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Yield recording based on individual sugar beets

Spatially specific yield recording and mapping are requirements for cropping adapted for small-area heterogeneity. Harvester throughput comprises a mix of beet, soil, leaves and head remains and its measurement is hampered by the raw conditions. This has led to the development of a new yield recording system based on the unharvested individual beet. The system is based on the measuring and counting of the beets.

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Keyworts

Sugar beet harvesting, yield measurement, yield mapping

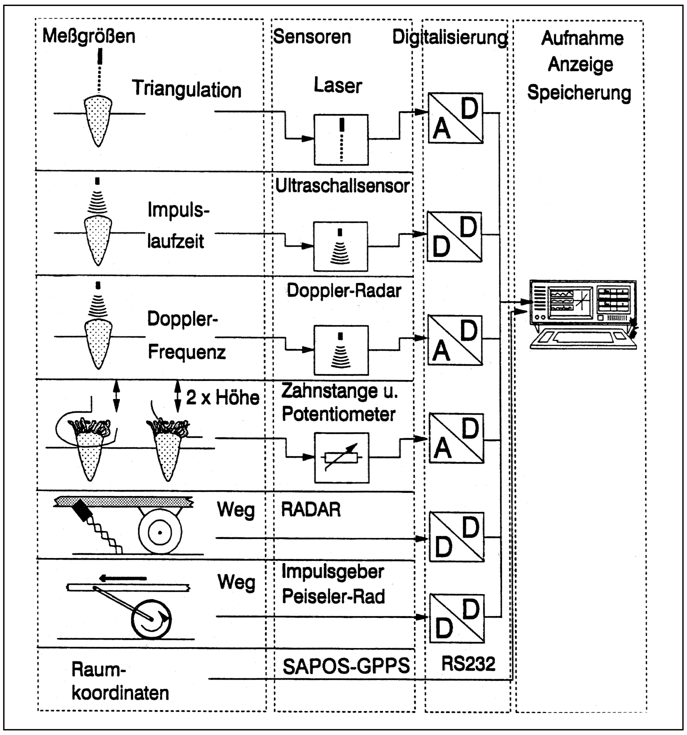


Fig. 1: Sensors for yield measurement

Structural economic and ecological farming conditions mean that possible optimisation potentials in cropping have to be sought. Existing yield potential should be exploited along with input minimisation. To achieve this, site yield potential and the effect and amount of the individual factors (location factors and cultivation actions) must be known and measurable. The importance of measurability increases with the homogeneity of the site.

Spatially specific farm management is based on the recording of yield promoting and yield influencing factors and recording of the yield as target parameter. For every cereal or rotational crop the yield must be known because the crop requirements from any one location are different. Cereal yield allows no direct prognosis for that of sugar beet. Through position data (GPS), information is linked and then controlled and processed into geographical information systems (GIS) From these, in association with expert knowledge, experience and production-technological cultivation models, application maps can be developed and cropping can be optimised from these for yield potential and sustainability.

Typical examples of precision farming are spatially specific drilling and yield mapping. Necessary for this is the application of reliable actoric, sensoric and navigation technology.

Up until now, no harvester-fitted yield recording system suitable for practical farming has been developed for sugar beet. And without this facility, site-specific beet growing is not possible.

Measurement of harvester throughput for yield recording also offers advantages for optimising the harvesting process. Ina machine management system, control circuits can be established for adjustment of the cleaning and transport units according to throughput.

Different approaches for throughput measurements are based on weighing, force or torque measurements in the lifter. But basically the results are measurements of a mix of beet, soil, head and leaf parts and therefore not of the beet alone. The result is dependant on the quality of tare evaluation and assessment of its fluctuations within the area being harvested. Weighing in the harvester is susceptible to strong variations and impact forces and therefore open to considerable imprecisions. On top of this, volume flow measurements require a uniform bulk density for determination of mass. All this means there's a real requirement for seeking new solutions.

Requirements

These can be assessed from the above-described problems for the finding of a new practical yield measurement system. The requirements are divided into functional, wor-

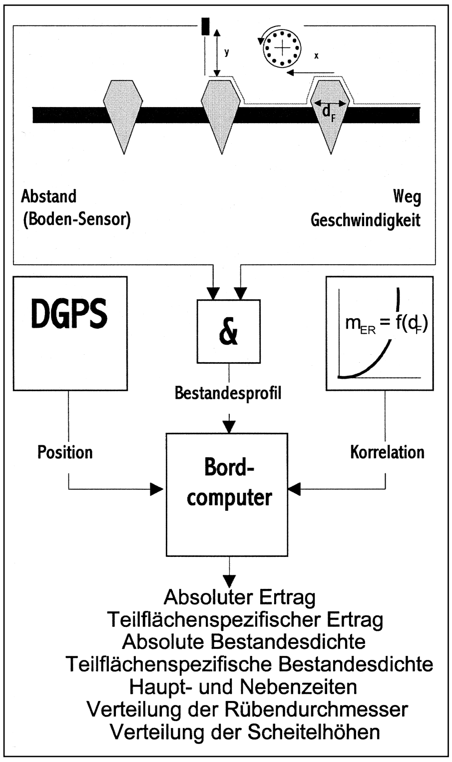
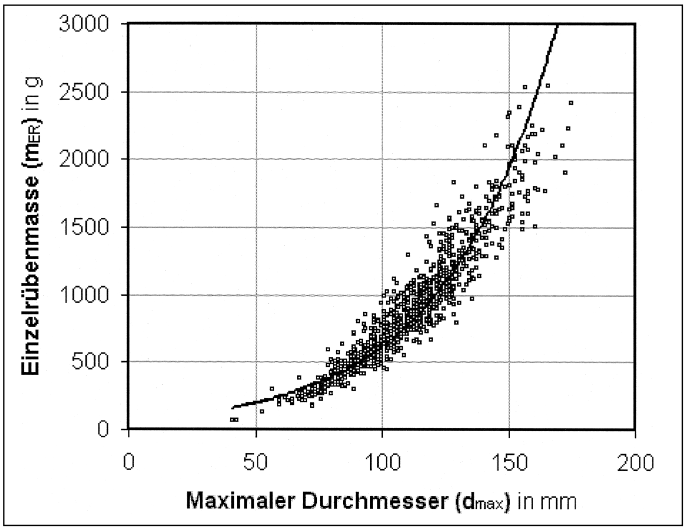


Fig. 2: Principle of beet contur measurement

Fig. 3: Maximal diameter versus single beet mass



king and interaction:

1. Functional requirements
   - Real time measurement of beet throughput
   - Positioning/navigation
   - Information collection for monitoring and for establishing the controlling system
2. Working requirements
   - High working and functional reliability
   - Simple operation
   - Absolute precision (harvested yield)
   - Relative precision (yield comparisons)
3. Interaction requirements
   - Fitting in all beet harvesters
   - Linking with GIS

Solutions

Two solutions were looked-into which avoided the aforementioned difficulties and were based on the unharvested beet.

1. Beet counting

In this, the frequency of the beets (n) was measured at harvesting. Through the known gap between the plants (S_R) and the additionally measured distance covered (l_F) can, under assumption of a relatively uniform individual beet weight (m_{ER}), the spatially specific yield be deduced (m'_A). According to this

$$m'_A = n \cdot \bar{m}_{ER} / l_F \cdot s_R$$

2. Individual beet measuring

This is an extension of beet counting. Morphological characteristics of the beet (maximum beet diameter d_{MAX} or the diameter in direction of travel d_F) serve the exact evaluation of the beet weight. Here applies:

$$m_{ER} = f(d_{max}) = e^{a \cdot d_{max} + b}$$
$$m'_A = \sum m_{ER} / l_F \cdot s_R$$

Methods

The relationship between beet diameter and individual beet weight was investigated. The selected method required the development of a measurement chain in a constructional-methodical process for the crop measurement, and the development of a suitable algorithm for software evaluation of the measurement values in real time. For this, first of all model beets were installed on a belt in the laboratory and a real plant population reconstructed in relation to gap between plants and beet diameter. The measurement chain so constructed and optimised was then gradually tested and evaluated in the field with a sensor carrier and finally with a single row header/lifter/bunker harvester.

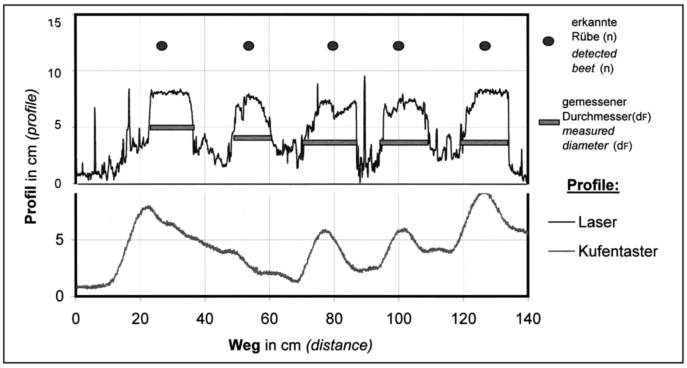


Fig. 4: Measurement of contour with a laser and a feeler skid

Single beet morphology and weight

The root shape influenced, among other things, by breeding and cultivation factors, was investigated for diameter and individual weight over several years and on different locations with different varieties and cultivation methods *(fig. 1)*.

The maximum diameter showed the closest relationship to individual beet weight (R^2 between 0.87 and 0.94). The correlation between diameter in direction of travel and the individual beet weight in the investigations was around 2 to 4% lower. To reach a high quality of evenness, consist calibration is necessary. If the same regression equation was used with all the various crops, the difference in the recorded yields was up to 4 t/ha. This is enough for mapping yield differences in the field areas. After final corrections related to the actual harvested weight, the error can be reduced.

The vertex was less easy to use in the calculation of the individual beet weight (R^2 = 0.46 to 0.52). Linking the information on diameter and vertex brought no better agreement.

Measurement chains

These have to be able to be fitted without problem in all beet harvesters and to work without fault under unfavourable conditions. For measuring precision and speed, chains differ in their capability for counting and/or weighing if the individual beet. A measurement chain consists of each case of a sensor for measuring the crop profile (y-vector). A further sensor measures the distance travelled (x-vector) *(fig. 2)*.

The ground surface level is measured with a „tooth rod potentiometer" on the skid sensor. The crop profile was measured without touching via ultrasonic, microwave sensor and with a laser, or through touching with the skid sensor (via „tooth rod potentiometer“). For measuring distances, a radar sensor and Peisler wheel were used. DGPS was used for site-specific classification of the results *(fig. 3)*.

Yield measuring and mapping

In field trials the sensors were built into the machines after the defoliator and header. The quality of the beet counting depended on the first instance on the height of the beet. Headed beets less than 2 cm above ground level were hardly able to be recorded via sensors. For this reason the best sensor position is directly behind the defoliator. Even deep-sitting beets could be identified through the already existing leaf brush and this allowed over 95% of the beet to be identified and counted during harvesting.

The beets have to be topped without any overhanging leaves remaining for the measurement of individual roots. Additionally, the beet drills must be free from disturbing factors (such as chopped leaves) and the harvester components including the fitted sensors must run without vibration. Measuring beet under such conditions with subsequent mapping is possible and under optimum conditions the precision of yield investigations can be over 80% *(fig. 4 and 5)*.

Fig. 5: Yield map