Roeb, Johannes and Bernhardt, Heinz

Application techniques to control remaining weeds in sugar beets

Even in modern sugar beet production systems the control of remaining weeds may cause problems. One important reason is the so called spray shadow. To estimate the potential performance of different application techniques, the spray distribution quality of four sprayers was investigated under field conditions. Image analysis was used for evaluation. Results show broadcast spraying is not suitable for herbicide treatments in sugar beets at advanced crop development. Purpose-built underleaf sprayers or droplegs deliver good results to a later date as well.

Keywords
Sugar beets, remaining weeds, weed control, distribution quality, application systems, application technique, double flat fan nozzles, underleaf application, dropleg

Abstract
Roeb, Johannes and Bernhardt, Heinz

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Remaining weeds in sugar beets have a remarkable damage potential: Main aspects are the reduction of yield, problems during harvesting and sugar beet processing as well as the enrichment of the soil seed bank [1]. Successful sugar beet cultivation requires an almost total weed control. In most cases three to four post-emergence herbicide applications are required to ensure a weed-free crop until the end of the season. Particularly in years with low precipitation and on fields with low sugar beet stand densities or appearing problem weeds this approach is not sufficient so other measures have to be used in addition. Herbicide treatments after the 6-leaf-stage of the sugar beets decrease in effectiveness due to the spray shadow of the crop [2; 3].

Application techniques against remaining weeds

Plant protection technology can contribute to an increasing performance of late timed herbicide treatments by reducing spray shadows. Double flat fan nozzles with two spray patterns inclined in forward and backward direction improve the spray distribution on the target area [4]. For herbicide applications in sugar beets this area can be equated with the soil surface. A range of underleaf-sprayers are purpose-built for late weed control measures in sugar beets and thus established for many years. Most of these devices consist of multiple spray units attached to a harrow frame [3; 5]. An alternative technique to carry out underleaf applications is provided with the so-called dropleg. These flexible spray arms are attached to the sprayer boom. The technique has not been used in sugar beets so far but delivers good results for weed control in maize and fungicidal or insecticidal measures in vegetables [6; 7].

Measurement techniques under field conditions

Until now research on spray distribution quality of herbicides in sugar beets has not been published [2]. Main reasons are high efforts and costs of photo- or fluorimetric analysis methods once the measurement area reaches a certain size. Moreover the probability of measurement errors increases with the resolution due to the reduced area and hence volume of each sample [8]. For examinations of large-scaled target areas members of the Swedish University of Agriculture (SLU) developed an image analysis technique based on the application of nigrosin-dyed spray water on a target material made of preglued wallpaper. Evaluation can be done with software [9]. So far this method has only been used to analyze the general spray distribution quality of different field sprayers and not for measurements within crops. Comparing different application techniques only the relative spray coverage can be used for evaluation. Spray distribution quality is an appropriate indicator for the expectable biological effectiveness of a treatment [8; 10].

Objective targets

Two objectives are pursued in this study. Before the beginning of the field experiments it was determined, whether the attached measurement procedure is suitable for testing under field conditions. Immediate objective of the following work was to compare the application quality of four different application techniques to control remaining weeds in a highly developed sugar beet crop.

Material and methods

Thus in the period of 29.05.12 to 07.07.12 four application rows were performed at the research estate Roggenstein of the Technical University of Munich. Previous sowing was done with a row space of 50 cm and an in-row seed distance of 22 cm. The chosen variety was “Sabrina KWS”. At high field emergence the leaf coverage degree increased from about 20 to over 90 % during the test period.

The following application techniques were examined:

- flat fan nozzles
- double flat fan nozzles
- “Lechler droplegs”
- “Schmotzer underleaf sprayer”

The sprayer boom for broadcast spraying and the applications with the “Lechler dropleg” was attached to the front hydraulic system of a Fendt tool carrier whereas the “Schmotzer underleaf sprayer” was mid-mounted. All applications were carried out with a driving speed of 6 km/h and a water volume of 250 l/ha. The nozzles used for the broadcast spraying were IDKN 120-03 and IDKT 120-03. Boom height was 60 cm and the spray pressure was adjusted to 3.3 bar. The “Schmotzer underleaf sprayer” was built up of multiple spray units, each equipped with a pair of off-centre nozzles type IDKS 80-02 and triangular leaf lifters. The distance between nozzles and soil surface was about 20 cm. Flood nozzles type FT-2.0 448 were used with the “Lechler droplegs”. The spray pressure was set to 2.0 bar. The intended spray height of 12-16 cm was adjusted by the height of the boom.

To generate the spray patterns for image analysis the spray water was dyed with 30 g/l nigrosine. Target material of several 40 x 60 cm sized pieces of preguled wallpaper was laid out between the sugar beet rows. Before every application the leaf coverage degree of the measurement area was recorded using photography. After the spray solution was applied to the target material the spray samples were digitized with an overhead tabletop scanner and analyzed with Adobe Photoshop CS 6 Extended. Therefore the image of the crop was placed on a second layer right on top of the spray distribution image, so both showed the same area. For image analysis this measurement area was subdivided into squares of 2.5 x 2.5 cm.

The application quality was determined by two separate parameters: Relative spray coverage degree indicates which percentage of spray volume is deposited to the soil surface. It is calculated by the grey value (0–255) of all squares in the measurement area in relation to a specified standard value. Due to the variable spray character and height of the different application techniques a separate reference value was determined for each of the application systems. **Table 1** summarizes the main results of this standardization. During the analysis it was possible to make a difference between the spray pattern between the leaves and in the leaves shadows. As in other studies, the coefficient of variation was used to describe the quality of spray distribution across the measurement area.

Results and discussion

It can be confirmed that the image analysis method developed at the SLU is suitable for determining spray distribution in sugar beets and under field conditions, by the time the crop is dry. Image analysis can be done with comparatively simple software. The standardization of each application system is absolutely necessary for proper evaluation: Both the distance between the nozzle and the target and the size and velocity of the droplets affect the formation of the spray pattern [8; 10]. At same water volume the absolute spray coverage degree ranges from 40 % using double flat fan nozzles to 57 % at applications with the “Schmotzer underleaf sprayer”. The estimation of distribution quality works well with a 2.5 x 2.5 cm grid. Adjusting the calculation method to the spray character of the nozzle is useful for the examination of underleaf application techniques.

160 individual measurements were carried out during the four application rows. The results of relative spray coverage degree and coefficient of variation are shown in **Figure 1**. Where these exist, results are consistent with further studies and practical experience [3; 4; 6; 7; 11].

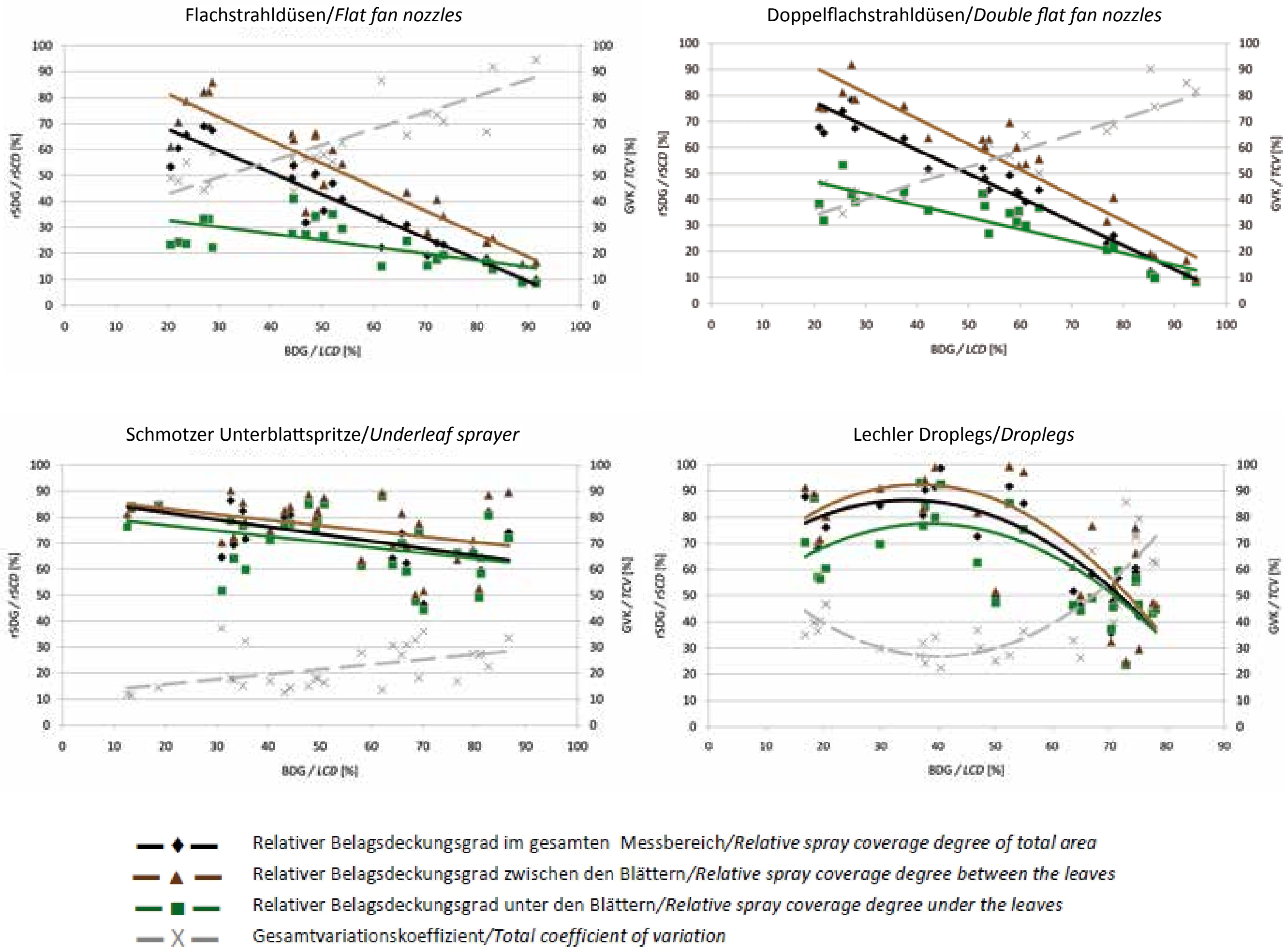
For late herbicide measures in sugar beets broadcast applications with field sprayers are - no matter which nozzles are used - not suitable. With increasing leaf coverage degree of the crop the amount of spray solution reaching the target area is reduced at the same degree [11]. The effect of spray shadows on

Table 1

Standardization of application techniques

Applikationsverfahren *Application technique*	**Belagsdeckungsgrad** *Spray coverage degree* [%]	**Variationskoeffizient** *Coefficient of variation* [%]		
		gesamt *total*	**quer** *transversal*	**längs** *longitudinal*
Flachstrahldüsen/*Flat fan nozzles*	48.02	8.78	2.18	5.05
Doppelflachstrahldüsen/*Double flat fan nozzles*	39.95	9.80	1.89	7.35
Schmotzer Unterblattspritze/*Underleaf sprayer*	56.96	28.93	27.43	5.50
Lechler Droplegs/*Droplegs*	48.10	36.29	34.64	6.30

Fig. 1



Relative spray coverage degree (rSCD) in three different areas and coefficient of variation (TCV) of the analyzed application techniques as a function of leaf coverage degree (LCD) of the sugar beets

the spray distribution of flat fan nozzles can be easily observed in **Figure 2**, which is also showing the two different pictures necessary for image analysis. With flat fan nozzles even at a leaf coverage degree of only 20 % less than 30 % of spray volume is attached to the underleaf area whereas at first non-covered parts of the target area are receiving a sufficient amount. The patchy spray distribution results in a coefficient of variation of 40 % at the beginning and up to 80 % when crops meet across the rows. A common used border for a non-limited biological effectiveness is 15 %. If the coefficient of variation is much higher than this value raised herbicide doses can no longer compensate the loss of application quality [12; 13].

Changing from normal flat fan to IDKT double flat fan nozzles can reduce the coefficient of variation by 30 %. Nevertheless the total spray coverage degree remains nearly unaffected. The two fan patterns in forward and backward orientation contribute to a reduction of spray shadows in driving direction. However this advantage is too low to achieve a sufficient application quality at the latest by begin of crop closing.

Purpose-built underleaf sprayers ensure a sufficient spray coverage degree in highly developed sugar beet crops. Even at complete crop cover more than 60 % of application volume reaches the target area. Differences between spray patterns under the leaves and between rows can rarely be identified and spray shadows are clearly reduced. Taking into account the possibility to improve lateral distribution by changing or adjusting the nozzles the coefficient of variation is permanently below 40 %. Therefore the "Schmotzer underleaf sprayer" is the only of the analyzed application techniques with a sufficient application quality independent of leaf coverage degree. The low spray attachment on the leaves of sugar beets and particularly on the susceptible heart could possibly allow the use of herbicides which are poorly tolerated by the crop.

Depending on some conditions the "Lechler droplegs" can provide high application qualities as well. These preconditions are a preferably upright leaf orientation and a leaf coverage degree below 60 %. At these terms about 80 % of the spray volume is attached to the target area and coefficient of variation re-

Fig. 2

Example for leaf coverage degree and spray distribution of an application with flat-fan nozzles

mains below 40 %. As with other underleaf sprayers the choice of nozzles is very important. Wide-angled band nozzles aligned to the soil surface by suitable swivels could be superior to the flood nozzles used here. Spray shadows only occur when the sugar beet leaves are standing low above the ground. This refers to early as well as late stages of sugar beet development. When leaf coverage degrees is above 60 % the distribution quality is disturbed by the movement of droplegs in the inter-row space: Spray arms are swinging across and with increasing leaf density also back and forth. This effect often is connected to the sticking of the droplegs at the leaves of the sugar beets. Whether it is possible to maintain a spray height of 16–20 cm at high boom widths was not part of this study.

Conclusions

The measurement technique developed at the Swedish University of Agriculture is suitable for the use in a developed but dry sugar beet crop. Calculating the relative spray coverage degree is a simple method to rate and compare different application techniques. Broadcast spraying is inappropriate for weed control measures in highly developed sugar beets. Double flat fan nozzles can contribute to an even spray distribution but only slightly influence the application quality in a developed crop stand. Purpose-built underleaf sprayers can be used at all development stages of sugar beets without an obvious loss of weed control potential. Applications with the “Lechler Dropleg” show about the same result, as long as sugar beet leaves are upright and rows are not completely closed.

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Authors

Johannes Roeb is Bachelor of Agricultural and Horticultural Sciences, **Prof. Dr. Heinz Bernhardt** is head of the Chair of Agricultural Systems Engineering at the Center of Life and Food Science Weihenstephan of Technical University of Munich, Am Staudengarten 2, 85354 Freising, e-mail: heinz.bernhardt@wzw.tum.de

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