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Photo optical sensors

An alternative method for weed mapping

Spatial differences in weed populations within a field make it possible through site specific spraying to reduce the amount of herbicide used by up to 70% [1]. With current herbicide costs this means a saving of around 80 DM/ha. However, in such cases, spray material can only be reduced by an amount that will still allow the working together of spray and the crop's own depression of weed populations to achieve suppression to a large extent of seed production from the remaining weeds. The achievable cost-saving effect depends, above all, on the efficiency of weed counting and mapping. The development of cost-efficient weed recognition systems is of great importance for the economic viability of site-specific spraying [2].

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In the development of methods towards automated recognition of weeds, two solutions are currently able to be identified. Firstly, photograph processing systems allow variety-specific classification of the pictured object according to form parameters. These can be evaluated with the help of knowledge-based methods [3]. Through the parallel application of this assessment procedure with a positioning system, maps with damage threshold related spraying decisions are able to be processed. As with every assessment procedure, here too, precision of information transference depends upon the intensity of sampling. Further development here is aimed at adoption into practical farming within the short term [4].

Secondly, photo optical detection offers a further promising system for the estimation of weed intensity. Appropriate sensors under the product names "Selectspray" and "Weedseeker" have already been in action as equipment involved in targeted weed control on harvested fields, railway property and public areas [5, 6]. Through reflection spectrometry these can identify active plants from their background through evaluation of two wavelengths (red and near infrared). Extensive investigations with multispectral imaging photometers indicate that with this measurement principle it is also possible to classify plants according to type [7].

Application requirements for spectrometry

For the development of cost-efficient weed identification systems it is of interest if, from simple to determine parameters (such as weed populations and weed ground cover) proven plant production evaluation criteria can be deduced which can be used for differentiated herbicide applications. The potential yield loss caused by a single weed because of its type-specific competition varies from 1 to 15 kg/ha according to type of weed and site conditions [8]. Large scale assessments show that field-specific weed communities comprise mainly of four to six main weed types which make up about 80% of the total population. A further eight to ten types, appearing very sporadically on-site, complement the weed community. Spraying decisions for the site-specific differentiated use of herbicide should be made according to threshold values based on yield loss calculations. The setting of thresholds is oriented on costs – conditions of use and aspects of weed reproduction dynamics. In trials, two application concepts have been tried up until now. In the case of assessed higher densities, which would mean fewer omissions in an overall spatial weed distribution, no spray would be applied under a certain threshold, and the full application amount above the threshold.

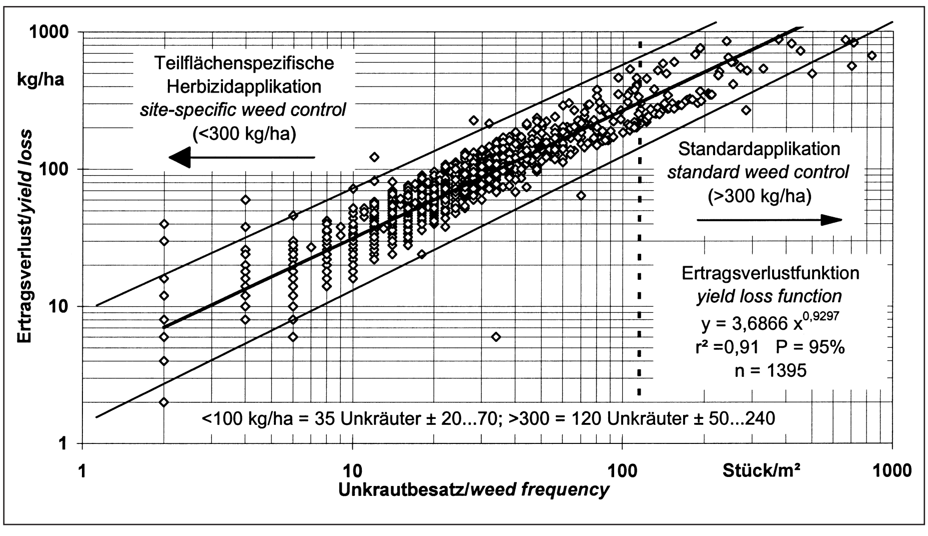

Fig. 1: Association of yield loss and weed population in winter wheat

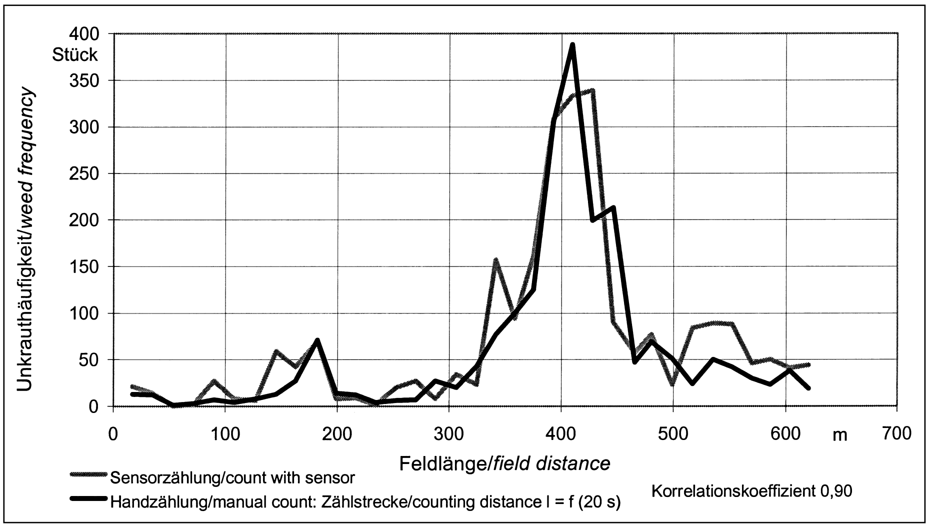

Fig. 2: Comparison of weed infestation results between manual and sensor counts in maize

Such a system can, for instance, be used in wheat where crop plant population is over 600 stems/m^2. Below the damage threshold, with larger assessment screens which offer a less precise picture of weed density, and with crop stands with limited plant population counts, half the recommended dose should always be sprayed for controlling the residual weeds [2].

Recognisable through the dominance of a few weed types – despite considerable small-area differences – is an exploitable association between the weed frequency and yield loss. From weed counts carried out over several years as decision aids for site-specific spraying a correlative association between weed frequency and yield loss can be proved (*Fig. 1*).

This association can be utilised for more detailed evaluation of, for example, frequency distribution as detected with photo optical sensors. Should the calculated function for the setting of damage thresholds be brought into the calculation, a standard deviation of yield loss estimation error of ± 57% is the be expected. From an economic point of view this means that for a damage threshold of 50 weeds/m^2 there's a decision error range of ± 15 to 20 DM/ha. The size of the error appears high. However, this can be relevated in comparison to the alternative spot-sample mapping. Because of the small-area variability of weed distribution, there occurs here considerable errors in the transference of exactly calculated assessment results onto adequately sized field areas based on the working width of field sprayers. If only five spot samples/ha are taken instead of around 25 counts/ha one has to reckon on a relative rise in the decisions errors of 25% [9]. Only tendencial decisions should, therefore, be drawn from weed estimations based on spot sampling, which can then lead to classification as strong, medium or low weed infestation field areas.

Weed countswith a photo optical sensor

For the application of sensors in grain crops, two weed scenarios are relevant in terms of spraying. Here the dominant weeds at the time of autumn spraying are small plants from cotyledon appearance through to the first real leaf stage. Up to the application period in spring an increasing differentiation within the weed community develops through new emerging individuals. Alongside plants at cotyledon stage dominate types with more advanced development which can be identified by the existence of several foliage rosettes or shoot axis branching. Evidence as to the types of weeds present at this stage of development can be deduced possibly also from the distribution of weed plant sizes. Accordingly, the weed sensor should make possible the recording of individual weeds and a classification according to size. The projection area of grass weeds (monocotyledon) which has to be detected begins, because of the upright standing cotyledon, at around 1 mm^2, dicotyledon weeds reach around 1 to 2 cm^2 on average.

The measurement principle of "green sensors" depends on the plant's own phenomenon of selective absorption of red (R) and high reflection near infra red (NIR) parts of the sunlight spectrum. Stable correlative associations between plant stands and spectral parameters are given especially through the development of a reflection minimum between 630 and 700 nm and the refection maximum above from 780 to 1200 nm [10]. In the primary development stages of plants, there are good proven correlations as to leaf surfaces on hand and (in near estimations) as to the biomass. The quota development for red reflection and NIR returned reflection gives a vegetation index (NDVI) which records the maximum spread of the reflection signals between plant and background [11].

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

Values given in literature for the ground tend between 1.3 to 1.5 and for plants between 6 to 11 [1,10].

Practical trials

In agricultural crops there is the possibility of using reflection spectrometry with the help of visual area sensors in inter-row spacing or on tracks running through the growing crop but without themselves having crop growing on them. Cereal stands with conventional inter-row spacing of between 12 to 18 cm are not suitable for weed density detection. This is because of the crop plant cover of the weeds and the, to be expected, imprecise directing of the sensor. Possible uses of photo sensors within such crops exist on the tram line areas which are there to facilitate fertilising and crop care, when the tram line tracks average a minimum 24 to 36 cm in width.

For the identification of weeds at cotyledon stage in cereal crops or maize, eight pairs of photo diodes were used. These continually detected the weed density at right angles to driving direction over a strip of 22 mm. In each case two diodes covered the same focal point in the wave length areas 650 nm and 830 nm. The quota was developed from the variation between both diodes. When this moved over a predetermined threshold, the signal was taken as green. At maximum spraying speed, for instance, a 5 mm high plant appeared for 1 ms before the lens of the sensor. For accurate determination of the size of smaller plants a scanning rate of 10000 scans per second is required. The identification of small plants of sizes in the region of millimetres is made even more difficult by the oscillation of the moving machine. The measurement recording and processing took place using universal measurement equipment.

Correlation coefficients between sensor appraisal and hand weed appraisal ranging from 0.6 to 0.9 (*Fig. 2*) resulted from different investigations for detecting the weed intensity in winter and summer cereals as well as maize.

From the results available so far it, may be deducted that, especially for identity precision under changing soil and surrounding conditions, further basic work is required for the matching of the signal interpretation in association with the plant form as well as the signal evaluation.