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Comparison of single acting and double acting EHR-valve in tillage operations

The double acting EHR-valve (EHR-da) was evaluated on its potential in soil tillage in a joint project between the Bosch Rexroth AG and the University of Hohenheim. There was made an experiment on the drawning-in behaviour of two tillage implements with and without the use of the EHR-da. Also was made an experiment about variable depth tillage. For each experiment 360 measurements were made. The test results showed advantages of the EHR-da, but they also clarify that there are many development requirements for an implementation of site specific tillage to mounted implements.

Keywords
Double acting EHR-valve, drawning-in behaviour, site specific tillage

Abstract
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Since Harry Ferguson founded the three-point linkage, it is an essential component of agricultural tractors. The development of control systems to optimize traction power and depth control of the implement was important in tractor development for many years. Initially mechanical systems were used, which were first replaced by hydraulic systems and later by electronic systems. Today the electro-hydraulic hitch control (EHR) is a standard component in many tractors [1].

The double acting EHR, developed by the Bosch Rexroth AG, constitutes the next step to better controllability of the three-point linkage. Now, infinitely variable adjustable pressure can be given on the lowering site of the hitch cylinder. The range of adjustment reaches from normal single acting behaviour to a maximal pressure according to the half of the rear axle load. Advantages yield from weight transfer from the tractor rear axle to the implement for a better drawning-in behaviour. Also the depth control of the implement is getting better. A potential, which is useable for site specific tillage. Currently site specific tillage is only realized with drawn and mounted PTO-driven implements [2; 3]. Objectives of the experiments described below, were to use three-point mounted tillage implements for site specific tillage and to point out potential developments.

Simultaneous working depth measurement with the packer roller

If the working depth should be adjustable during tillage operation, a continuous detection is required. Previous researches showed that a tactile wheel is a common, well functioning method [4]. If the tactile wheel is replaced by the packer roller of the implement, a measurement of the working depth over the whole working width is possible. Errors depending on soil roughness can be avoided. In comparison to the tactile wheel, which runs on the virgin soil surface, the working depth is detected in relation to the tilled soil surface.
Normally the working depth on tillage implements is fixed with the packer roller. Because the packer roller must be free movable for the depth measurement, the working depth must be controlled only by the tractor linkage.

Experimental set-up

The experiment was conducted on a Südzucker AG farm in Einsiedel, Baden-Wuerttemberg. For mapping soil properties, measurements of the soil cone index and soil moisture content were made. Soil moisture content was 30 %. The penetrometer data was homogenous and showed no soil compaction. It was assumed that there was almost no influence on the experiment results.

A tractor, equipped with the double acting valve (EHR23C-da) was used for the experiments.

For the measurement and control unit, multiple networked computers were installed on the tractor (**figure 1**). On defined GPS-Positions the job computer forced the set working depth and the EHR-mode (sa/da). The working depth was conducted with a combination of an external angle sensor on the packer roller and the angle sensor of the hitch drive and adjusted on

the basis of the value given from the job computer. The values in the following graphs are only based on the values from the sensor on the packer roller.

Field navigation and documentation were made with a RTK-GPS-System. Experimental design was done with the „Hohenheim Software for Plotting Field Experiments“. The whole experimental sequence was automated with GPS; the driver had only controlling functions.

To evaluate the drawning-in behaviour in dependency on the EHR-mode a three-point linked cultivator and disc harrow were used. On both implements the fix attachment of the packer roller was modified with a hydraulic cylinder. For both EHR-modes (sa/da), three for the stubble cultivation typical working depths were investigated: 5 cm, 10 cm, and 15cm, each with 30 replications in a bloc design.

The variable depth tillage experimental design was a randomized strip trial with 30 replications. Measurements were only made with the cultivator. Conducted was the distance for set depth adjustment between two working depths.

Methods

Ground speed was fixed to 8.5 km/h for the drawning-in experiment and to 10 km/h for the variable depth tillage. Down pressure in double acting mode was 50 bar. Ground speed, draught force, hitch force, fuel consumption and slip were conducted over the CAN-Bus or sensors on the tractor. Working depth was measured with the angle sensor on the packer roller. The distance to reach the set depth was calculated from measurement time, ground speed and working depth.

Results

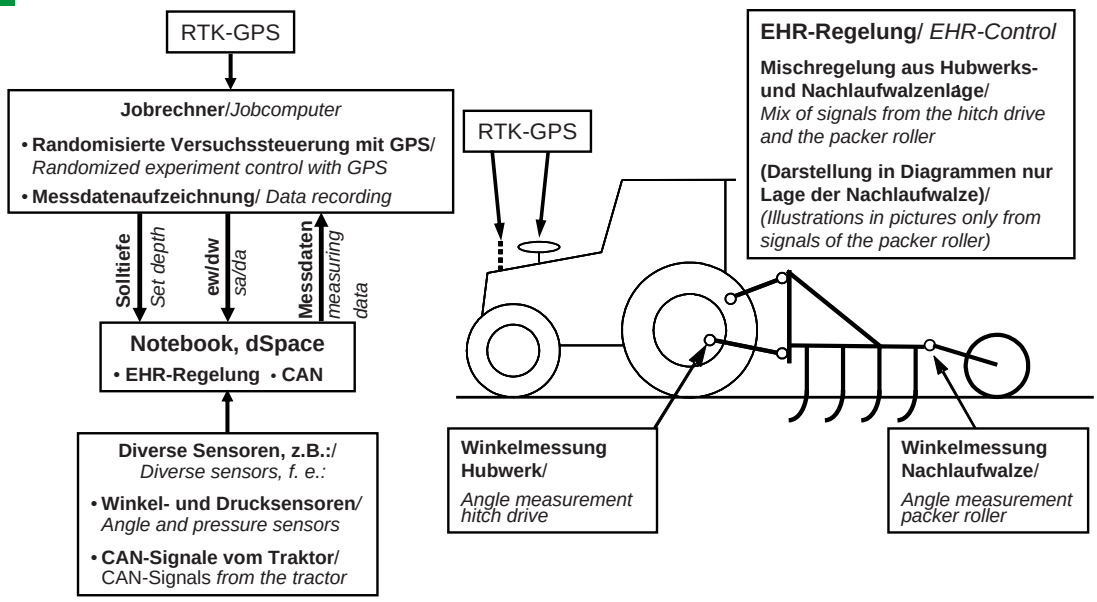
Drawning-in test: The arithmetic mean and a mean drawning-in behaviour were calculated from 30 measurements for each variant. In **figure 2** the effect of active lowering is shown for one variant, exemplarily. The curve of the working depth is clearly steeper. The drawning-in distance is 3 m shorter, than with single acting EHR.

The analysis of the measured data pointed out, that the shortening of the drawning-in distance isn't only influenced by the use of the EHR-da (**figure 3**). Crucial is an interaction between the EHR-mode and the set working depth. With a deeper set depth, the effect of the EHR-da increases. To avoid a deeper drawning-in of the cultivator, the EHR readjusts very early, at low working depths. Nameable shortenings of the drawning-in distance were reached at 10 cm and 15 cm working depth, only.

The drawning-in of implements takes generally place in the headland of a field. This area is heavier loaded than the core area because of the headland turns. Particularly harvesters with heavy axle loads can cause soil compaction under wet field conditions [7]. Also a heavy compacted soil layer can be established, when the soil surface is drying-out after harvest. This layer is hardly to penetrate. In both cases the EHR-da provides a faster drawning-in of the implement.

Variable depth tillage: In heterogeneous field conditions it is meaningful to vary tillage depth. Site specific tillage is the instrument for farmers to do this. A fast adjustment of the working depth is important, so that every area is treated with the right tillage depth. For this, experiments about the adjustment of the working depth to a set value while driving were made. The EHR-sa and the EHR-da were compared again.

Fig. 1



Signal and control principle on the tractor

The results are illustrated in **figure 4**. The shortest distance, with 6,45 m, was measured in double acting mode by the adjustment from 10 to 15 cm. For the adjustment from 5 to 15 cm in single acting mode, the maximal distance of 11,65 m were needed to reach the set tillage depth. The maximal shortening of about 4 m, compared to EHR-sa, was reached in the variant 5 to 15 cm. In adjusting to a deeper working depth, the EHR-da was generally faster. In the opposing direction it seems, that the EHR-sa has advantages against the EHR-da. Because both EHR-modes act similarly, this result isn't explainable.

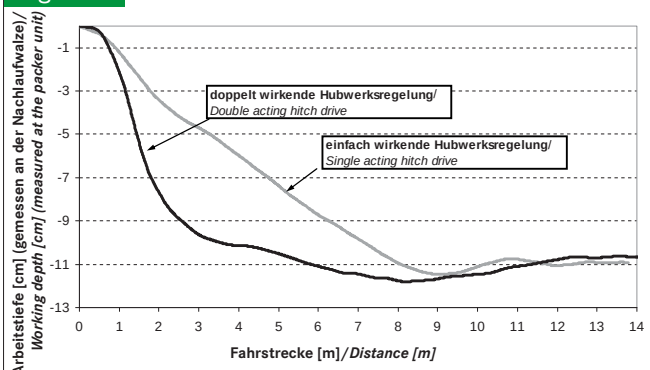
Conclusions

The drawning-in measurements showed the advantages of the EHR-da. Both implements reached working depth faster as compared to the EHR-sa. In dry soil conditions and in the headland the positive effect should be considerably stronger.

None of the EHR-modes had clear advantages in variable depth tillage. Both, EHR-sa and EHR-da had specific advantages and disadvantages.

The experiments illustrated, that site specific tillage is possible with modified three-point mounted implements. But they make clear, that for the adoption, developments on implement and on electronic site have to be made. The detection of the working depth with the packer roller worked reliably. It should be considered, that recompression is affected by the free rolling packer roller. Developing an electronic control, it is conceivable to give pressure in the attachment cylinder between cultivator and packer roller in order to push the roller in the soil active.

Fig. 2



Drawning-in behaviour of the cultivator to 10 cm depth (Means of 30 replications)

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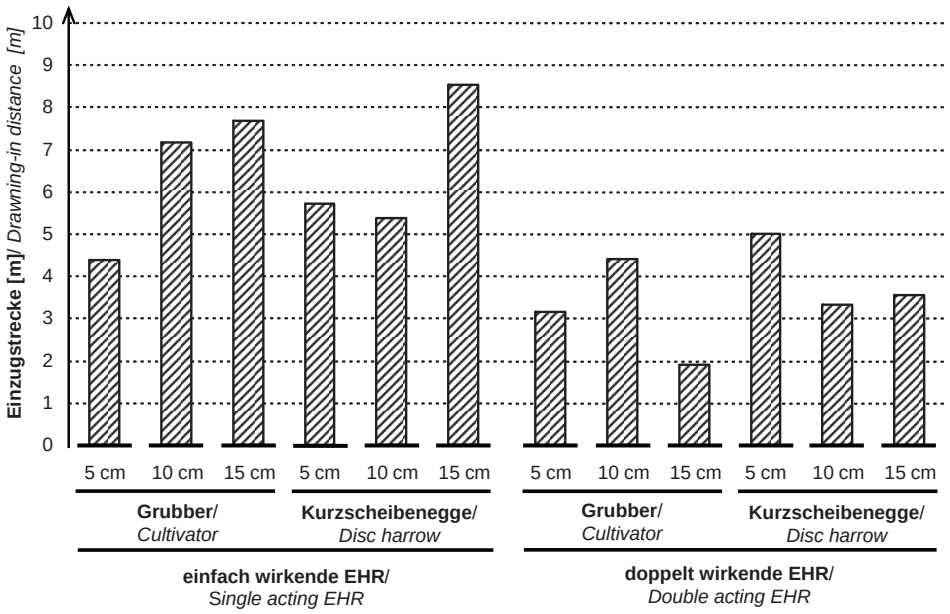
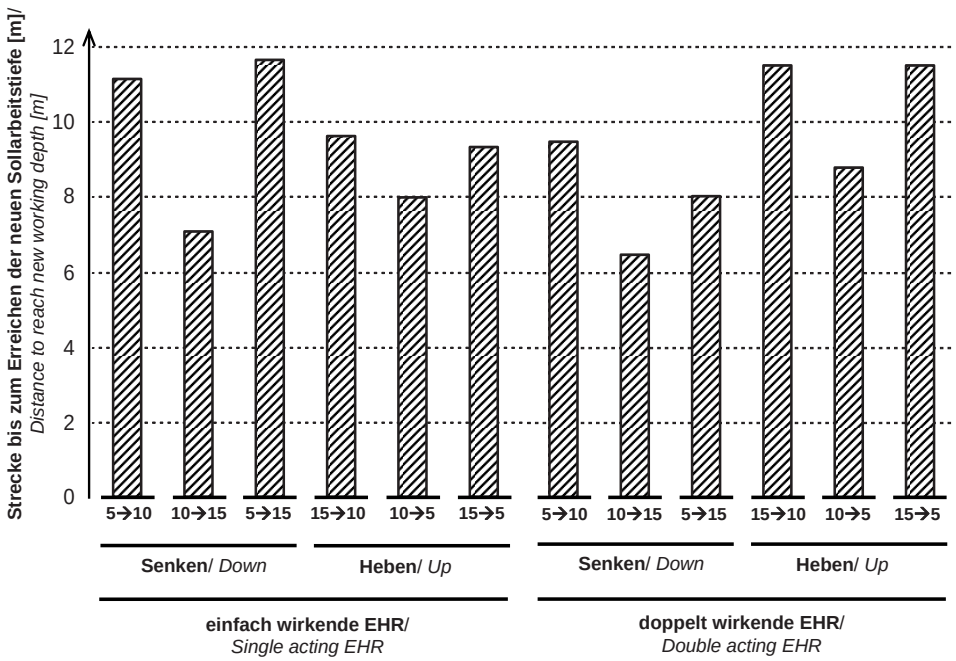
Fig. 3



Arithmetic mean values of the variants from the drawning-in experiment

Fig. 4



Distance to new set depth with single acting and double acting EHR

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