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THE EFFECT OF THE PREVIOUS CROP AND DIFFERENTIATED FERTILISATION ON YIELDS AND CONTENT OF N-SUBSTANCES IN SPRING BARLEY GRAIN

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Abstract

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In small-plot experiments established in 2001–2004 we studied the effect of the chemical composition of the plant dry matter of spring barley, varieties Kompakt and Jersey, on grain yields. A relatively strong correlation was confirmed between the chemical composition of the plant dry matter and yields. The correlation was most intensive in the case of nitrogen ($r = 0.536$), phosphorus ($r = 0.503$), magnesium ($r = 0.464$) and sulphur ($r = 0.431$) at the beginning of shooting (DC 30); in the case of potassium ($r = 0.557$) at the beginning of tillering (DC 23) and calcium ($r = 0.530$) during ear formation (DC 55). A relatively strong correlation remained from the beginning of tillering to the beginning of ear formation and later decreased. The weather conditions of the year and variety significantly affected grain yields and also the previous crop was important. Grain yields of the variety Kompakt were statistically significantly lower than of the variety Jersey (6.02 $t.ha^{-1}$ and 6.45 $t.ha^{-1}$, respectively). The yields of barley grown after sugar-beet were the highest (6.30–6.79 $t.ha^{-1}$); the grain yields of barley after maize decreased by 9.1–9.7 %. Higher grain yields of the Jersey variety resulted in levels of N-substances (11.35 %) lower than in the Kompakt variety (11.35 % and 11.60 %, resp.). No correlation was discovered between the nitrogen level in the plant dry matter during vegetation and the content of N-substances in barley grain.

spring barley, forecrop, chemical composition, grain yield, N-substances content

Apart from the weather conditions of the year and soil type stabile yields and quality of spring barley are affected by a number of other agronomical factors; their order has not been unambiguously defined (Kulík, 1995; Procházka, Hudcová, 1989; Petr et al., 2000, Zimolka et al., 2006). A very important factor in the system of production of spring barley intended for malting in terms of yields and quality of grain is a suitable previous crop (Cerkal et al. 2001; Příkopa et al., 2005). The best previous crops are thought to be organically fertilised tuber crops which maintain the good field strength of the soil. Particularly suitable are such crops whose post-harvest residues decompose rapidly after incorporation and mineralise before the barley plants emerge. The released nutrients are then utilised for rapid and smooth plant growth from the very beginning of vegetation.

The high dynamics of growth of spring barley is connected with its rapid development. The short vegetation period and weak root system further increase the demands of barley. In nutrition the focus is on nitrogen from the very beginning of vegetation. The high demands of barley for nitrogen at the beginning of vegetation are complicated by intricate soil dynamics dependent on the content of organic substances in the soil, the C:N ratio, soil temperature, soil humidity, content of micro-organisms which support the release or immobilisation of nitrogen in the soil environment etc. (Arisnabarreta et Miralles 2004; Zimolka et al. 2006).

Regulation of the nutritional status of spring barley is one of the important factors. In order to produce high yields of good quality nitrogen fertilisation must be balanced and based on soil analyses and analyses of plants in the early stages of vegetation. The reason is that from emergence until the 25th to 30th days (DC 29) spring barley absorbs 40–60% of all nutrients and in this period produces only about 20% of dry matter (Richter and Bezděk, 2000). An optimal content of nitrogen and phosphorus stimulates the production of tillers. Plants require higher nitrogen intake especially until the stage of elongation growth when spring barley produces a high amount of biomass. In the stage of elongation of leaf sheaths the intensity of nitrogen uptake is closely connected with barley yields (Weston et al., 1993; Kubinec, 1998). Overfertilisation with nitrogen results in a higher content of N-substances in the grain. Carreck et al. (1992) discovered that nitrogen rates increased by 25 kg per ha increased the content of N-substances in the grain by 0.1%. But the question still is how to specify the optimal rate and what in fact is the increase. The thing is that of late we have often seen that barley lacks nitrogen and this is negatively reflected in a low content of N-substances in barley grain. If grain yields are above 6 t.ha^{-1} the content of N-substances is much below 10%. That is why we must provide proper fertilisation, and not only with nitrogen. It is no easy task as you will see in the present study.

MATERIAL AND METHODS

In 2001–2004 spring barley, varieties Jersey and Kompakt, was grown after three different previous crops: winter wheat, sugar-beet and maize for grain.

The experiment was established in the form of randomised blocks and each treatment was sown in four replications. The size of the experimental plot was 19.5 m^2. When the previous crop was harvested the post-harvest residues (wheat and maize straw, sugar-beet tops) were crushed and incorporated along with stubble ploughing followed by mean ploughing. Soil preparation was the same every year, i.e. smoothing and harrowing performed twice. A number of operation steps were carried out during vegetation; Tab. I gives a survey. The plants were harvested in the stage of full ripeness with the SAMPO–ROSENLEW small-plot combine harvester.

Before sowing the spring barley the soil samples were taken to analyse the basic agrochemical soil properties using the method according to Melich III. At the same time the content of the nitrate and ammonia forms of nitrogen were determined (Tab. II). In 2002 basing on the results of these analyses Amofos (12% N, 22.7% P) was applied before sowing barley at a rate of 200 kg.ha^{-1} in order to increase the content of available phosphorus. In 2003 due to a lower pH value we applied the fertiliser Hyperkorn (11.4% P, 1.8% Mg) after wheat and sugar-beet at a rate of 200 kg.ha^{-1}. In 2002 the basic rates of nitrogen after wheat were reduced by the rate of nitrogen applied in the Amofos fertiliser.

After sowing and before emergence of the plants we applied ammonium nitrate (34% N) with nitrogen at rates of 30 and 50 kg.ha^{-1} after wheat and maize, respectively; after sugar-beet the first treatment was not fertilised and in the other treatments we applied 30 kg.ha^{-1} (Tab. III).

At growth stage DC 23, 30-31, 33, 55, 71 plant samples were taken to assess the contents of N, P, K, Ca, Mg, S. An average sample of grain was taken after harvest and the basic nutrients were determined according to the methods used by the Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ) (Zbíral et al., 2005).

Statistical processing was conducted using the method of variance analysis followed by Tukey's test (Meloun et Militký, 1998). For statistical evaluation we used the UNISTAT 5.1 programme. To evaluate the correlations we used the method expressing the linear course of dependences – regression – using the regression line. Calculations of parameters of linear regression functions draw on the method of least squares.

On the contrary if it equals 0 it means that the regression equation is not able to predict the values. The strength of the dependence was expressed as a correlation coefficient subsequently tested at a significance level of $\alpha \leq 0.05$ (significant dependence).

The F-test (Fischer - Snedecor) was used to decide if the dependent / independent variable relationship was not random.

I: *Survey of operation steps*

Operation steps	**Year**			
	2001	**2002**	**2003**	**2004**
sowing	3. 4.	13. 3.	25. 3.	5. 4.
plant sampling (tillering – DC 23)	15. 4.	23. 4.	29. 4.	4. 5.
application of Campofort P fertiliser	15. 5.	7. 5.	13. 5.	16. 5.
plant sampling (beginning of shooting – DC 30-31)	23. 5.	7. 5.	13. 5.	16. 5.
plant sampling (3rd node – DC 33)	–	14. 5.	20. 5.	2 .6.
application of Campofort P fertiliser	5. 6.	30. 5.	30. 5.	10. 6.
plant sampling (ear formation – DC 50-55)	5. 6.	6. 6.	10. 6.	17. 6.
plant sampling (milk ripeness – DC 71)	3. 7.	–	25. 6.	30. 6.
harvest	31. 7.	22. 7.	11. 7.	6. 8.

II: *Soil analysis before sowing barley and content of available nutrients in the 0–30 cm soil layer*

year	previous crop	pH/KCl	(mg.kg^{-1})						
			P	K	Ca	Mg	N-NO$_3^-$	N-NH$_4^+$	N$_{min}$
2001	winter wheat	7.0	122	226	5 354	376	8.1	4.4	12.5
	sugar-beet	6.8	135	207	4 930	396	10.5	3.0	13.5
	maize for grain	6.8	114	253	4 700	399	8.7	3.2	11.9
2002	winter wheat	6.2	63	214	3 836	447	10.7	5.9	16.6
	sugar-beet	6.6	113	195	4 434	340	11.9	5.4	17.3
	maize for grain	6.7	112	235	5 142	198	4.9	4.9	9.8
2003	winter wheat	5.9	68	210	3 900	368	11.2	5.6	16.8
	sugar-beet	5.9	95	197	3 576	311	7.4	4.8	12.2
	maize for grain	6.5	131	254	3 997	323	5.3	5.4	10.7
2004	winter wheat	6.3	73	186	4 081	420	3.7	4.6	8.3
	sugar-beet	6.8	94	213	4 387	440	7.1	8.9	16.0
	maize for grain	7.1	108	227	4 848	418	5.0	6.2	11.2

III: *Experimental layout*

	Fertilisation treatments / previous crop	sugar-beet	wheat and maize
1	N$_0$PK – fertilisation according to previous crop	0 kg N.ha^{-1}	30 kg N.ha^{-1} in AN
2	N$_1$PK fertilisation according to mineral N in the soil (N$_{min}$)	30 kg N.ha^{-1} in AN	50 kg N.ha^{-1} in AN
3	N$_1$PK + K$_1$ fertilisation according to N$_{min}$ in soil and plant analysis	30 kg N.ha^{-1} in AN + CP-P in stage DC 30	50 kg N.ha^{-1} in AN + CP-P in stage DC 30
4	N$_1$PK + K$_2$ fertilisation according to N$_{min}$ in soil and plant analysis	30 kg N.ha^{-1} in AN + CP-P in stage DC 50	50 kg N.ha^{-1} in AN + CP-P in stage DC 50

Legend: AN – ammonium nitrate (34% N); CP-P – Campofort garant P (5 % MgO; 14 % N; 24 % P$_2$O$_5$) at a rate of 5 kg.ha^{-1}.

IV: *Average sum of monthly precipitation and temperatures*

month	precipitation in mm				normal (mm) 1961–1990	temperature (°C)				normal (°C) 1961–1990
	2001	2002	2003	2004		2001	2002	2003	2004	
I	25.5	3.1	18.2	69.5	24.8	0.2	–0.8	–1.5	–3.1	–2.0
II	9.5	17.4	0.4	29.5	24.9	1.5	4.5	–2.3	1.5	0.2
III	46.0	21.2	3.0	56.7	23.9	5.8	5.8	5.1	3.8	4.3
IV	31.7	28.7	18.2	25.0	33.2	9.3	10.4	9.5	10.4	9.6
V	31.8	68.8	42.2	33.0	62.8	17.6	18.0	17.4	13.0	14.6
VI	42.0	103.8	11.6	68.4	68.6	17.0	19.2	21.4	17.2	17.7
VII	68.6	107.5	48.6	30.5	57.1	21.2	21.1	20.6	19.1	19.3
III–VII	220.1	329.9	123.6	213.6	245.6	14.2	14.9	14.8	12.7	13.1

RESULTS AND DISCUSSION

The analysed samples of barley plants taken during vegetation confirmed that there was a relatively strong correlation between the chemical composition of the plant dry matter and yields (Tab. V) and that it appeared the strongest when nitrogen, phosphorus, magnesium and sulphur were applied at the beginning of shooting (DC 30), potassium at the very beginning of shooting (DC 23) and calcium during ear formation (DC 55). We should point out that a relatively strong correlation remained from the onset of tillering until the onset of ear formation and the effect of the nutritional status on grain yields did not decrease until later. Baier et al. (1990), Richter et Bezděk (2000), Otegui et al. (2002) discovered that it was also connected with a higher content of nutrients in the plants in the early stages of development which is basically decisive in terms of the uptake and accumulation of the nutrient in tissues during tillering and shooting. The ensuing reduced uptake during ear formation and re-distribution into the reserve organs distorts this correlation and decreases the correlation dependence which is seen in the decrease in values of the correlation coefficient.

Focusing on the dynamics of changes in the correlations between the chemical composition of the plant dry matter and grain yields we see that the decisive period for nitrogen is the onset of the shooting and ear formation stages; in practice it means that the plants must have a sufficient supply of nitrogen as early as during tillering and sustain a good supply of nitrogen also during the shooting stage. The correlation between phosphorus and yields is stronger in the initial stages of development and because in this period uptake by plants is often difficult it must be applied as near as possible to the roots. In terms of yields potassium and calcium are important throughout vegetation, particularly during period DC 50–55. The correlation between the level of magnesium and sulphur and yields was not as strong as the other nutrients. The effect of sulphur on yields was the strongest in the first two developmental stages. In the early developmental stages (DC 23–30) the content of S in the plants is relatively high. Smith et Lang (1988), Geda et al. (1995) reported that in these stages it is primarily the redistribution of sulphate from older leaves to the new developing ones. The S content in the nutritious medium also positively affected the S supply. Thus sulphur could have a positive effect on N utilisation, much like in wheat (Schnug et al., 1993).

In contrast to grain yields no correlation was confirmed between the content of N-substances in grain and uptake of nutrients by the plant (Tab. V). It is particularly important for N and P where the correlation coefficients are very low. The correlation between the content of N-substances in grain and the S content in plant dry matter was more marked during shooting until ear formation. From these results we can deduce that the content of N substances was affected most of all by the weather conditions of the year.

Tab. VI shows that the weather conditions of the year, the variety and previous crop had a highly significant ($P > 0.999$) effect on the yields of barley grain. Tab. VII and IX give the average 4-year results of grain yields of the Kompakt and Jersey varieties. The grain yields of the variety Kompakt were statistically highly significantly ($P > 0.999$) lower (6.02 $t.ha^{-1}$) than Jersey (6.45 $t.ha^{-1}$); the lower yields of the latter variety contributed to high grain N-substances contents (Tab. VIII).

We evaluated the individual previous crops and discovered that the best was sugar-beet for both barley varieties. By contrast, yields were the worst when the previous crop was maize which reduced yields

V: *Correlation coefficient between grain yields ($t.ha^{-1}$), content of N-substances in grain and absorption of nutrients (mg per plant) in 2001–2004*

Stages of development	**years**	**2001–2004**	**2001–2004**	**years**	**2001–2004**	**2001–2004**
	nutrient	**Correlation with yields**	**Correlation with N substances**	**nutrient**	**Correlation with yields**	**Correlation with N substances**
DC 23	N	*0.468*	*0.126*	Ca	*0.481*	*–0.072*
DC 30		*0.536*	*0.079*		*0.509*	*0.003*
DC 33		*0.487*	*0.174*		*0.470*	*0.000*
DC 50–55		*0.510*	*0.160*		*0.530*	*–0.146*
DC 71		*0.294*	*–0.039*		*0.410*	*–0.166*
DC 23	P	*0.494*	*0.101*	Mg	*0.376*	*–0.002*
DC 30		*0.503*	*0.111*		*0.464*	*0.075*
DC 33		*0.434*	*0.112*		*0.388*	*0.047*
DC 50–55		*0.421*	*–0.082*		*0.381*	*–0.040*
DC 71		*0.302*	*–0.187*		*0.326*	*–0.106*
DC 23	K	*0.557*	*–0.007*	S	*0.398*	*0.181*
DC 30		*0.536*	*0.112*		*0.431*	*0.235*
DC 33		*0.433*	*0.098*		*0.320*	*0.337*
DC 50 - 55		*0.546*	*0.022*		*0.390*	*0.322*
DC 71		*0.335*	*–0.101*		*0.239*	*0.033*

VI: *Results of variance analysis for grain yields and content of N-substances*

source of variability	**d.f.**	**yields in $t.ha^{1}$**		**N-substances in %**	
		average square	**sign.**	**average square**	**sign.**
year	3	24.96	***	91.80	***
variety	1	8.25	***	5.26	***
previous crop	2	6.08	***	26.77	***
fertilisation	3	0.48	NS	3.26	***

NS – insignificant effect

VII: *Average values of grain yields in t.ha^{-1} (Kompakt)*

Previous crop	Factor	treatments				average
		1	2	3	4	
winter wheat	yields (t.ha^{-1})	6.04	5.90	6.21	6.14	6.07
	relative %	96.30	94.10	99.00	97.90	96.30
sugar-beet	yields (t.ha^{-1})	6.27	6.40	6.31	6.22	6.30
	relative %	100.00	102.00	100.60	99.20	100.00
maize	yields (t.ha^{-1})	5.56	5.66	5.86	5.68	5.69
	relative %	88.70	90.30	93.50	90.60	90.30
Average		5.96	5.99	6.13	6.01	6.02

VIII: *Average contents of N-substances in grain (Kompakt)*

Previous crop	Factor	treatments				Average
		1	2	3	4	
winter wheat	N-substances (%)	11.8	12.3	12.1	12.0	12.1
	relative %	108.9	113.6	111.0	110.9	107.3
sugar-beet	N-substances (%)	10.9	11.1	11.6	11.4	11.2
	relative %	100.0	102.7	106.7	104.8	100.0
maize	N-substances (%)	11.4	11.3	11.6	11.4	11.4
	relative %	105.0	103.8	106.5	105.2	101.5
Average		11.4	11.6	11.8	11.6	11.6

of the Kompakt and Jersey varieties by 9.7% and 9.1%, respectively. If we assess the yields of the variety Kompakt on the basis of fertilisation we see that when N_{min} nitrogen (treatment 2) was applied after sugar-beet as the previous crop we achieved the highest yields (6.40 t.ha^{-1}). If Campofort Garant P was applied in the DC 30 and 50 stages to correct the nutritional status it did not affect grain yields after this previous crop. By contrast when barley was grown after wheat and maize the foliar application of the fertiliser had a positive effect on grain yields but the yields of treatment 3 and 4 increased within the range of 0.3–4.9%. A higher increase in grain yields was monitored after application in the DC 30 stage; to a certain extent this corresponds with the fact that in terms of the effect of phosphorus this growth stage is decisive for yields (Tab. V).

The tendency of the barley variety Jersey was different. The yields were the highest (6.93 t.ha^{-1}) again after sugar-beet as the previous crop. To achieve these yields additional nitrogen fertilisation was necessary according to the content of N_{min} and an application of Campofort Garant P (treatment 3) in the DC 30 stage. The effect of Campofort application had no marked effect on barley grown after the other previous crops.

With higher grain yields the level of N-substances in the Jersey variety decreased as compared with the Kompakt variety, i.e. 11.35 % and 11.60 %, respectively. Likewise Faměra et Beber (1989), Kopecký (1985) and Tichý et al. (1991) arrived at the same conclusions proving that yields affected the content of N-substances. An application of nitrogen at a rate of 30 kg.ha^{-1} after sugar-beet as previous crop based on the level of N_{min} (treatments 2–4) and increasing the rate of nitrogen by 20 kg.ha^{-1}, i.e. from 30 to 50 kg, of barley grown after wheat and maize increased the content of N-substances in barley grain (Tab. VIII and X).

IX: *Average grain yields in t.ha^{-1} (Jersey)*

Previous crop	Factor	treatments				Average
		1	2	3	4	
winter wheat	yields (t.ha^{-1})	6.25	6.44	6.36	6.46	6.38
	relative %	95.10	98.00	96.80	98.30	94.00
sugar-beet	yields (t.ha^{-1})	6.57	6.85	6.93	6.82	6.79
	relative %	100.00	104.30	105.50	103.80	100.00
maize	yields (t.ha^{-1})	6.09	6.21	6.18	6.19	6.17
	relative %	92.70	94.50	94.10	94.20	90.90
Average		6.30	6.50	6.49	6.49	6.45

X: *Average contents of N-substances in grain (Jersey)*

Previous crop	Factor	treatments				Average
		1	2	3	4	
winter wheat	N-substances (%)	11.6	11.8	12.2	11.8	11.90
	relative %	109.1	110.6	114.9	111.4	106.90
sugar-beet	N-substances (%)	10.7	11.2	11.4	11.1	11.10
	relative %	100.0	105.5	107.2	104.4	100.00
maize	N-substances (%)	10.9	11.1	11.1	11.3	11.10
	relative %	102.3	104.5	104.0	105.7	99.90
Average		11.1	11.4	11.6	11.4	11.36

SUMMARY

In small-plot experiments established in 2001–2004 we studied the effect of the chemical composition of the plant dry matter of spring barley, varieties Kompakt and Jersey, on grain yields. A relatively strong correlation was confirmed between the chemical composition of the plant dry matter and yields. The correlation was most intensive in the case of nitrogen ($r = 0.536$), phosphorus ($r = 0.503$), magnesium ($r = 0.464$) and sulphur ($r = 0.431$) at the beginning of shooting (DC 30); in the case of potassium ($r = 0.557$) at the beginning of tillering (DC 23) and calcium ($r = 0.530$) during ear formation (DC 55). A relatively strong correlation remained from the beginning of tillering to the beginning of ear formation and later decreased. The weather conditions of the year and variety significantly affected grain yields and also the previous crop was important. Grain yields of the variety Kompakt were statistically significantly lower than of the variety Jersey (6.02 t.ha^{-1} and 6.45 t.ha^{-1}, respectively). The yields of barley grown after sugar-beet were the highest (6.30–6.79 t.ha^{-1}); the grain yields of barley after maize decreased by 9.1–9.7 %. Higher grain yields of the Jersey variety resulted in levels of N-substances (11.35 %) lower than in the Kompakt variety (11.35 % and 11.60 %, resp.). No correlation was discovered between the nitrogen level in the plant dry matter during vegetation and the content of N-substances in barley grain.

SOUHRN

Vliv předplodiny a diferencovaného hnojení na výnos a obsah N-látek v zrnu jarního ječmene

V rámci maloparcelních pokusů založených v letech 2001–2004 byl sledován vliv chemického složení sušiny rostlin jarního ječmene odrůdy Kompakt a Jersey na výnos zrna. Bylo potvrzeno, že existuje poměrně silný vztah mezi chemickým složením sušiny rostlin a dosaženým výnosem. Síla tohoto vztahu byla nejsilnější u dusíku ($r = 0{,}536$), fosforu ($r = 0{,}503$), hořčíku ($r = 0{,}464$) a síry ($r = 0{,}431$) v období počátku sloupkování (DC 30), u draslíku ($r = 0{,}557$) hned na počátku odnožování (DC 23) a u vápníku ($r = 0{,}530$) během metání (DC 55). Poměrně silný vztah přetrvával od počátku odnožování až do počátku metání, později se snižoval. Výnos zrna byl významně ovlivněn ročníkem, odrůdou, významně se projevila také předplodina a úroveň hnojení. Odrůda Kompakt (6,02 t.ha^{-1}) byla statisticky průkazně horší ve výnose zrna než odrůda Jersey (6,45 t.ha^{-1}). Nejvyšší výnos byl dosažen u ječmene pěstovaného po cukrovce (6,3–6,79 t.ha^{-1}), u ječmene jdoucího po kukuřici byl výnos zrna snížen o 9,1–9,7%. Vyšší výnos zrna u odrůdy ječmene Jersey se projevil poklesem obsahu N-látek (11,35 %) oproti odrůdě Kompakt (11,60%). Nebyla prokázána korelace mezi obsahem N látek v sušině rostlin během vegetace a obsahem dusíku v zrnu ječmene.

ječmen jarní, předplodina, chemické složení, výnos zrna, obsah N-látek

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