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Influence of Fertilisation on Yield Heterogeneity and the Effect on Combine Capacity

The Hydro-N-Sensor is increasingly being used for nitrogen fertilisation in grain production. This optical reflection sensor installed on the tractor cab roof determines the biomass index while driving through the field, based on plant reflection characteristics, and calculates the recommended fertiliser dose to be applied by the tractor mounted fertiliser spreader. N-sensor fertilised crops exhibit a homogeneous canopy structure, as well as batch quality and protein content. In order to quantify the effects of sensor fertilisation on yield and protein content in crop areas, large scale experiments with 48 m wide fertilising strips with different variants have been established. Based on this data the effects on yield and protein are presented.

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Quality and yield fluctuate more or less clearly around an average value. This heterogeneity expresses itself on the specific sites of the crop area in yield fluctuation and varying protein content. With constant and/ or variable rate of N-fertilisation this heterogeneity is due to changing characteristics of the soil. Light, sandy patches exhibit another potential of yield than clayey part fields. From this, different N-supply status during the vegetation period exist, which later results in different yields. At harvest the yield measurement in the combine notes zones with high or lower with the well-known yield map.

The hydro N-sensor adapts the fertilisation to the current need of the plant, therefore the fertilisation is hence variable with different fertiliser rates. Soil caused heterogeneities in plants habitus are detected by the sensor. It differentiates at the fertilisation dates N2 and N3 as well as, if necessary, also at the N4-amount between the bright, thus less well supplied areas and the darker, better supplied areas of the field. This heterogeneities become balanced by the varied N-fertilisation. More weakly appearing plants receive a increased N-rate -, while darker and hence better supplied areas smaller N-quantities are assigned. To the N4 the rule algorithm is reversed: dark, plant-structurally active crop areas are promoted purposefully, the additional nitrogen is used to the protein synthesis. The experiment has a standard constant variant and a variant with the N-sensor adapted to the crops. The soil is classified due to the apparent electrical conductivity with the EM38 according to sandy and clayey areas. It exists a dependence between the conductivity and the sand portion of the soil: the higher the electrical conductivity, the more heavily and thus more yield potential the soil has. *Table 1* shows the values determined with the EM38 on the experiment areas. The parcels of the sensor variants exhibit clearly larger heterogeneities than the parcels of the constantly fertilised variants. The higher ranges and higher coefficients of variation in the sensor variants document their heterogeneities.

Numbers in the parentheses show the variants, which can be compared. With test series (1), the average N-quantity was 182 to 185 kg N/ha, in the test series (2) the appropriate N-amount was 208 kg/ha for the sensor variant and 222 kg/ha for the constant variant. The cultivated variety was a of "B"-quality, i.e wheat for baking. Pest management of the crops is accomplished by the plant manager, who decides on region-adapted rules. A usual combine with yield mapping system was used to harvest the grain. The yield measurement was extended at the institute by the measurement device for the protein content of grain [2]. For protein measurement on-line during the harvest the NIR spectroscopy is used. Thus yield quantity and quality of protein content can be mapped by using a DGPS-receiver. The evaluation of the data takes place then in a GIS.

Influence on the yield

Table 2 presents on the left the results for the yield. It is shown that yields of the respective sensor variants exhibit smaller ranges and concomitantly smaller coefficients of variation compared to the constant N-amounts. However light advantages in average yield for the constant fertilisation variants are present. This is due in (2) to somewhat higher N-application rates. While maximum yield reaches similar levels in each case, the minimum yield of the sensor variants does not

Table 1: Apparent electrical conductivity acc. to EM 38 and BMI of experimental variants

	Electronic conductivity				Biomass-Index			
	Average	Max.	Min.	CV %	Average	Max.	Min.	CV %
N-Sensor (1)	25.9	56.1	13.9	32.8	12.2	13.0	10.4	2.5
Konstant (1)	25.7	49.3	11.8	25.3	12.1	13.0	10.2	4.1
N-Sensor (2)	23.5	50.1	13.1	29.8	12.3	13.4	11.2	3.3
Konstant (2)	25.6	40.4	14.8	17.6	12.0	12.8	11.0	2.5

decrease as strong as in the constant variants. This is a clear sign for the fact that the undersupplied areas of the constant fertilisation were promoted here with the fertilisation by using the sensor. The constant fertilisation deepens the effects caused by the different soil qualities: it leads to an inefficient distribution of the N-fertiliser, since the amount of nitrogen is not oriented to the current need of the plants. The N-sensor however moderates these effects. The result is then a homogeneous crop, whose ranges in yield are reduced.

The differences between the variants in *Table 2* do not appear serious. In particular the small differences between the CV's actually permit no excessive interpretation. It applies however the values in *Table 1* should be considered for the heterogeneity of the soil. It came out from the data that the soil in the sensor variants exhibited clearly larger variabilities than in the constantly fertilised areas. The yields of the sensor variants nevertheless exhibit clearly smaller ranges. Therefore the sensor has balanced the soil-caused heterogeneities.

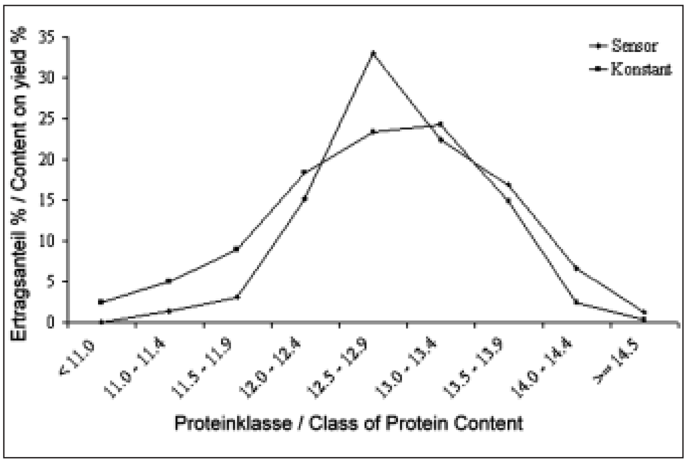

Fig. 1: Percentage of protein content classes within yield

Influence on the Protein Content

Average protein content of the areas fertilised with sensor are around 0.2 to 0.3 % absolutely higher than those of the constantly fertilised variants (*Table 2*, right), which is an advantage for the sensor. The increased protein content by 0.3 % causes (1) the harvested crop to be classified in a new, better group of quality. While the average protein content of the constantly fertilsed variant amounts 12.7 % and thus is to be classified under the group of quality "B", the identical nitrogen quantity is sufficient for the 13.0 % protein content of the sensor variant. This batch is now classified to the better quality group "A," quality wheat. This improved quality brings, depending upon market situation an increase of value of up to 10 % in relation to the quality group "B". Thus this effect attains substantial monetary advantage.

The heterogeneity of the quality is also affected. In test series (1) the range of the protein content of the sensor fertilised area decreases by around 1 % absolutely in relation to those of the constantly fertilised variant, i.e. the extreme values of the distribution shift toward the average value. In test series 2 the range is reduced by 1.1 % absolutely. By the reduced ranges, a larger portion of the harvested crop corresponds to the average protein content, while the portions in the extreme classes decrease. *Figure 1* shows this effect. At the abscissa the protein contents are divided into classes, a class covers 0.5 % points. The curves represent the respective portion of the protein classes of the total yield, represented at the ordinate. The flat increase and decrease of the graph of the constant variant shows that substantial portions of the yield are to be assigned to the extreme classes. On the other hand the steep graph of the sensor variant shows that the largest portion, about 33.0 % of the harvested crop, belongs of the protein class 12.5 to 12.9 %. The flat decrease of the curve in the higher protein classes causes that an average content is reached nevertheless of 13.0 %.

Whether the processing industry will honour the homogeneity of a batch in the future, is not to be foreseen at present yet. If an appropriate addition should be paid, also this is to be added as monetary advantage of the sensor fertilisation.

Influence on the combine throughput

Farmers using the N-Sensor report, that crops fertilised with N-Sensor could be threshed better. Different large scale experiments demonstrated this: sensor fertilised crops could be harvested faster at same loss level [2]. So far however no data are present, the effects are not directly measurable. They are only based on the experiences of the combine drivers. To get any measurable data, standing crop is scanned with the N-sensor to get an indirect parameter. As criterion for the density of the standing crop the sensor calculates the biomass index (BMI). Depending upon colouring and density of the plants it assumes different values. In a homogeneously standing crop this value may have only small fluctuations. The examination of the BMI is based on the hypothesis that a homogeneously developed crop does not only exhibit small yield fluctuations, but also can be processed by the combine harvester more easier. FEIFFER examined these effects and points out,that the homogeneously standing crop, among other things, is better cut by the cutting unit of the combine harvester. The material also runs easier through the combine. The whole machine runs more calmly and evenly. Thus with the BMI no direct process parameter of the combine is selected, yet the effects can be transferred on the combine indirectly.

Indices of *Table 1* were measured during the fertilisation after stem elongation. At this time the plant development is not yet final, but after tillering and shot is however the vegetative apparatus completely trained. The plant density is fixed, serious changes in the plant structure will not occur. Thus at this time the BMI could be used for determining heterogeneity. The biomass indices vary apparently only small; ranges and coefficients of variation of BMI in the sensor areas achieve the same level as on the constantly fertilised plots. It applies to consider the increased locational variability of the sensor area. Nevertheless only small differences in the sensor fertilised plants appear. This could be considered as an indicator of the homogenising effect of the standing crop, due to the N-sensor application.

Table 2: Yield and protein content of experimental variants

	Yield dt/ha				Content of Protein %			
	Average	Max.	Min.	CV %	Average	Max.	Min.	CV %
N-Sensor (1)	99.2	129.1	34.2	12.5	13.0	14.7	10.8	5.1
Konstant (1)	103.3	127.7	27.7	14.1	12.7	15.1	10.2	6.4
N-Sensor (2)	102.1	128.5	49.7	12.6	13.4	15.1	11.7	3.6
Konstant (2)	102.8	128.5	33.4	12.8	13.2	15.8	11.3	5.8

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