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TECHNICAL APPROACH FOR ROW CROP SEEDING IN SQUARE TO IMPROVE MECHANICAL WEED CONTROL EFFICIENCY

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ABSTRACT Row crops are highly affected by weeds at early stage of growth. The most commonly applied weed control in row crops currently is herbicide field spraying. An alternative is the mechanical weed control by hoeing, which is still not a satisfactory method because of low capacity and the fact that only up to 85% of the soil surface is treated. The space between the plants is not accessible for the weeding tools of conventional hoeing machines. To extend the area of mechanical treatment other cropping systems are required to support the operation of hoeing machines. On an experimental farm seed placements were arranged to allow machine hoeing inter and intra row. An electronic precise steering mechanism was integrated in a conventional seed space drill. To comply with an adequate plant population for sugar beets a seed placement of 33 by 33 cm was chosen. This distance is coincidentally an acceptable clearance between the plants for machine traffic. Aim of the field experiments was to evaluate the weeding efficiency of different methods. Hoeing was applied three times and weeds have been counted before and after operations. As compared to inter row hoeing by a conventional machine additional intra row hoeing eliminated 21% more weed plants. The most effective weed control system was the herbicide application eliminating weeds to less than two weed plants per square meter. In the mechanically treated plots more than 12 weed plants per square meter were found after the weed control of the plots was terminated.

Keywords: Equipment engineering for plant production, Precise seeding, Weed control, Seed compounds, Geo seeding.

INTRODUCTION Seeding can be seen as the first measure of weed control when cultivating a crop. Succeeding measures need to be applied for weed control when the plants are small and low coverage of soil does not limit weed emergence and growth of unwanted plants. Dominating measure of weed control these days is chemical weeding by herbicides. Farmers apply herbicides to almost all crops besides some special crops as herbs, and vegetables as well as in bio-farming. The chemical industry producing herbicides suffer under high expenses for the development of new herbicides, have difficulties in readmission of existing agents and will take herbicides out of the market in case of doubt or if low sales appear.

Aspects which are relevant for the environment, like ground water pollution, proper application, different marketing strategies like 'bio-products', are further arguments to boost alternatives.

Mechanical hoeing has lost importance because weed control by herbicides has been much more effective, but is still an outstanding alternative (Schmittmann et al., 2004). Weak points of mechanical weed control are the higher labour costs (less working width, low velocity) and the lower effectiveness, because hoeing is applicable only between the rows (inter row) and not within the rows (intra row). For sugar beets with a row distance of 45 cm a protecting distance from the plant needs to be considered and in consequence only 85% of the field area can be held free of weeds. Therefore the advantages – like better soil aeration - play only a minor role. This leads to the idea to create cross compounds, which allow hoeing in two directions: in machine travel direction and in transversal direction. As a consequence the weed free space is raised up to 90%.

For the plant population density of sugar beets 80,000 - 100,000 plants per hectare are desired. This is equivalent to distances of about 20 x 45 cm or to the desired cross compounds with 30 x 30 cm up to 35 x 35 cm. To some extend lower rates in plant densities are compensated by higher single beet masses. For this reason the optimal distance can be selected regarding the conditions of the hoeing technique or tools and the tractor wheel dimension. Another important issue is that no plants get damaged by tractor wheels or hoeing tools.

The technical challenge is to sow the plants in geometrical compounds so that a conventional hoeing machine can be used. The accuracy of the plant position is influenced by accuracy of the seed deposition including the rolling effect of the pill. The demanded accuracy as a sum of these factors should be less than 3 cm for velocities between 1-3 m/s (Schmittmann et al., 2008).

For establishing geometrical compounds an electronic precise steering mechanism was implemented in a seed space drill steered by different sensors including DGPS (Schmittmann et al. 2008, Siemes et al. 2007).

SEED CONCEPTION An electronic precise steering mechanism was integrated in a conventional precise seed spacing drill. Each seeding unit (cell wheel) was adjustable in spacing independently.

The position determined by the required spacing of the next seed deposition (the angle of the cell wheel) and the desired position in dependence of the neighbouring row was determinded by DGPS and an additional space sensor (Schölderle et al., 2008). With the difference of both positions the relevant angular speed depending on the driving speed was calculated. The following steps were applied to create cross compounds:

1. Sowing of an initial track in the middle of the field in a straight lane for reference of the subsequent tracks. The locations of deposition have to be recorded with coordinates.
2. After sowing the first track the machine turns at the headland and proceeds parallel to the first track. The cell wheels have to be justified in a way that they depose the seeds at the desired places.

Commentaire [L1]: Unklar, was ist gemeint?

3. During operation, a comparison of the real and the desired deposition for each unit is necessary. If there is any difference the cell wheel velocity is to be raised or reduced automatically.

The described concept assumes optimal terms with right angled and flat fields. In other cases tracks end acute-angled. The cell wheels must be stopped individually or the seeds which are out of the track have to be eliminated by hoeing. The fact that the first track is in the middle of the field causes four border tracks. To comply with the desired plant population density for sugar beets of about 100,000 plants per hectare the desired cross compounds were defined as 33 x 33 cm. For seeding and hoeing a tractor with a wheel track of 3 m was used carrying 8 seeding units or 10 hoeing tools.

CONSTRUCTION AND TESTING OF THE PRECISE STEERING UNIT The mechanical chain drive of the seeding unit (Kverneland/Accord Monopill S) was replaced by a toothed belt and actuated by a stepping motor resulting in a transmission ratio of 4:1. For steering function an impulse generator was employed. One motor step caused 1/400 rotation of the cell wheel and the distance between two seed deposition were 800 motor steps. An encoder was installed at the belt for determination of slip, which was compensated by a microcontroller.

Parallel to the cell wheel a second disc with a hole parallel to each cell was installed. A light-barrier detected each seed release to determine each seed position indirectly.

If high accuracy of position is requested, a sensor system containing DGPS assisted by other sensors is necessary. A RTK-DGPS on the seeding machine with a reference station next to the field on a well known geodetic position and an additional optical space sensor was used. The measured values were integrated in a Kalman filter (Kuhlmann et al., 2007) to calculate the precise coordinates in real-time.

METHODS OF INDOOR EXPERIMENTS The precision of seed placement originated from the seed space drill was measured by a light barrier recording the time between dropping of single pills. Taking the speed of the cell wheel into account the spacing can be calculated. The spacing error was determined using the coefficient variance (CV).

The tests for evaluation of the roll effect were performed in a soil bin with soil water content 13% and regular seed bed preparation. The position of the pills after leaving the cell wheel was recorded by a high speed camera and the distance between the first contact with the soil and the final position was measured using the sequence of photos.

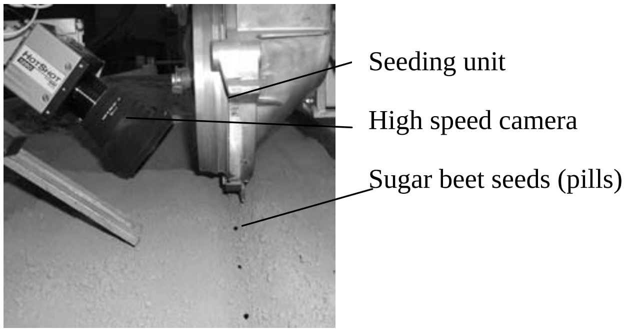

Figure 1. Experimental arrangement with high speed camera for recording the rolling effect

METHOD OF FIELD EXPERIMENTS Field experiments were conducted on an experimental farm in Wesseling near to Cologne/Germany in 2008 and 2009 (s. Fig. 2). The field experiments were aimed at evaluating the weeding efficiency of different methods. 5 different treatments (herbicide, hand hoeing, hoeing longitudinal and transverse, longitudinal hoeing and control) were applied.

Herbicide applications (3 times) started at early stage of plants. Weed hoeing was carried out in May and June. The control plots without treatment were located in the same field to compare them with the other four variants. Weed growth, plant population density and plant societies were observed.

Figure 2. View on longitudinal (left) and transverse (right) rows, sugar beets in four leaves stage (BBCH 12).

RESULTS

Variation of seed spacing

Seed space drills place seeds by singling and spacing. The variation of the spacing is the outstanding criteria to evaluate this seeding equipment. As statistical parameter t~~T~~he coefficient of variation (CV) wa~~i~~s used ~~as statistical parameter~~ (Heier, 1999 ~~Kromer~~). The coefficient of variation was determined for different theoretical speeds between 0.5 and 4.5 m s^{-1}. The highest ~~best~~ quality (lowest CV) was obtained for ~~by~~ a speed of 1.5 m s^{-1} (Fig. 3). According to trials, the reason~~s~~ is ~~for this are~~, that the filling process of the cells is less reliable ~~by~~on low~~er~~ operation speed/ ~~and~~cell wheel rotation because ~~. There are too~~

~~much~~ double fillings occur. On~~By~~ higher speeds~~s~~ the CV increases~~higher~~ because the variation of the pill trajectories are extended.

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The advancement of th~~main question, how big is the benefit~~ e developed drive~~traction~~ system was that it created no double depositions, no missing depositions and about 95 % of all depositions vary less than 1 cm. The accuracy of deposition of the new system was ~~...~~ 97,5% (relative number of pills +/- 1.5 cm- around the target position) in comparison to the old one with ~~…~~ 91,1% (Thelen, 1992).

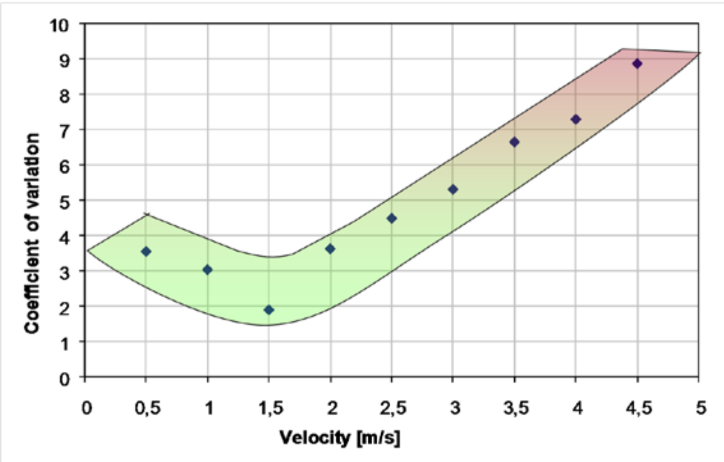

Figure 3. Influence of driving velocity o~~f~~n seed deposition with new steering unit.

Rolling-Effect

Spacing of seeds in soil additionally is affected by the trajectory of the pill after being released from the cell and by rolling when hits the soil surface at the bottom of the seed furrow. The deviation in spacing for both effects are dependent of the conformity of the cell wheel speed and forward speed of the drill. In case these two speeds are fully in accordance there is no horizontal speed left for the pill dropping on the soil surface (zero deposition).Even though the condition for zero deposition is adjusted by choosing the accurate speeds the seed pills roll when touching the soil surface depending on roughness of the soil surface. Figure 4 represents the frequency of the rolling distances in classes of 0, 0.5 and 1 cm. 35% of the pills did not move and the maximum rolling distance was 1 cm. Deviation caused by rolling of the pills is an indicator for intra row precision and is crucial for the transverse hoe operation.

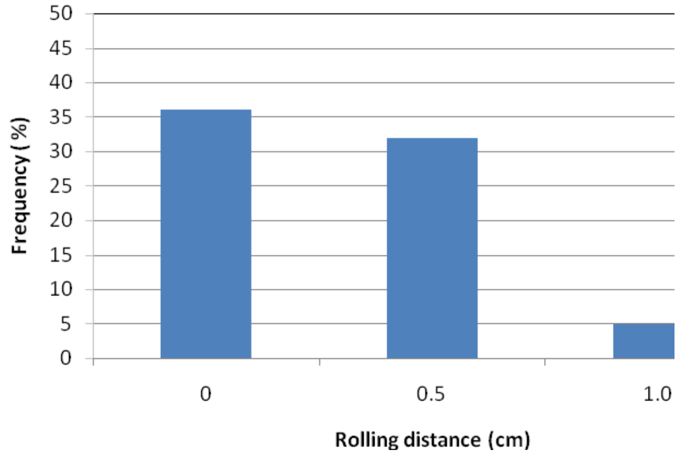

Figure 4. Frequency of rolling distances

By cross hoeing the treated area is expanded but still limited by the near to plant area which is needed to avoid plant and root damages. The deviation of plants in the row is another item to evaluate whether the cropping system is applicable to mechanical hoeing. Figure 5 outlines the lateral deviation of the beet plants from an ideal seeding line for both directions (longitudinal and transverse). The highest frequency (42%) occurred for the precisely deposited seeds (zero deviation). This is true for both cases, the longitudinal and the transverse rows and the distribution is normal for both rows. With the transverse rows however the maximal deviation was greater (4 cm). It can be stated that the conditions for cross hoeing were not worse than for longitudinal hoeing as far as the row geometry is concerned

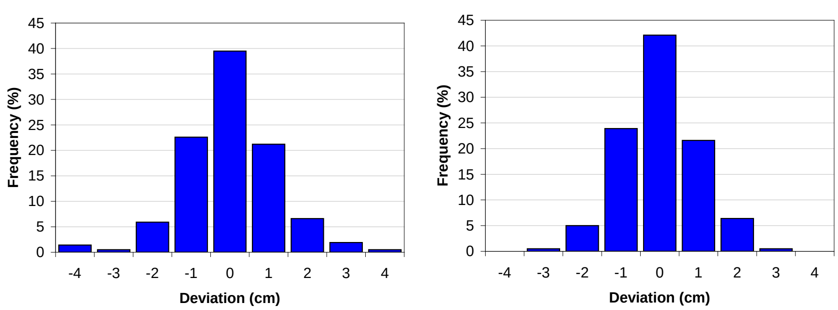

Figure 5. Deviation of plant positions in transverse (left) and longitudinal (right) rows.

Weed-control-effectiveness

The population of weeds in the test plots recorded in 2008 and 2009 are presented in Figure 6. As compared to the control plot on average 62% of the weeds were eliminated by longitudinal hoeing as conventionally done. There was an average improvement through cross hoeing taking the percentage of weeds eliminated to 80 %. Still applying herbicides was the most effective method to control weeds, eliminating 94% of the weed plants (Kam et al., 2009). From the results obtained from the control plot it can be seen that the weed population grows during spring time. Therefore hoeing needs to destroy not only the weed plants which survived the previous application but the newly germinated weeds as well. In 2009 the final situation after the third cross hoeing was as successful as hand hoeing and there were 8.3% weeds left in the cross hoed plots while in the plots treated with longitudinal hoeing 35.4% survived. Even hoeing the plots by hand left weeds; these weeds were close to the beets plants.

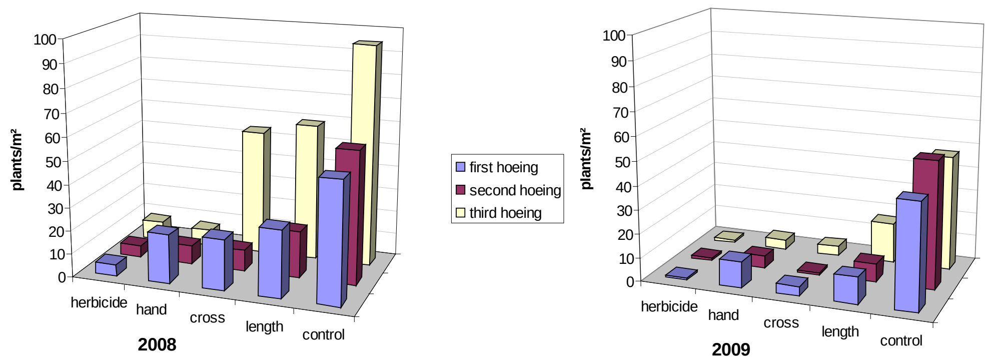

Figure 6. Weed population in test plots of 3 x 3 m with different treatments 2008/2009

CONCLUSION To extend the area of mechanical treatment cropping systems supporting the operation of hoeing machines were established. On an experimental farm seed placements were arranged to allow machine hoeing inter and intra row. By adjusting the seed spacing drill to place the seeds in neighbouring rows and in succession passes rectangular, transverse rows were generated. The developed steering and drive~~traction~~ system was tested with standardized methods under laboratory conditions. As essential~~outstanding~~ criteria for evaluation of ~~i~~the precision of deposition was chosen. The results showed, that without modifications the accuracy could be raised from about 91% to 97.5%. The best results could~~an~~ be obtained~~reached~~ for~~with~~ a sowing speed of 1.5 ms^{-1}. Up to 0.5 cm accrues from rolling effect~~s~~ under condition of zero-deposition. To comply with an adequate plant population for sugar beets a seed placement of 33 by 33 cm was chosen. This distance is coincidentally an acceptable clearance between the plants for machine traffic. By longitudinal hoeing as conventionally done, 62% of the weeds were eliminated. There is an improvement by cross hoeing which eliminated 78% of the weed plants. Still the most effective weed control is by applying herbicides eliminating 94% of the weed plants.

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