Influence on yield and quality components of stalk- and leaf crops by changing the production intensity

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Abstract

The effects of various cropping intensities on yield and product quality were investigated for a crop rotation of six fields with winter wheat, silage maize, winter rye, potatoes, winter barley and sugar beet between 1997 and 2001. The intensity levels studied were; (1) nitrogen supplied as cattle slurry with conventional plant protection and sowing intensity, (2) conventional mineral fertilizer, other activities as in 1, (3) mineral nitrogen reduced by 25 % and reduced pesticide use and (4) mineral nitrogen reduced by 40 %, herbicides only allowed, and sowing density reduced by 20 %. With the exception of potato cultivation, the lowest yields were obtained in intensity level 1. The crop cultivations were specifically effected by reduced production intensities. For all three grain crops, the yield reductions in fields with organic nitrogen fertilisation compared with mineral fertiliser supply were proportionally higher than in those with root crops. The yields of intensity level 3 did not differ significantly from those of level 2, with the exception of winter wheat and winter barley. In the intensity level 4, higher yields were obtained for grain crops and sugar beet than in level 1. Potato yields were positive with organic fertilisation. With regard to product quality, reduced nitrogen fertilisation decreased protein contents in all grain crops and maize in the sequence, level 2 > level 3 > level 4 > level 1. For this reason considerable loss of quality with regard to baking (wheat and rye) and fodder quality (barley, maize) were observed for levels 3, 4 and 1. High nitrogen supply reduced carbohydrate contents in sugar beets, silage maize and potatoes A comparison of the productivity of the four intensity levels based on dry matter production showed that the highest economically usable annual dry matter yields were obtained with intensity level 2. Significantly lower productivity was observed in levels 4 and 1..

Media Summary

A reduction of production intensity lead to higher yield and quality losses for grain crops than for root crops. The productivity of a crop rotation consisting of six fields decreases with increasing extensive cultivation.

Key Words

Extensive methods of production, influence on yield, effects on quality, productivity of crop rotations

Introduction

Extensive methods of agricultural land cultivation are based on the reduction of the cropping intensity in all areas of activity in agro-ecosystems. (Isselstein et al 1991) They target the reduction of surpluses and environmental pollution that are caused by present cultivation practices. These targets can be achieved by reducing the production intensity or with environmental conservation, and also by specific activities in plant production. The instruments farmers can implement to reduce cropping intensity can be defined as follows:

- Production with site-specific extended crop rotation
- Reduction of soil tillage intensity
- Reduction of fertiliser and pesticide supply
- Reduction of livestock per hectare grassland, conversion to extensive methods of livestock management

- Conversion to ecological land cultivation

All activities have consequences on inputs of labour and capital, they have influences on yield and quality of harvested crops (Guy et al 1995; M?rl?nder et al 2003; Reust and Neyrood 2003) they may result in changing techniques and therefore create not only ecologic but also economic effects. With the "principles for the promotion of a market and site specific land cultivation," the federal German government has enacted directives for promotion measures. The following extensive production procedures will be promoted: cultivation without herbicides, cultivation of at least five main crops on cultivated fields, cultivation of intercrops or underseeds in agriculture, the practice of mulch sowing, the use of biological and bio-technical plant protection measures in permanent cultures, extensive grassland use, ecological cultivation procedures and perennial fallowing.

Methods

A six field crop rotation with sugar beet, winter wheat, silage maize, winter rye, potato and winter barley was the basis of experiments for an investigation on the effects of various cropping intensities on yield and quality of harvest products running since 1997. All six crops were cultivated every year. The intensity levels were chosen according to typical restrictions underlined in actual agricultural and environmental programmes like directive (EWG) 2078/92. The base for comparison is the actual agricultural practice for the compared crops. All intensity levels are described in table 1.

Table 1. Chosen Intensity Levels

Level	Amount of Nitrogen fertlizer	Activities of plant protection	Sowing intensity
1	conventional* org. slurry	conventional	conventional
2	conventional mineral KAS	conventional	conventional
3	conventional mineral minus 25%	herbicides 1x fungicide insecticides when double infection no stem stabilizers	conventional
4	conventional mineral minus 40%	herbicides	conventional minus 20%

* conventional according to FAL experimental station Braunschweig (loamy sand, ∅ 620 mm precipitation, 8.9 ?C average temperature)

The intensity levels 1 and 2 were applied site specific with conventional intensities in all production methods (Table 1). In level 1, nutrients were supplied with slurry, in level 2 with mineral fertilisers. Conventional production methods indicate 120 kg N/ha for sugar beets, 130 kg N/ha for winter rye, winter barley and potatoes, 150 kg N/ha for maize as well as 170 kg N/ha for winter wheat. In level 3 the mineral nitrogen supply was reduced by about 25 % of level 2 and no culm stabilizers were used in grain crops, only one fungicide treatment was allowed and insecticides were applied only when double infestation occurred in comparison to level 2, the sowing density was reduced by about 20 %, and no pesticides were applied with the exception of herbicides.

Results

Nitrogen supply with slurry (level 1) lead to significantly smaller yields in all crops than conventional nitrogen supply with mineral fertiliser (level 2). The extent of the depression varied with crop (Table 2). .

Table 2. Effects of intensity level on yields and the relationship to yields under conventional cropping intensity (? 1997-2001)

Crop	Level 1		Level 2		Level 3		Level 4	
	(dt/ha)	(%)	(dt/ha)	(%)	(dt/ha)	(%)	(dt/ha)	(%)
Wi-Wheat	50.9 c	71.3	73.7 a	100	69.1 ab	94.4	64.4 b	88.7
Silage maize	157.4 b	88.3	178.2 a	100	182.9 a	102.6	157.4 b	88.3
Wi-Rye	54.4 d	66.7	83.3 a	100	73.4 b	83.6	66.9 c	80.7
Potatoe	511.0 a	95.2	532.2 a	100	499.6 a	92.8	438.0 b	82.0
Wi-Barley	62.7 d	75.7	86.0 a	100	77.2 b	90.4	71.8 c	85.3
Sugar Beet	434.2 b	88.7	489.2 a	100	480.1 a	98.1	465.0 ab	95.0

different letters indicate significance within a crop ($p < 0,05$; Tukey-Test)

A reduction of mineral nitrogen fertilisation (levels 3 and 4) to 75%, and 60% respectively, in combination with reduced application of pesticides lead to smaller yield declines than sole nitrogen supply with slurry in all crops with the exception of potatoes. Winter rye was most seriously affected in yield of all cereals when factor input is reduced. The yield decline of sugar beet, maize and potatoes was proportionally less than that in cereals. Despite reduced cropping intensity, the yields of sugar beets and maize in level 3 were comparable with those in “conventional” level 2, in which significant higher yields were obtained for all crops of the rotation.

Particularly in level 1, but also in levels 3 and 4, a decrease of protein content in cereals and maize lead to serious loss in quality with reference to baking quality (winter wheat) and fodder quality (barley, maize), whereas positive effects on sugar content in sugar beets and starch content in potatoes and maize were recorded (table 3). On average of the five year experimental period, the content of raw protein in winter wheat decreased from 13.4 % (level 2) across 12.1 (level 3) and 11.0 % (level 4) to 8.8 % in level 1. For appropriate bakery quality protein contents above 11.5 % are required. In winter barley, the protein content in level 2 was 9.3 % on average and decreased across level 3 (8.6 %), level 4 (8.3 %) to level 1 (7.1 %). This clearly showed quality loss in both cereals as a result of reduced nitrogen supply. The protein content in “conventional” level 2 was significantly higher for all three cereals and maize than that in the other intensity levels (Table 3). On the other hand, the sugar content in sugar beets decreased with increasing nitrogen supply from 19.1 % in level 1 to 18.7 % in level 3 and 18.5 % in level 2. For maize, the highest starch content occurred in level 1 with 28.8 %, and it decreased with increasing nitrogen supply to 25.4 % in level 2 (Table 3).

Table 3. Influence of production intensity on quality parameters (%) of different crops

Crop	Parameter	Level 1	Level 2	Level 3	Level 4

Wi-Wheat	Protein	8.8 d	13.4 a	12.1 b	11.0 c
Silage maize	Protein	5.6 d	7.5 a	6.9 b	6.5 c
Silage maize	Starch	28.8 a	25.4 b	26.0 b	27.6 ab
Wi-Rye	Protein	7.5 c	8.7 a	8.0 b	7.8 b
Potato	Starch	18.2 b	18.3 b	19.0 a	18.8 ab
Wi-Barley	Protein	7.1 c	9.3 a	8.6 b	8.3 b
Sugar Beet	Sugar	19.1 a	18.5 b	18.7 b	18.8 ab

different letters indicate significance within a crop ($p < 0,05$; Tukey-Test)

For potato crops, the highest starch content of 19.0 % was obtained in level 3, and high nitrogen supply lead to a decline in starch content. The intensity levels 1-4 can be compared for all years on the basis of the sum of the average dry matter production of every crop (Greef et al 1993). Only the economically valuable plant parts were regarded as dry matter for every crop. The results of the calculations show that for the experimental period 1997-2001, the highest economically usable annual dry matter yields were obtained with intensity level 2. Lower, but insignificantly different dry matter yields, were produced with intensity level 3. The intensity level 4, with more reduced factor input than in level 3, produced significantly lower dry matter yields compared to levels 2 and 3, but the values were higher than those in level 1 with organic fertilisation (Table 4). Ultimately, an economic assessment will determine the excellence of production systems with different intensities.

Table 4. Performance of production procedures with same crop rotation but different intensity (dt DM/ha ? 1997-2001)

Crop	Level 1	Level 2	Level 3	Level 4
Wi-Wheat	43.8	63.4	59.4	55.4
Silage maize	157.4	178.2	182.9	160.8
Wi-Rye	46.6	71.5	62.3	57.4
Potato	125.0	133.6	127.2	110.7
Wi-Barley	53.9	74.0	66.4	61.7
Sugar Beet	102.0	113.9	111.7	157.4

?Σ / year	522.6 b	632.3 a	607.3 a	551.2 b

different letters indicate significance ($p < 0,05$; Tukey-Test)

Conclusion

The results obtained show that extensive production methods lead to diverse results, dependent on crop characteristics which must be assessed individually for each crop. An economic assessment of these results and the performance of the whole crop rotation will provide information about the relevance of such extensive cropping activities in agricultural farms.

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