Dedicated to the anniversary of Prof. Ing. Jiří Petr, DrSc., Dr.h.c.

CULTIVATION OF WINTER WHEAT TO PRODUCE GRAIN FOR BIOETHANOL CONVERSION

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Biennial factorial field trials were conducted at the location 'Ihinger Hof' of Hohenheim University to produce bioethanol grain. Winter wheat cultivars ('Batis', 'Previa') were grown after different previous crops (pea, wheat/triticale) at varied levels of intensity. The crop management was dedicated to carbohydrates, the substrate of bioethanol fermentation. The problem was to optimize the energy output/input relations. The production intensity was aggregated from the available nitrogen levels, varied by the N source, and the plant protection measures, done either chemically or non-chemically. The residual N of a previous pea crop, slurry N, or stillage N substituted for mineral fertilizer N, due to conserve input energy. Stillage remains from bioethanol processing containing organic N. The fertilizers were applied at equal total N input. The measurement included the grain yield (t ha^{-1}), the bioethanol conversion rate (L t^{-1}), the grain protein concentration (%) and the bioethanol yield (L ha^{-1}). The crop production intensification increased the grain yields. Peak yields amounted to 7.65 t ha^{-1}. Wheat following a previous pea crop outyielded wheat grown after a previous grain crop by almost 2 t ha^{-1}. The bioethanol conversion rate ranged from 438–454 L t^{-1} on average. Conversion was affected by the grain protein concentration, which is the counterpart of carbohydrates, but the effects remained inconsistent. The bioethanol yield and the grain yield were closely correlated and mainly affected by the crop production intensity. According to the examined conditions, the mineral fertilizer nitrogen substitution effect of stillage or slurry N remained low regarding the grain yields ha^{-1}. The results indicate that peak bioethanol yields per hectare require high – mineral N fertilized, production intensity crops. Particularly wheat following a previous pea crop at adjusted mineral fertilizer N levels revealed as significant option to produce bioethanol grain effectively.

bioethanol grain; nitrogen fertilization; stillage; slurry; previous crop; grain yield; bioethanol conversion rate; grain protein concentration; bioethanol yield

INTRODUCTION

Bioethanol is produced from grain by biochemical conversion of the carbohydrates, which are primarily stored in the form of starch. From a global perspective, bioethanol is already widely used as a renewable energy source. In overseas countries, namely in Brazil, the United States of America and in Canada, bioethanol from various agricultural feedstock is widely commercially marketed to substitute for gasoline of fossil origin. The production and the use of bioethanol for industrial and energy purposes in Europe is currently rather marginal, but obviously increasing (Loyce, Meynard, 1997; Wiedenroth, 2001; Branntweinwirtschaft, 2001).

Grain that is destined for bioethanol production must permit high bioethanol conversion rates per ton of processed grain dry matter and per hectare. The decisive factors are the amount of starch that has been accumulated in the storage organs and the grain yield per hectare. Increasing grain protein concentrations result in decreasing starch contents. In consequence, the bioethanol conversion rate per ton of grain declines. A protein concentration increment of 1% results in losses of about 0.5 liter of bioethanol per 100 kg of grain dry matter (Aufhammer et al., 1996a). Bread making crop management is therefore not adapted for bioethanol grain production, since bioethanol grain differs significantly at the quality level: Properties that are associated with high grain protein concentrations can be consistently ignored in favour of starch accumulation.

The protein content of wheat is considerably affected by both the dosage and the timing of nitrogen applications (Kübler, 1994; Retzer, 1995; Schuster et al., 1998; Schilling, 2000). Mineral fertilizer nitrogen that was applied up to stem elongation was predominantly grain yield effective, whereas N applications at heading stage or later increased mainly the grain protein concentration (Fischbeck et al., 1997; Sieling, Hanus, 1997). According to Feil (1997, 1998) and Feil and Bänziger (1999), the grain yield per hectare and the grain protein concentration of a range of cereals was regularly correlated inversely – this is attributed to yield-affected protein dilution effects.

Among the inputs in crop husbandry, mineral fertilizer nitrogen is considered to be the main yield-producing factor, but, on the other hand, also the dominating component of the energy expenses in agriculture (Reinhardt, 1993; Rathke et al., 1998; Kuesters, Lammel, 1999; Gawronska-Kulesza, Suwara, 2001). Moreover, there is a risk of unwanted enhancement of the grain protein concentration – either by overestimating the local yield productivity or by exceeding the yield effective optimum of nitrogen fertilization. Thus, the nitrogen nourishment strategy of bioethanol grain comprises a set of contrasting aspects.

To that background, field trials with winter cereals were conducted in order to optimize the production of grain for bioethanol conversion – particularly from an energy point of view. The objective was to answer the following questions:

1. How much is the grain yield, the bioethanol conversion rate and the bioethanol yield of high-yielding winter wheat cultivars affected by the growing conditions after different previous crops coupled with different levels of crop production intensity?
2. Could the substitution of mineral fertilizer nitrogen by alternative N sources be a feasible option with respect to the grain yield and the bioethanol yield formation?

MATERIAL AND METHODS

Empirical data were taken from field trials with winter cereals carried out in 1996/1997 and 1997/1998 on the experimental station 'Ihinger Hof' of Hohenheim University. The site is located in southwestern Germany nearby Stuttgart. The factorial design and the main site characteristics are presented in Table I. Two winter wheat (*Triticum aestivum*) cultivars were cultivated. Wheat for either starch or alcohol production is used in Germany due to its availability on the market as well as on account of value added co-products, e.g. gluten. Under German environmental conditions, winter wheat as compared to spring wheat in general assures increased grain yield levels. The criteria to select the winter wheat cultivars 'Batis' and 'Previa' were a low risk of lodging in order to reduce growth regulator spreading. Furthermore, a high disease resistance to keep the assimilation organs for extended grain filling, and, finally, a high grain yield potential. In addition, the cultivar 'Batis' was characterized by an increased N uptake efficiency (Bundessortenamt, 1996) of which high grain yields at even lowered external N input was assumed. The crops were cultivated after different previous crops, since winter wheat is known for highly reacting to the previous crop conditions (Christen et al., 1992; Christen 2001) and the available N levels. The inclusion of a previous pea crop should allow diminished external fertilizer nitrogen inputs. In turn, wheat following a previous grain crop reflects the current economic situation of grain production in Germany. Particularly high-yielding wheat cultivars for feed production are frequently recommended to follow a previous grain crop. The pea straw was incorporated with intercropping mustard (*Genus sinapis*) in order to prevent premature nitrogen depletion. After the catch crop was chopped, shallow primary tillage took place,

I. Experimental design: Location 'Ihinger Hof': 480 m a.s.l, 7.9 C 1), 687 mm 1), leached brown soil, pH 7.2

1. Experimental periods: 1996/1997 – 1997/1998				
2. Previous crop (annually)		Pea, Winter grain 2)		
3. Species/ properties 3)	Winter wheat cv.	Lodging risk	Foliar/ear disease susceptibility	Grain yield performance
	'Batis'	mean	low	very high
	'Previa'	low – mean	low	high – very high
4. Crop management				
Intensity level	Nitrogen source		Plant protection	
High	Calcium ammonium nitrate		Herbicidal weeding, fungicidal foliar and ear disease control 4) Growth regulation	
Medium/Stillage	Liquid grain stillage			
Medium/Slurry	Cattle slurry			
Minimum	Soil borne nitrogen		Mechanical weed control	
Nitrogen dosage (kg N ha^{-1})	High	Medium/ stillage	Medium/ slurry	Minimum
Previous pea crop	100	130 5)	110 5)	0
Previous grain crop	160	185 5)	155 5)	0

1) long-term means
2) 1996 wheat, 1997 triticale
3) according to the Descriptive Variety List of the Bundessortenamt (1996)
4) after a previous grain crop additional applications against foot rot fungus
5) on average over the two growing seasons

while the previous grain crop site was ploughed to reduce the incidence of rotational diseases. In order to establish a nitrogen sink rapidly, the crops were sown after a previous pea crop right at the beginning of October with 350 germinable seeds per m^2. Whereas, to abate the risk of autumnal foot-rot infection, the sowing of wheat following a forecrop grain was retarded by 2 weeks as compared to wheat after a previous pea crop. The sowing density was increased to 400 germinable seeds per m^2.

II. Mean dry matter content (%), mean total N content (kg t^{-1} of fresh weight) mean ammonia content (kg t^{-1} of fresh weight) and annually on average applied organic fertilizer quantities (m^3 ha^{-1}) after a previous pea and a previous grain crop

Organic fertilizer type	DM	N-total	NH_4-N	Annually applied quantities after a...	
				previous pea crop	previous grain crop
	(%)	(kg t^{-1})	(kg t^{-1})	(m^3 ha^{-1})	(m^3 ha^{-1})
Grain stillage	5.9 (2.5–8.0) 1)	2.8 (1.8–4.2)	< 0.1	46	66
Cattle slurry	9.2 (6.3–12.3)	3.5 (2.7–4.2)	1.4	32	44

1) range

According to Table I, four crop production intensity levels were applied. The fertilizer nitrogen dosages were adjusted to the predicted nitrogen redelivery according to the forecrop conditions (Table I, bottom). High production intensity crops should act as a reference for achieving maximum site-specific grain yields. With minimum production intensity crops, the relative yield productivity of the production intensification strategies should be revealed. We intended to apply the fertilizers calcium ammonium nitrate (CAN, 27% N, 13.5% NH_4-N), stillage and slurry at equivalent total N levels per hectare. The specifications and the applied quantities per hectare of both stillage and slurry are outlined in Table II. The stillage was received from the Institute for Food Technology, Fermentation Technology Section of Hohenheim University. The slurry was derived from a cattle herd resided at the experimental station 'Ihinger Hof'. The nitrogen fertilizers were dressed intermittently on the top of the growing wheat crops between tillering to stem elongation stage.

Measurement and data analyses

The bioethanol conversion rate, which is specified as liter bioethanol per dt of grain dry matter, was analyzed by fermentation experiments of each grain set produced in the field. The enzymatically-catalyzed analyses were done in the laboratory of the Fermentation Technology Section of Hohenheim University. The applied methodology refers on Aufhammer et al. (1993) and Schäfer (1995), respectively. Slight methodological modifications were reported by Rosenberger et al. (2000). The bioethanol yield per hectare (L ha^{-1}) resulted from the harvested amount of grain dry matter per hectare (t ha^{-1}) multiplied by the bioethanol conversion rate. The grain raw protein content (% of grain dry matter) – as the counterpart of the carbohydrate fraction, was derived from nitrogen analyses done after Kjeldahl multiplied by the factor 5.7, which is recommended for wheat (Schilling, 2000). The collected data were evaluated by analyses of variance using the procedure ANOVA of the computer program SAS. Each ANOVA that was carried out comprised 96 observations, which resulted from the two experimental periods, the two forecrops, the two wheat cultivars, the four levels of intensity and three replicates. Least significant differences (LSD) were calculated on the basis of the *t*-test when *F*-values indicated significant effects at $P < 0.05$. In order to quantify interdependences of parameters, correlation coefficients were computed by the procedure CORR.

RESULTS

Variance analyses

Table III provides the *F*-values of the ANOVA that were performed for the parameters grain yield, bioethanol conversion, bioethanol yield and grain protein concentration (GPC). *F*-values enable both to specify and to quantify rapidly the effects of the factors and their interactions on the mentioned parameters. Except for the GPC, effects of the year were not proven, but each parameter was affected by the factor forecrop, respectively by the interaction of forecrop and year. With respect to the bioethanol conversion rate, the forecrop effect dominated evidently. Main effects of the factor cultivar and its interactions were insignificant and/or remained quantitatively marginal. The cultivars were thus no large source for variability; respectively they were affected relatively in the same way by the trial variation. On the other hand, the factor crop production intensity was by far the dominating source of variance with regard to the grain yield, the bioethanol yield and the GPC. Moreover, interactions of intensity and forecrop suggest that there is still scope to improve the forecrop-related crop management. Interactions exceeding bilateral levels remained without or of minor relevance considering the initially mentioned questions. *F*-values of both the grain and the bioethanol yield were qualitatively and even quantitatively to a large extent congruent, since these parameters were closely and positively correlated ($r = 0.99$). Thus, variability at the bioethanol yield is almost completely explained by the variability of the grain yield. On the contrary, the grain protein content and the dependent variable bioethanol conversion rate were not only less close, but even inversely linked as shown by the negative correlation coefficient of $r = -0.74$. Based on the ANOVA results, the following sections present the means of the grain yield, the bioethanol conversion, the bioethanol yield and the grain protein content. Apart from the main effects of the factors forecrop, cultivar (for protein only) and intensity, means are displayed for the interactions of forecrop and intensity as well as for year and forecrop.

III. *F*-values for effects on the grain yield, the bioethanol conversion rate, the bioethanol yield and the grain protein content

Source	Parameter			
	grain yield	conversion rate	bioethanol yield	protein content
Year (J)	0.4	0.1	0.4	77.5^{***}
Forecrop (O)	118.4^{***}	273.2^{***}	137.6^{***}	123.2^{***}
J x O	28.5^{***}	94.4^{***}	34.2^{***}	41.4^{***}
Cultivar (S)	1.7	1.5	1.6	11.0^{*}
J x S	0.1	0.3	0.1	3.2
O x S	0.9	2.5	1.1	0.8
J x O x S	0.1	12.0^{**}	0.4	4.4
Intensity (V)	407.6^{***}	10.4^{***}	417.0^{***}	271.1^{***}
J x V	3.8^{*}	99.9^{***}	8.5^{***}	82.4^{***}
O x V	19.6^{***}	25.2^{***}	15.7^{***}	72.1^{***}
S x V	1.9	0.7	2.1	0.7
J x O x V	0.6	17.5^{***}	0.3	61.9^{***}
J x S x V	1.2	0.6	1.3	1.5
O x S x V	0.8	1.7	0.9	1.2
J x O x S x V	1.9	0.5	2.1	0.6

$^{*}, ^{**}, ^{***}$: significant at $P < 0.05, < 0.01, < 0.001$

Grain yield

Wheat following a previous pea crop outyielded wheat grown after a previous grain crop by almost 2 t ha^{-1} (Table IV, top). Basically, the crop production intensification increased the grain yield performance. High production intensity crops yielded about 3.1 t ha^{-1} more grain dry weight than minimum intensity crops, as well as about 2 t ha^{-1} more grain than medium intensity crops. The difference in favour of the stillage manured as compared to slurry manured crops amounted to 0.3 t ha^{-1}. As affected by the forecrop, the relevance of the crop production intensification increased. High in comparison to minimum production intensity crops following a previous pea crop increased in yield by 2.5 t ha^{-1}, whereas the grain yield of wheat following a previous grain crop increased – from a comparatively low level, by 3.7 t ha^{-1}, accordingly (Table IV, middle). Nevertheless, the grain yields of wheat following a previous pea crop exceeded the yields of wheat succeeding a previous grain crop consistently. As dependent on the intensity level, the differences ranged from 1.0 to 2.2 t ha^{-1}. Peak grain yields of high production

IV. Grain dry weight (t ha^{-1}) as affected by the forecrop, the production intensity (top) as well as by the interactions forecrop x intensity (middle) and forecrop x year (bottom)

Forecrop		Production intensity			
Pea	Grain	High	Medium/Stillage	Medium/Slurry	Minimum
6.28 a	4.43 b	7.15 a	5.27 b	4.98 c	4.02 d
Production intensity	High	Medium/Stillage	Medium/Slurry	Minimum	LSD$_{5\%}$
Previous pea crop	7.65	6.25	6.08	5.14	0.26
Previous grain crop	6.64	4.29	3.89	2.91	
Wheat following a...	Previous pea crop		Previous grain crop		LSD$_{5\%}$
Growing period 1996/1997	5.77		4.83		0.55
Growing period 1997/1998	6.79		4.03		

intensity crops amounted to 7.65 t ha^{-1}. With respect to the grain yield, the previous crops interacted with the natural growing conditions (Table IV, bottom). In the growing season 1997/1998 after a previous pea crop, yield increases of 1 t ha^{-1} were determined compared to the preceding period, while wheat following a previous grain crop lost 0.8 t ha^{-1}, accordingly.

Bioethanol conversion rate

As affected by the previous crop conditions, the bioethanol conversion rate differed significantly. Wheat, which had been grown after a previous pea crop, resulted in 452 L bioethanol per t of grain dry matter that corresponded to a benefit of 10 liter in comparison to wheat following a previous grain crop (Table V, top). Within a declining intensity scale, the bioethanol conversion increased by 5 L t^{-1} in comparison of minimum to high production intensity crops. Considering the bioethanol conversion rate, the crop production intensity interacted with the previous crop conditions. As shown by the range of 451–454 L t^{-1}, the intensification-related effects on the bioethanol conversion of wheat following a previous pea crop remained quantitatively marginal (Table V, middle). In contrast, minimum production intensity crops exceeded high production intensity crops cultivated after a previous grain crop by 10 liter of bioethanol conversion per dt of grain dry matter. As dependent on the interaction of forecrop and year, the bioethanol conversion rates varied contrastingly (Table V, bottom). After a previous pea crop the bioethanol conversion rate increased by 6 L in 1997/1998 compared to the

V. Bioethanol conversion rate (L t^{-1} of grain dry matter) as affected by the forecrop, the production intensity (top) as well as by the interactions forecrop x intensity (middle) and forecrop x year (bottom)

Forecrop		Production intensity			
Pea	Grain	High	Medium/Stillage	Medium/Slurry	Minimum
452 a	443 b	445 c	447 bc	448 ab	450 ab
Production intensity	High	Medium/Stillage	Medium/Slurry	Minimum	LSD$_{5\%}$
Previous pea crop	453	454	451	451	2.0
Previous grain crop	438	440	445	448	
Wheat following a...	Previous pea crop		Previous grain crop		LSD$_{5\%}$
Growing period 1996/1997	449		445		2.0
Growing period 1997/1998	455		440		

preceding season, while after a previous grain crop, conversion declined by 5 L, accordingly.

Grain protein concentration

As mentioned in section 1, the grain protein concentration (GPC) and the starch content behave, as they were counterparts. Thus, the concentration of protein enables to estimate indirectly how successful the crop management dedicated to starch accumulation had been. Table VI provides the means of the grain protein content. Wheat, that was cultivated after a previous pea crop accumulated 1.2% less grain protein than wheat grown after a previous grain crop (Table VII, top). The GPC of the wheat cultivar 'Batis', which is characterized by increased N uptake efficiency, increased by 0.4% compared to the cv. 'Previa'. Basically, the grain protein concentrations declined from 11.6 to 9.6% within a decreasing intensity scale. However, organically fertilized crops differed by 1.4% in favour of significantly reduced GPC of slurry-manured crops. As affected by the crop production intensity, the GPC of wheat following a previous pea crop ranged from 9.5 up to 10.5% of grain dry matter (Table VI, middle). As demonstrated by the range of 9.8–12.7%, the GPC variability of wheat following a preceding grain crop doubled in comparison to wheat produced after pea. Moreover, the results revealed a considerable GPC decrease by 2.1% when slurry instead of stillage was used for nitrogen manuring. Within the same scale, but after a previous pea crop, the GPC decline amounted to merely 0.7%. The GPC of wheat follow-

VI. Grain protein content (% of grain dry matter) as affected by the forecrop, the cultivar, the production intensity (top) as well as by the interactions forecrop x intensity (middle) and forecrop x year (bottom)

Forecrop		Cultivar		Production intensity			
Pea	Grain	Batis	Previa	High	Medium/ Stillage	Medium/ Slurry	Minimum
10.0 b	11.2 a	10.8 a	10.4 b	11.6 a	11.4 b	10.0 c	9.6 d

Production intensity	High	Medium/ Stillage	Medium/ Slurry	Minimum	$LSD_{5\%}$
Previous pea crop	10.5	10.4	9.7	9.5	0.2
Previous grain crop	12.7	12.3	10.2	9.8	

Wheat following a...	Previous pea crop	Previous grain crop	$LSD_{5\%}$
Growing period 1996/1997	9.9	10.4	0.4
Growing period 1997/1998	10.2	12.1	

ing a previous pea crop was not influenced by the growing season (Table VI, bottom). However, the GPC of wheat succeeding a preceding grain crop differed by 1.7% as affected by the growing period.

Bioethanol yield

Due to the close correlation of the grain and the bioethanol yield per hectare, the trial factors affected the bioethanol yield just as described for the grain yield. As the crop production intensity declined, the bioethanol yield decreased (Table VII, top), but to a considerably smaller extent after a previous pea than after a previous grain crop (Table VII, middle). Peak bioethanol yields (3465 L ha^{-1}) were determined with high production intensity crops following a previous pea crop. The lowest bioethanol yield (1301 L ha^{-1}) resulted from minimum intensity crops grown after a previous grain crop. Stillage manured crops outyielded slurry fertilized stands by up to 166 L Bioethanol ha^{-1}. Moreover, the bioethanol yield of stillage-manured crops produced after a previous pea crop (2833 L ha^{-1}) was statistically equivalent to the bioethanol yield of high production intensity crops following a previous grain crop (2911 L ha^{-1}).

DISCUSSION AND CONCLUSIONS

The crop yield formation and the grain conversion quality were highly affected by the previous crop conditions and the applied crop production intensities, respectively their interaction. Each parameter among investigation showed improved results in favour of wheat following a previous pea than a previous grain crop. The growing conditions after a previous pea crop affected the grain yield and thus the carbohydrate yield per hectare favourably as indicated by increased bioethanol conversion rates and increased bioethanol yields per hectare. In contrast, the crop management was evidently incapable to compensate for the unfavourable conditions after a previous grain crop with regard to the considered parameters. Basically, that is in agreement to results reported by Christen (2001) for the yield reduction of wheat after unfavourable preceding crops despite of adapted crop husbandry. However, the sowing delay of wheat following a previous grain crop affected the yield performance of the crops adversely, too, since crop emergence in autumn of 1997 was considerably retarded by drought stress, whereas wheat cultivated after pea emerged without any retardation (Rosenberger et al., 2000). On the other hand, the incidence of foot-rot fell due to the sowing delay after a previous grain crop.

VII. Bioethanol yield (L ha^{-1}) as affected by the forecrop, the production intensity (top) as well as by the interactions forecrop x intensity (middle) and forecrop x year (bottom)

Forecrop		Production intensity			
Pea	Grain	High	Medium/Stillage	Medium/Slurry	Minimum
2842 a	1959 b	3188 a	2364 b	2238 c	1812 d

Production intensity	High	Medium/Stillage	Medium/Slurry	Minimum	$LSD_{5\%}$
Previous pea crop	3465	2833	2748	2324	113
Previous grain crop	2911	1895	1729	1301	

Wheat following a...	Previous pea crop	Previous grain crop	$LSD_{5\%}$
Growing period 1996/1997	2597	2154	246
Growing period 1997/1998	3087	1746	

To improve the conversion quality, the crop management was aligned to the accumulation of carbohydrates instead of protein. The grain protein concentration (GPC) of the cv. 'Batis' and the cv. 'Previa' amounted to 10.6% on average, which is up to 6% less protein than accumulated by wheat for bread making (Fischbeck et al., 1997). The GPC and the bioethanol conversion rate were correlated inversely. Thus, bioethanol conversion losses due to incremental GPC were determined, but the effects were inconsistent as affected by the trial factors and primarily by the forecrop conditions: The

GPC of wheat following a previous pea crop increased by 1% from minimum to high production intensity crops, but the bioethanol conversion enhanced, too. Thus, crop production intensification, particularly by increasing the N dosage, does not mandatorily result in bioethanol conversion losses. That disagrees to results reported by Aufhammer et al. (1996a). According to the correlation coefficient of $r = -0.74$, the variability of the bioethanol conversion is merely explained to 50% by the variability of the GPC. Schäfer (1995), who calculated a similar coefficient, presumed that the accumulation of carbohydrates might compete to further grain components apart from protein of which the conversion traits are affected as well. Our results suggest that the protein fraction – possibly as affected by its composition and distribution within the grains, might contributed favourably to the conversion quality – in case, certain absolute concentrations were not exceeded. But to verify this assumption, further investigations would be necessary going beyond the scope of the study.

Undoubtedly, wheat following a previous pea crop at adjusted mineral fertilizer N levels was a significant option to produce bioethanol grain effectively. Whereas, according to the examined conditions, the mineral fertilizer nitrogen substitution effect on the grain yield of either stillage or slurry N remained low in relation to the amounts that were applied per hectare. Aufhammer et al. (1996b), on the other hand, proved no effect of the fertilizer type on the grain yield of maize fertilized by mineral N or stillage N, respectively. However, that was due to initially high soil mineral N contents and a high mineralization from the soil. In comparison of the organic manures applied, the mean dry matter content, the mean amount of total N and the average NH_4-N proportion of slurry consistently exceeded the specifications of stillage. It turned out that stillage is almost completely free of NH_4-N. Nevertheless, the stillage-manured crops outyielded the slurry-manured crops. Based on calculations of the grain N uptake per hectare of fertilized relative to non-fertilized crops, the applied nitrogen was exploited by 15, 22 and 58% in order of slurry < stillage < CAN fertilization. Thus, the grain withdrew merely 15% of the applied slurry N. Dittert et al. (1999) found 15% N uptake by wheat in case slurry was applied in autumn, but 35% when applied in spring – as done here, too. The exploitation discrepancy as compared to stillage N could maybe explained by gaseous ammonia losses or by the increased slurry viscosity of which soaking into the soil was slowed down and/or prevented. However, disregarding the possible reasons for the yield differences of stillage and slurry manured crops, the substitution of mineral fertilizer N by either stillage N or slurry N was, under the examined conditions, no feasible option for an effective production of bioethanol grain due to poor grain yields.

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ROSENBERGER, A. – AUFHAMMER, W. (University of Hohenheim, Institute of Crop Production and Grassland, Stuttgart, Germany):

Pěstování ozimé pšenice k produkci bioetanolu.

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Na pokusné stanici v Ihinger Hof Univerzity v Hohenheimu se vedly pokusy s ozimou pšenicí k produkci bioetanolu. Odrůdy Batis a Previa byly pěstovány po různých předplodinách (hrách, pšenice a tritikale) a při různé intenzitě. Agrotechnika byla zaměřena na produkci sacharidů jako zdrojů pro produkci bioetanolu. Problémem byla optimalizace vstupů energie při pěstování pšenice a výstupů energie při produkci bioetanolu. Intenzita pěstování byla dána hladinou dostupného dusíku, která byla ovlivněna zdroji dusíku a chemickou a nechemickou ochranou rostlin. Zásoba dusíku v půdě po předplodinách a dusík z kejdy a výpalků nahrazovaly hnojení průmyslovými dusíkatými hnojivy kvůli snížení vstupní energie. Lihovarské výpalky zůstávají jako zbytek po produkci bioetanolu, a tak se dusík, který obsahují, vrací do půdy. Hnojiva byla aplikována na stejnou úroveň dávek dusíku. V pokuse se sledoval výnos zrna (t.ha^{-1}), výtěžnost bioetanolu v litrech z 1 t zrna, obsah bílkovin v procentech a výnos bioetanolu v litrech z 1 ha. Intenzitou pěstování se zvyšoval výnos zrna. Nejvyšší výnos byl 7,65 tun. Pšenice pěstovaná po hrachu překonala výnosově pšenici pěstovanou po obilninách o 2 tuny na 1 ha. Výtěžnost bioetanolu se pohybovala v rozmezí 438–454 litrů z 1 t zrna pšenice. Bílkoviny provázející sacharidy ovlivňují konverzi v bioetanol, ale jejich účinky byly rozdílné. Výnos zrna a výtěžek bioetanolu jsou v úzkém vzájemném vztahu a ovlivňuje je intenzita pěstování. Z pokusů vyplývá, že vliv substituce dusíku z průmyslových hnojiv lihovarskými výpalky a dusíkem z kejdy byl nízký z hlediska dosaženého výnosu. Vysoké výnosy bioetanolu vyžadují značné množství dusíkatého hnojení z průmyslových hnojiv a obecně vysokou intenzitu pěstování. Jen pšenice pěstovaná po hrachu, při řízených dávkách dusíkatých hnojiv, ukázala možnost efektivní produkce bioetanolu.

pšenice; produkce bioetanolu; agrotechnika k produkci bioetanolu; předplodina; hnojení dusíkem

(Překlad abstraktu do češtiny byl pořízen v redakci časopisu.)

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