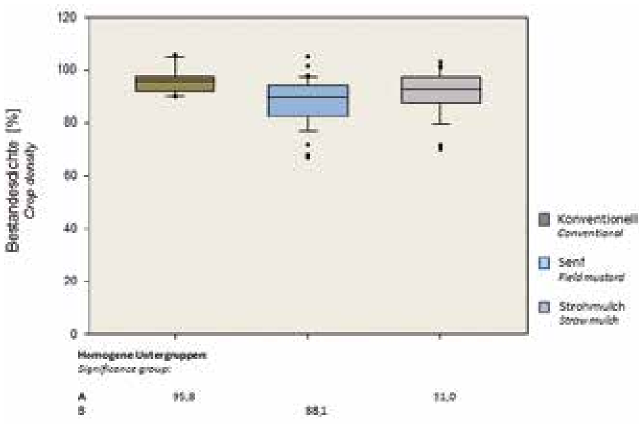
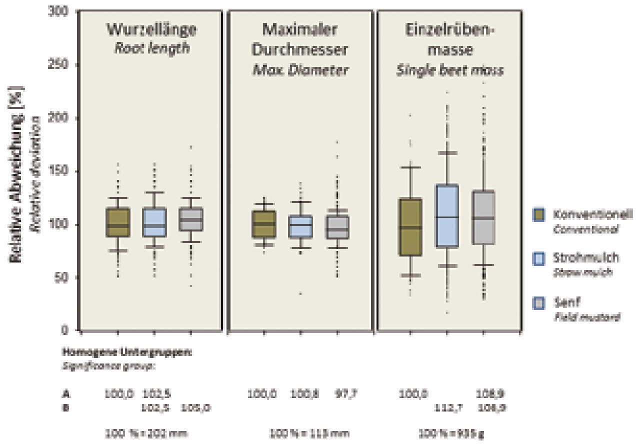
Fig. 2



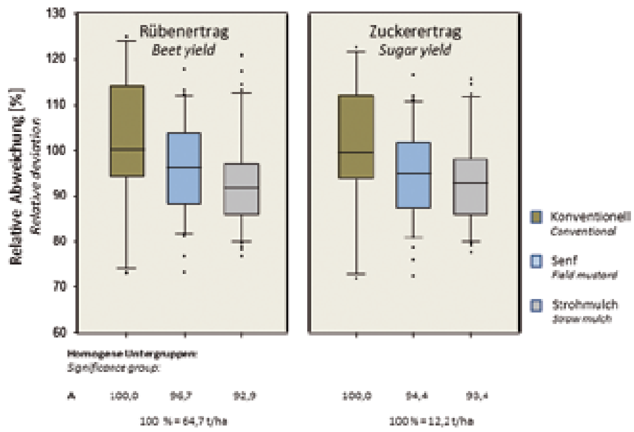
Comparison of crop density in 2012 and 2013

Fig. 3



Morphological differences in cropping systems, year 2012 and 2013

Fig. 4



Relative beet yield and sugar yield, year 2012 and 2013