Joachim Brunotte and Claus Sommer, Brunswick

Good farming practice in the application of high-performance harvesting machinery

Results of technique and machinery application in cultivations and sugar beet harvesting – Decision aids towards good farming practice

Within farm management the „soil-plant-climate" complex including rotation, cultivation, fertilisation, plant protection and harvest are accepted steps towards achieving high quality yields. Here the farmer uses a wide selection of highly-specialised and expensive technology which on cost grounds must be optimally exploited. But in order to remain competitive and environmentally protective at the same time damaging side-effects must be avoided[1].

Good farming practice should be applied to avoid conflicts in this area. Here's an example involving soil compaction damage.

Dr. sc. agr. Joachim Brunotte is a member of the scientific staff, Dir. and Prof. Dr.-Ing. habil. Claus Sommer is managing director of the Instituts für Betriebstechnik und Bauforschung der FAL, Bundesallee 50, 38116 Brunswick; e-mail: joachim.brunotte@fal.de

Keywords

Soil stress, soil protection, good practice management

With the described measuring methods it was possible to achieve practice-relevant results which could help in the communication of good farming practice to farmers, advisors and industry. An import key in the reduction of soil compaction damage problems to the level of risk that remains unavoidable in practical farming lies in the processes of cultivation and harvest which are depicted in the following example centred around sugar beet cropping.

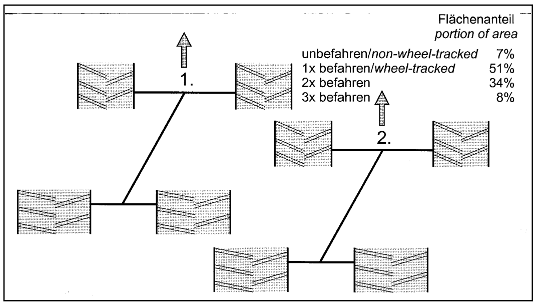

Fig. 1: Track-surface ratio of a 6-row complete beet harvester with offset axles with an angle joint

The basic cultivations should bring the ground structure into a suitable condition for the following crop. If soil is ploughed before sugar beet, the ground becomes over-loosened as a rule and is subsequently more sensitive to compaction compared with a non-ploughed surface. Soil-protective loosening – i.e., not inverted and loosened according to the coming crop such as a single treatment with chisel plough or paraplough – leaves behind a slightly higher density and therefore a surface with higher load-bearing capacity and better drivability.

The critical point for soil-protective driving is the increasing load per wheel. The dynamic soil moisture content in topsoil and lower topsoil make impossible the establishment of dependable threshold values for the mechanical sensitivity of the ground. Long drills demand large-capacity bunkers and this means high wheel loads. The applied harvesting systems differ with respect to wheel loadings, the average contact area pressure, the tyre inner pressure and the frequency with which the field surface is driven over [2].

To this background, the following results from practically-based field trials regarding technological applications will be discussed and conclusions with regard to good farming practice drawn.

Application trials on brick clay

Technical data from various harvesting systems and their effects on track depth and penetrometer resistance

Rationalisation requirements in the sugar beet harvest has led to a development from 1 to 2 rows and now 6-row harvesters. Today,

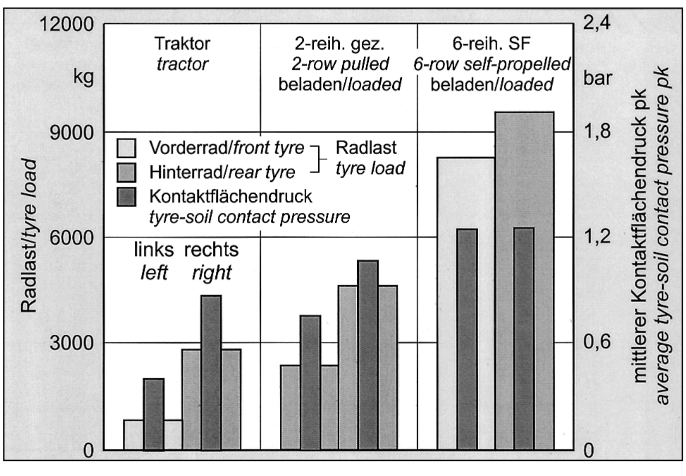

Fig. 2: Vehicle parameters of sugar beet harvesting systems

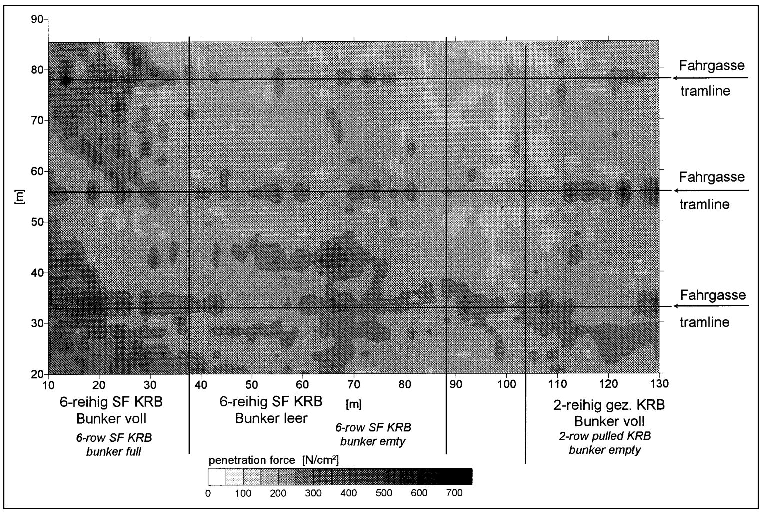

Fig. 3: Soil stability in 40 cm depth following different loads caused by harvesting systems

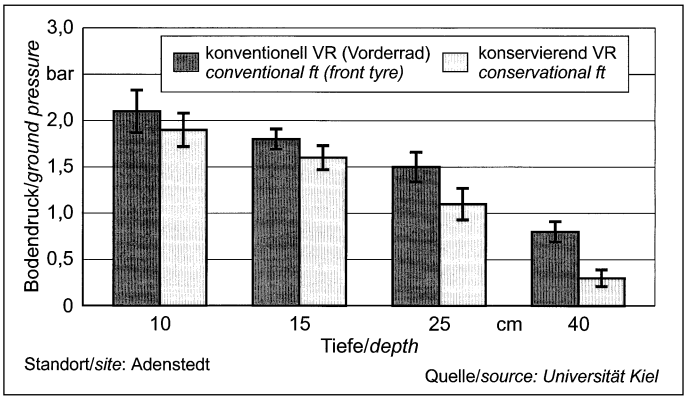

Fig. 4: Soil pressure underneath the front wheel of a 6-row harvester following different tillage for sugar beets

around 75% of the sugar beet is thus harvested by 6-row machines. Reaction to the consequent increase in wheel loads with the 6-row system has led to broad tyres and the development of new running gear. Whereas a 2-row pulled header-harvester with bunker (control in the trial) with a well-filled hopper reached a maximum wheel load of 4.5 t and drove over the ground a total of six times, a 6-row header-bunker harvester (KRB) reached 10 to 12 t wheel load and tracked the ground one to three times, according to the setting of the running gear (*fig. 1*).

The ground contact areas of the tyres are different according to the weight to be borne and the pressure within the tyre. This means that between the systems there exists comparable calculable average contact area pressures from 1.0 to 1.3 bar on the contact area between tyre and ground (*fig. 2*).Whilst the 2-row harvester was driven with a tyre inner pressure of 1.3 bar, the advised load carrying capacity of the tyres with the 6-row harvester was reached when a pressure of 2.3 bar was used. This had an influence on the ground pressure produced.

For the farmer, the depth of the track produced by the wheels is a simple indicator as to the drivability of his field. This effect comes from wheel load, tyre inner pressure, ground contact area, soil moisture and initial degree of soil compaction. A 6-row KRB makes wheel contact with 60% of the field surface twice during straight-ahead driving, 20% of the area once and leaves 30% of the area without wheel contact. On a brick clay soil with empty bunker this machine leaves a track depth of 8.5 (± 1.5) cm and, with a full bunker, of 12 (± 2) cm (soil moisture 20 mass%, layering compaction 1.47 g/cm³). If articulated running gear is used for steering, 8% of the field surface would be wheeled three times, 35% twice, 50% once and 7% not at all. The track depth sank by 8 (± 1.5) cm with an empty bunker and by 9.0 (± 1.7) cm with a full one. This indicates that the running gear development led to a shallower track. This had influence not only in avoiding compaction through reducing the number of repeated wheel trackings, it also improved conditions for the following preparation work in that the field surface after the beet harvest was more even.

By a medium soil moisture content (20 mass%) high wheel loads lead to an increase in the layering density and eventually to compaction damage. After the wheat harvest the density of the soil following various degrees of loadings during the sugar beet harvest was investigated with a horizontal penetrometer. With this, an area measurement comprising 1700 values was determined (*fig. 3*).

Different soil cultivations before and after using sugar beet harvesting machinery

Alongside the further development of technical possibilities, improving the carrying-capacity of the ground is an important aspect in the concept „Soil-protective field operations". Because of this, the variants „conventional sowing after spring ploughing", and „direct drilling after soil-protective loosening with chiselplough" have been followed on a brick clay soil in trials since 1995. During beet harvester journeys, the wheel loads led to soil stresses. The ground pressure at 20 cm (topsoil) and 40 cm (lower topsoil) was measured with pipe sensors under the harvesters.

Figure 4 shows the ground pressure at four different soil depths – for 9 t wheel load, tyre inner pressure p_i = 2.3 bar, calculated average soil contact pressure p_k = 1.3 bar, 24% soil moisture – on brick clay-loam soil during driving operations on 20.11.1998. Immediately under the tyre-ground contact area (10 cm depth) values of 2.2 (conventional variant) and 1.9 bar (direct drilling variant) were measured and these were a little less that the tyre inner pressure (p_i = 2.3 bar). In the topsoil (down to 25 cm) the soil pressure

Table 1: Wheat yield (dt/ha) after different soil loadings during the previous sugar beet harvest with 2-row and 6-row harvesting systems as well as different cultivation methods before wheat establishment

	Not driven over			2-row, 2 - 4 t 6-times driven over			6-row, 9 – 11 t 1 to 2 times driven over			Headlands
	P	MSmL	MSoL	P	MSmL	MSol	P	MSmL	MSoL	P
Beet lifting'95 Wheat'96	114	115	110	98	98	97	98	100	101	
Beet lifting'96 Wheat'97	101	103	103	103	106	102	101	101	99	96
Beet lifting'97 Wheat'98	-	-	-	98	96	102	100	101	102	
Beet lifting'98 Wheat'99	121	106	-	117	-	-	118	117	-	86

P: plough MSmL: Direct drilling with loosening (for winter wheat sowing)
MSoL: Direct drilling without loosening (for winter wheat sowing) -: not investigated

differences between the two cultivation variants lay from 0.3 to 0.4 bar whereby the lesser value applied in every case to the direct drilling variant. These ground pressure measurements prove:

1. That the actual tyre inner pressure is relevant and not a theoretical average contact area pressure.
2. Soil-protective ground loosening /direct drilling results in higher soil stability and, with this, better ground carrying capacity. On top of this, this variant exhibited a well-developed vertical pore system which avoided soil damage.

Parallel to the ground pressure measured in the soil, the track depths were measured on the field surface. Deep tracks existed where soil was over-loosened or where the area had been driven over with soil moisture high. During autumn 1998, water remained lying in wheel tracks in many areas and this led to bogging-down of the harvester now and again, despite the broad tyres used (800/65 R 32 XM28). Under the same wheel loads, shallower tracking is proof of better ground carrying ability.

To this background, a first technical solution towards a drivability sensor on a beet harvester was developed for the 1999 harvest at the Institute for Business Technology and Building Research. During driving, the depth that the harvester front axle sunk towards the field surface was measured by this sensor and a reading was made available in the driving cabin (*fig. 5*). Using the data recorder UNILOG it is possible to develop a continuous record of the tracking depth during increasing loading of the bunker. Thus, the effect of different ground and working conditions (in sugar beet) could be investigated. The further development of this sensor now concerns the measurement of the soil structure during driving.

Nowadays, the root development and yield of the following crop (winter wheat) is well suited for the quantification of the effect of heavy harvesting machinery on soil structure. The root density indicates no significant difference between the cultivation and machinery variants. Among other reasons, this can be explained by the balanced moisture conditions in spring over the last three years. The winter wheat yield (*table 1*) can be regarded up until now as the end-result of all influential growth factors from beet harvesting through to the following vegetation.

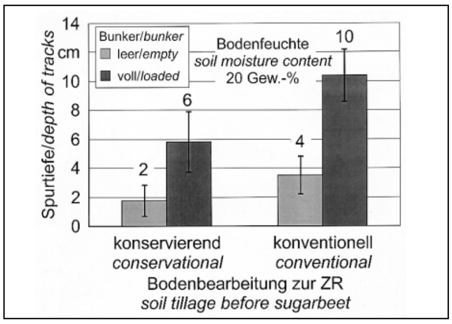

Fig. 5: Depth of tracks of a 6-row beet harvester following different tillage before sugar beets

Mainly, alongside the technical parameters, the respective weather conditions determined the extent of damage to soil structure during harvest:

1995: dry conditions – 12 mm in October
1996: medium moist soil after 100 mm in October
1997: Moist topsoil over dry lower topsoil in that precipitation (70 mm) started first October 12th
1998: Very moist soil – from 18.10 to November 15. 98 alone, precipitation totalled 180-200 mm
1999: dry conditions – 35 mm in October

It can be seen from table 1 that a loosening operation beforehand with/without plough had no influence on the wheat yield in 1996. In 1996 experience led farmers to carry out a single loosening operation. This could be the reason for even and high yields of wheat in 1997 for all variants. The winter wheat harvest in 1998 showed no difference between the different beet harvesting systems used.

1998 was the most difficult season for years for sugar beet harvesting, and direct drilling winter wheat was hardly possible because of the soft condition of the soil surface. This meant most land was ploughed. The very high yields for land, tracked or untracked by the harvesters indicated no soil structure damage had occurred – this is also proved by the investigations as to the physical state of the soil and root development. It appears that the pore system, which was filled with water, acted as a good buffer during the split seconds that the land was driven over with high wheel loads. On the other hand, the picture was different on the headlands where repeated tracking led to kneading of the soil. This could be proved by horizontal penetrometer readings and the drop in yield of 3 t/ha.

Conclusion

Rationalisation actions within agriculture have lead to an increase in the total sizes of harvesting and transport vehicles. Worries about the ground condition did not begin with the introduction of the Federal German Ground Protection Statute (BBodSchG). Demands for the limiting of wheel loads when driving on fields (from ca. 2 to 5t) without consideration of the actual moisture content of the soil are not helpful towards the communication of „good farming practice" for the reduction of soil compaction damage.

Moreover, the investigations carried out in practical circumstances over five years into soil reaction and the results of heavy harvesting machinery on soil structure and yield prove that it requires a concept of „soil-protective field operations" consisting of a number of building blocks and resulting in differentiated conclusions as far as beet harvesting is concerned:

a) Adjustment of working procedures
- The application of modern defoliating/leaf distribution systems so that harvesting and winter wheat sowing can take place alongside one another and thus reduce demands on the soil.
- Automatic tyre pressure adjustment which reacts to, and complies with, weight changes as the bunker is filled.
- Dual tyre systems with appropriate interior tyre pressures.

b) Further development of technological possibilities
- Further development of running gear linked to wide tyres which allow tyre inner pressure to be kept < 1 bar, even with high wheel load.
- On-line determination of the actual driving conditions of the field surface and an indicator of critical ground conditions for the driver so that operative decisions can be made on the spot (such as unloading at both ends of the field, moving with the harvester to less compaction-sensitive areas).

c) Improving of ground „drivability"
- Soil-protective loosening and direct drilling (conserving soil operations).

d) Limiting of mechanical stresses
- On-land ploughing in order to reduce the stress on the deeper soil layers;
- Avoiding filling bunkers to capacity;
- Exploiting all possibilities for reducing the actual soil contact area pressure (reduction of tyre inner pressures plays a dominating role here);
- Sensible limiting of the tendency up until now towards increasing wheel loads.

In total, further work is required into the ways available up until now of measuring soil structure reactions to high wheel loads under moist conditions through practically-relevant, easily-operated and innovative possibilities. With these and the indicated building blocks of a „soil-protective field operation policy", good soil care is possible in the sense of the soil protection law.

Literature

[1] *Sommer, C.*: Ein Konzept zur Vorbeugung von Bodenschadverdichtungen in der pflanzlichen Produktion. Bodenschutz 1 (1998), S. 12 – 16

[2] *Brunotte, J.* und *C. Sommer*: Bodenschonung bei der Zuckerrübenernte. Zuckerrübe 57 (1998), H. 5, S. 4 – 6