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A method of spread pattern control in granular broadcast spreaders

Even distribution on the field is of decisive importance for the spreading of mineral fertilizers. For spread pattern control (for which collection trays have been used so far), work quality during mineral fertilizing could be checked continuously and without time shift using the aid of digital image processing, and a control signal could be given if deviations occur. The results of studies on the influence of fertilizer granule properties and environmental conditions on the detection rate are presented.

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Keywords

Granular broadcast spreader, spread pattern, digital image processing, closed-loop control

Literature

Literature references can be called up under LT03108 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

The most recent developments of fertilizer spreader manufacturers allow the currently spread fertilizer quantity to be checked precisely using weighing- and flow-metering systems [1]. However, the driver does not receive any information about the achieved distribution accuracy or at least whether or not the chosen working width is being met even though influencing factors such as the weather, soil conditions, or fluctuating fertilizer properties can significantly influence the spread pattern of granular broadcast spreaders in particular. For spread pattern recording, the only method available for test stations and farmers is the collection tray system with subsequent re-weighing, which results in significant labour requirements. During field use, this system does not enable the driver to react immediately to deviations due to the time shift [2]. Therefore, studies are being carried out to examine whether a new, automated test- and evaluation technique can be developed based on digital image analysis. In addition to the function of retrospective work control, such a system may also be used for the development of a closed-loop control system, which enables mineral fertilizers to be spread with high accuracy.

Methodological Approach

With the aid of digital image processing, pictures of a field surface can be analyzed, and objects lying on the surface, such as mineral fertilizer granules, can be distinguished using specific differentiation characteristics, such as granule colour as well as the size and the object form of soil particles and plant parts. Reliable identification and, hence, the detection rate, is influenced by environmental conditions, such as soil properties, light conditions, and plant cover. In order to be able to estimate the achievable accuracy of such a system and to develop a suitable recording technique, trials were carried out under laboratory conditions and on the field during which the parameters „granule properties" and „environmental conditions" were varied.

Material and Method

The pictures were taken by a digital camera positioned vertically above the soil surface at a height of 0.5 m. Resolution was 4 million pixels, and the pictures were evaluated using the image processing program OPTIMAS. 30 granules of each different kind of fertilizer were spread within the viewfinder field of the camera (660 cm^2). This corresponds to a fertilizer application of approximately 400 kg/ha, which roughly matches practical conditions. The examined kinds of fertilizer were widely used standard fertilizers, which differed in colour and shape: in addition to calcium ammonium nitrate (CAN), the universal nitrogen-phosphorus-potassium (NPP) fertilizer „Blaukorn", which is a different

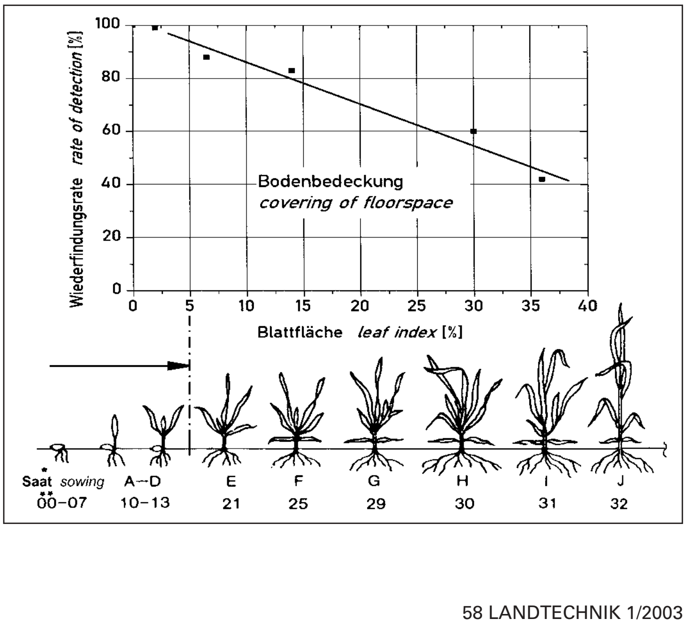

Fig. 1: Dependence of the detection rate upon the degree of soil coverage and relation to the BBCH plant growth stages

colour, along with CAN specially coloured for trial purposes and a potassium-sulphate fertilizer characterized by its edged granule shape were employed. In preliminary trials, the influence of different light sources (daylight, different artificial light sources at 3,200 K to 5,600 K) was established, and a recording mode with a flashlight directed to the front (guide number 40, automatic exposure, colour temperature 5,600 K) was determined. In addition to images on uncovered, friable soil (mean aggregate size 10 mm), pictures were taken while varying the factors „soil water content“ (1 and 15 weight-%), „clod percentage“ (mean size 50 mm), „plant cover“ (barley and wheat at the 1-, 3 leaf stage as well as stocking), and „mulch cover“ (chopped straw, degree of coverage: 60%).

Results

Under soil conditions equivalent to those on freshly cultivated summer grain fields after seeding, all fertilizer granules were able to be detected by the image processing system. Thus, a detection rate of 100% was reached. This result was achieved at low and high soil water content, which led to a darker colour of the soil surface. Under extreme, cloddy soil conditions, which do not occur in practice in such a pronounced form, observations showed that up to 50% of the granules spread were covered and could no longer be detected even by the human eye. Of the still visible granules, the image processing system was able to detect between 58 and 100%. The coloured fertilizers provided particularly high detection rates. Similar results were also reached in the trials with a mulch cover. Here, only about two thirds of the granules spread could still be detected by the human eye and were not covered by straw. The still visible, coloured fertilizer granules were completely detected by the image processing system. The granules without colour marking, however, could not be detected at all.

On covered soil, a growing number of granules was also covered by plant parts depending on the growth stage, which made evaluation more difficult. Nevertheless, a large number of the fertilizer granules spread was able to be detected: in both cereal species at the one-leaf stage, all granules were able to be discerned by the eye. They were also completely detected by the image processing system. At the three-leaf stage, only about 90% of the granules were still visible. However, 100% of these granules were able to be detected independent of their colour and shape. At the stocking stage, only approximately two thirds of the granules were visible to the human eye. Of these, between 45 and 100% were detected by the image processing system depending on the colour and the kind of fertilizer. Once again, the coloured granules were detected completely.

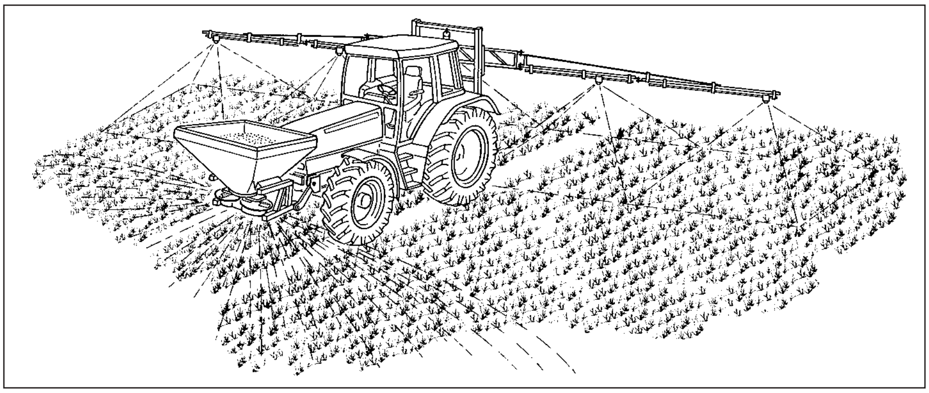

Fig. 2: Proposal for a closed-loop control spreading system

Evaluation

The choice of a suitable colour threshold value alone allows the fertilizer granules to be identified. The additional consideration of the potential distinction characteristics „size“ and „shape“ did not provide a higher detection rate. Like for visibility to the human eye, the decisive criterion for identifiability is that a fertilizer granule is at least partially optically visible and not completely covered. On freshly seeded soils, the image processing system is able to identify all fertilizer granules completely. Only when the granules are covered more and more mainly by growing vegetation does the error rate increase. Then, the greatest possible colour contrast between the fertilizer granules and the soil is decisive for detection. Given these considerations, it proves advantageous that for marketing reasons the fertilizer industry is increasingly putting more colour-marked fertilizers on the market in addition to traditionally coloured standard fertilizers, such as „Blaukorn“ [3]. If colour-neutral fertilizers are used, the most intensive contrast possible must be striven for during recording. In addition to the factor „colour“, other picture recording techniques which increase the contrast are conceivable. Initial orienting experiments with UV-light (which allows a simple photographic distinction between fertilizer granules and soil particles to be made due to the special properties of the fluorescence-active filling materials contained in industrial fertilizers, such as lime marl) and with a thermography camera, which uses the virtually ever present temperature difference between the soil and the fertilizer granules, have already provided a promising approach. If the granules are entirely covered due to extreme clod formation, for example, no identification is possible. In this case, the use of a stereo recording system may have to be considered.

Conclusions

The results have shown that in principle an image processing system enables spread fertilizer granules to be detected automatically and their number to be used as a controlled variable. With growing coverage in particular by growing vegetation, the accuracy of the system decreases. The detection rate can be shown as a function of the degree of soil coverage, and the covering leaf area can be correlated with the BBCH scale of the developmental stages of cereal plants (*fig. 1*).

Based on a required detection rate of 95%, for example, the system can be employed up to a soil coverage by leaf mass of about 5% (stage BBCH 17).

Future Prospects

In addition to experimental use, the development of a self-regulating system for general practical application should be possible. In such a system, a front-mounted fertilizer spreader would be combined with a camera system mounted at the rear end of the tractor, for example, which checks the spreading results with a slight time shift (*fig. 2*).

Multiple camera modules mounted to a linkage of bars can record the entire spreading width. Image processing not only allows the number of fertilizer granules spread to be determined, but it also shows the exact position of each granule in the form of x/y-coordinates. Class formation thus enables a spread pattern to be generated using a simple calculation step, which immediately allows the work result to be evaluated. The indication of a deviation from the set value would thus make information about the achieved spreading quality available to the driver, and the machine setting could be corrected automatically using a control system.