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Pendulum meter in practical operation

With the aid of a mechanical sensor in the form of a physical pendulum, the grown plant mass in culmiferous plant cultures can be determined indirectly by means of measuring technology. Through the combination of the sensor with a centrifugal fertilizer spreader and a plant-protection sprayer, technical solutions working in real time were created which resulted in a reduction of 13.5% of the nitrogen fertilizer and 18.7% of the fungicides used under practical conditions.

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The studies were financially supported by the Federal Ministry of Education and Research (BMBF).
Thanks are also due to the numerous farms for their cooperation in the realization of the trials.

Keywords

Site specific farming, pendulum-meter, nitrogen fertilising, fungicide application

Literature

Literature references can be called up under LT 03124 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Knowledge about site-specific plant growth is a basic prerequisite for the assessment of the heterogeneity of areas used for agriculture as well as site-specific crop management.

At the Institute of Agricultural Engineering Bornim, a sensor for the indirect measurement of the plant mass in standing culmiferous plant cultures was developed. This sensor is a vehicle-based physical pendulum which is moved through the crops in the regular tramlines [1]. The practical field use of the pendulum sensor showed that carrier vehicle inclination, use on hilly terrain, and the depth of the regular tramlines distorted the measurement result.

In another stage of development, the design has been altered since 2001 in order to compensate for the distorting influencing variables. *Table 1* contains the most important technical data. The vegetation season 2002 was used intensively to gain secured knowledge about the function and operability of the improved pendulum meter under practical conditions.

Trial programme

The trials carried out focused on the following points:

- Evaluation of the functional reliability of the pendulum meter for plant mass mapping at different locations and in different crops
- Real-time application and assessment of the pendulum meter for the application of nitrogen fertilizer by a centrifugal fertilizer spreader
- Application and evaluation of the pendulum meter for fungicide application by a plant-protection sprayer

Plant mass mapping

For functional tests, a high-clearance implement carrier from Hege was used. Due to its low service mass of ~ 1,000 kg and its ground clearance of 800 mm, it allowed grain fields to be driven over in the regular tramlines and was able to pass grassland areas at all vegetation stages in a soil-protecting manner. A specially developed adapter enabled the sensor developed for front-mounting to be installed at the implement carrier. In order to test the suitability of the pendulum meter under the specific conditions of different locations, high mobility was guaranteed by using a special car trailer. Thus, it was possible to map plant-mass distribution in winter barley, winter rye, triticale, winter wheat and meadow grass on approximately 1,000 ha from Mecklenburg to Saxony in the year 2002. During these test rides, no significant technical problems were encountered. Only during the measurement of inclination did malfunctions occur, which were eliminated by replacing the inclination sensor.

Basic concept	Three-point front-mounting on tractors
Total mass	ca. 40 kg
Working width	1000 mm
Operating voltage	12 V
Wattage	max. ca. 200 W
Inclination compensation	Inclination sensor
Track depth compensation	Feeler and linear drive

Table 1: Technological parameters of the pendulum-meter

The statistical evaluation of the measured pendulum angle showed very different plant mass distributions. Under the growth conditions of the year 2002, a right-slanted distribution form was predominant. Thus, the percentage of areas where plant growth was significantly reduced was relatively small due to the ample precipitation during the growth phase.

Nitrogen fertilizing

It is known from the literature that healthy crops exhibit a close correlation between nitrogen demand and the plant mass to be developed during shooting and grain filling [2]. Thus, the possibility of using the proven close correlation between the pendulum angle and the plant mass as a basis for the demand-oriented nitrogen fertilizing of heterogeneous crops arises [3].

Technically, this approach is realized by using the pendulum angle to integrate measurable growth differences into a control signal and an algorithm for fertilizer metering during the second and/or third N-applicati-

on. The technology used for this purpose consisted of the pendulum meter, the tractor with the centrifugal fertilizer spreader, and the job computer on the basis of LBS (*fig. 1*).

After initial results of nitrogen fertilizing with the pendulum meter were reported on in LANDTECHNIK 2/2001, all trials regarding site-specific nitrogen fertilizing meanwhile comprise an experimental area of more than 500 ha. The experiments were mainly carried out as strip trials with several repetitions. In order to keep the labour requirements for the realization and evaluation of the experiments within limits, supplemental production experiments in the form of sensor-based nitrogen spreading were carried out on the entire field. In this form of experiment, nitrogen savings resulted from the difference between this technique and the farm's usual uniform application on the entire field. In the strip trials and production experiments, nitrogen fertilizer savings of 13.5 % as compared with uniform fertilizing were able to be achieved when considering the average of the locations, fields and years (*table 2*). A trend based on the currently available results shows that these resources were saved while at the same time the yield level increased slightly. Despite the nitrogen savings, a clear tendency towards a reduction in grain quality could not be discerned.

Fig. 1: Tool carrier with pendulum-meter for plant mass mapping

Fungicide application

Currently, there are no practically applicable process solutions which would allow plant diseases on the field to be clearly detected by sensors during the ride in the regular tramlines. For this reason, the parameter „occurrence of diseases" is not available as a decision criterion for demand-oriented fungicide application.

An important initial step towards more demand-oriented fungicide application is the differentiation of the application rate in heterogeneous grain stands according to the actual plant surface. The leaf area index, which defines the ratio of the plant surface to the standing area, is a measure for the quantitative description of the site-specific plant surface. This index can be determined punctually with the aid of optical hand measuring instruments, such as SunScan® [4] and LAI2000® [5].

The goal of demand-oriented fungicide application is the deposition of an approximately identical concentration of the fungicidal substance per unit of plant surface. Therefore, less growthy crops require less plant spray than growthy ones. Under these conditions, one does not have to expect negative effects, such as higher disease infestation and yield losses. The positive correlation between the pendulum angle and the leaf area index proven in previous studies [6] provides the basis which allows the index to be estimated in the crops with high information density. Thus, the plant surface to be wetted and, hence, the resulting spray rate can be determined.

This application strategy was technically implemented by combining the pendulum meter with a field sprayer. In order to guarantee a favourable droplet spectrum, the field sprayer was equipped with twin-fluid nozzles in the years 2000 and 2001 and with the VarioSelect system in the year 2002. A specially configurated job computer on an LBS basis was used in order to allow for site-specific fungicide application in real time.

The method of sensor-based fungicide application has been tested in practice for three years. For the evaluation of the effect of variable fungicide application, one tramline was treated uniformly with the application rate common on the farm in strip experiments on selected grain fields depending on the working width of the field sprayer, while application in the neighbouring tramline was carried out based on the measurement values of the pendulum meter. For the determination of the effects of variable fungicide application on the grain yields, combines with yield mapping equipment were used.

Table 3 shows the results of sensor-based fungicide application classified according to grain cultures and trial years. The fungicide savings achieved on the individual fields are dependent upon both crop heterogeneity and the application parameters determined by the farmer. During the experiments carried out thus far, fungicides were applied at differentiated rates on a total of approximately 150 ha using the aid of the pendulum meter. On average, fungicide savings reached about 20 %.

Grain threshing (combine with a yield mapping system and disease surveys at the milk ripeness stage, BBCH 75) in both variants neither showed lower yields nor heavier disease infestation caused by the sensor-based technique.

Crop/Year/Field	Area (ha)	Development stage (BBCH)	Fertilizer mass (kg/ha)	Savings (%)
Winter wheat/2000/1[1)]	50	55 - 59	7 - 68	9,6
Winter wheat/2001/1[1)]	30	55 - 59	7 - 68	11,7
Winter wheat/2001/2[1)]	60	55 - 59	7 - 65	23,1
Winter wheat/2002/1[2)]	40	35 - 55	60 - 160	8,3
Winter wheat/2002/2[2)]	52	35 - 55	60 - 160	17,1
Winter wheat/2002/3[2)]	82	35 - 55	60 - 160	11,7
Total	314			13,5

1) only 3rd N-application 2) 2nd and 3rd N-application in real time

Table 2: Application rates and savings in site-specific nitrogen fertilising

Crop/Year/Field	Area (ha)	Development stage (BBCH)	Application rate (l ha^{-1})	Savings (%)
Winter wheat/2000/1	44	47 - 51	100 -250[2)]	16,1
Winter wheat/2000/2	5	47 - 51	119 - 250[2)]	12,8
Winter wheat/2000/3	5	47 - 51	175 - 300[1)]	7,0
Summer barley/2000/1	6	61 - 65	104 - 300[2)]	27,4
Winter wheat/2001/1	21	55 -59	120 - 300[3)]	25,0
Summer barley/2002/1	19	69 - 71	40 - 200[1)]	37,5
Winter wheat/2002/1	44	59 - 61	55 - 200[3)]	8,5
Winter wheat/2002/2	5	59 - 61	90 - 200[3)]	15,0
Total	149			18,7

1)Juwel Top® 2)Opus Top® 3)Caramba®

Table 3: Conducted experiments, application rates, and savings in sensor-based fungicide application