The influence of the year, fore-crops and fertilisation on yield and content of crude protein in spring barley

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ABSTRACT

In the years 2001–2003 in field trials we studied the effects of the conditions of year, fore-crops (winter wheat, sugar-beet, grain maize) and optimalization of the nutritional status on the yield and crude protein content in the grain of spring barley. From the analysis of the plants we can see that dry matter production and nutrient concentration in the plants were influenced by the conditions of the year and the fore-crop. After sugar beet, the growth of the dry matter was intensive and the concentrations of nutrients per one plant were higher as early as in the initial stages of vegetation. The yields in the years 2001 and 2002 corresponded with these results while the highest yields were seen after the sugar beet. Due to the extreme lack of precipitation, the best fore-crop in 2003 was maize. While the dose of 50 kg N/ha increased the yields after maize, after wheat it reduced the yields and increased the crude protein content in the grain.

Keywords: spring barley; fertilisation; chemical analyses of plants; fore-crop; yield; crude protein

Stabile yields and a good quality of spring barley are dependent on the weather conditions of the year, the soil type and many agronomical factors (Conry 1994). The order of these factors has not been exactly specified. Kulík (1995) considers fertilization to be the most important factor, while Procházka and Hudcová (1989), Ehrenbergerová et al. (1999), Petr et al. (2000) and Cerkal et al. (2001) point out the strong effect of the weather of the respective year.

One of the important factors is the optimisation of the nutritional status of spring barley. Balanced nitrogen fertilisation based on the analyses of soil samples (Fecenko et al. 1989) and on plant analyses in the early stages of vegetation (Otegui et al. 2002) is necessary to provide high and good-quality yields. The reason is that spring barley consumes 40–60% of all the nutrients within 25–30 days of growth and in this period it produces only about 20% of its dry matter. Optimal levels of nitrogen and phosphorus stimulate the production of shoots. Plants require higher levels of nitrogen until the stage of elongation growth when the production of biomass in spring barley is very high. In the period of elongation of the leaf sheath the intensity of nitrogen uptake is closely correlated with barley yields (Weston et al. 1993, Kubinec 1998).

MATERIAL AND METHODS

The effects of the conditions of the year, fore-crops and the optimisation of the nutritional status on yields and content of crude protein in spring barley (*Hordeum vulgare* L.) grain were studied at the experimental station of the School Farm of Mendel University of Agriculture and Forestry in Žabčice near Brno. The locality is situated in the maize growing production type, barley sub-type, in an altitude of 184 m, in the lowland area of the Dyje-Svratka dale, and is characterised as warm and moderately dry, with mild winters. The soil type is fluvial gley soil (FM_G), moderately heavy to heavy textured, the content of carbonates is below 0.5%, the content of humus in the topsoil is 2.44% and proportion of humic acids and fulvic acids is 0.49. Tables 1 and 2 show the results of analyses of soil samples before sowing and average temperatures and precipitation.

In the experiment we used the spring barley variety Kompakt (low semi-early variety with medium large grain and very good yields of front grain, the indicator of malting quality 9), grown after the following fore-crops: winter wheat (*Triticum aestivum* L.), sugar beet (*Beta vulgaris* L.) and grain

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Table 1. Agrochemical soil analysis and content of available nutrients (mg/kg) in layer 0–30 cm

Forecrop	pH/KCl	P	K	Ca	Mg	$N\text{-}NO_3^-$	$N\text{-}NH_4^+$	N mineral
Winter wheat (2001)	7.0	122	226	5354	376	8.1	4.4	12.5
Sugar beet (2001)	6.8	135	207	4930	396	10.5	3.0	13.5
Maize (2001)	6.8	114	253	4700	399	8.7	3.2	11.9
Winter wheat (2002)	6.2	63	214	3836	447	10.7	5.9	16.6
Sugar beet (2002)	6.6	113	195	4434	340	11.9	5.4	17.3
Maize (2002)	6.7	112	235	5142	198	4.9	4.9	9.8
Winter wheat (2003)	5.9	68	210	3900	368	11.2	5.6	16.8
Sugar beet (2003)	5.9	95	197	3576	311	7.4	4.8	12.2
Maize (2003)	6.5	131	254	3997	323	5.3	5.4	10.7

maize (*Zea mays* L.). The experiment had 4 replications on plots of 19.5 m^2; the harvesting area was 15 m^2. Disease and pest control was conducted according to methods valid for plant protection. A small-plot harvester was used for harvest and the yields were converted to 12% humidity. The yields and contents of protein in the grain were tested by analysis of variance and successive Tukey's test using the computer programme Statgraphics version 4.0.

According to the low content of phosphorus in the soil, Amofos (200 kg/ha) was applied in the year 2002 after winter wheat and Hyperkorn (200 kg/ha) in the year 2003 after winter wheat and sugar beet. These phosphorus fertilizers were applied before sowing in early spring and the following dose of amonium nitrate was reduced by the content of nitrogen in Amofos. Hypercorn was chosen because of the low pH in the soil (pH 5.9), but according to the lack of rainfall it remained on the soil surface for a long time. Other mineral nutrients (K, Ca, Mg) in the soil were of a good level so they were not added in mineral fertilisers.

The following factors were taken into account in the determination of the nitrogen fertiliser dose and optimisation of the nutritional status (Table 3): A – the fore-crop only (treatment 1), B – fore-crop and level of mineral nitrogen (N_{min}) in the soil (treatment 2), C – fore-crop, N_{min} in the soil and analyses of the aboveground parts of the plants (treatments 3 and 4). During the growing season, samples of aboveground parts of plants were obtained in individual stages of stand development to determine the dry matter of one plant and concentrations of major nutrients. The nutritional status of the plants was adjusted by the application of foliar fertilisers on the basis of the results in laboratory analyses. The choice of the fertiliser was based on the model concentration curves of nutrients published by Baier and Baierová (1991). Since the content of phosphorus in the plants during the growing season was quite low (Table 4) we tried to affect growth by applying a foliar fertiliser

Table 2. Average monthly temperatures and sums of precipitation

	Precipitation (mm)			Normal (mm) 1961–1990	Temperatures (°C)			Normal (°C) 1961–1990
	2001	2002	2003		2001	2002	2003	
January	25.5	3.1	18.2	24.8	0.2	–0.8	–1.5	–2.0
February	9.5	17.4	0.4	24.9	1.5	4.5	–2.3	0.2
March	46.0	21.2	3.0	23.9	5.8	5.8	5.1	4.3
April	31.7	28.7	18.2	33.2	9.3	10.4	9.5	9.6
May	31.8	68.8	42.2	62.8	17.6	18.0	17.4	14.6
June	42.0	103.8	11.6	68.6	17.0	19.2	21.4	17.7
July	68.6	107.5	48.6	57.1	21.2	21.1	20.6	19.3
March–July	220.1	329.9	123.6	245.6	14.2	14.9	14.8	13.1

Table 3. Treatments of the experiment

Treatments	Sugar beet	Winter wheat	Maize
1	0 kg N/ha	30 kg N/ha in AN	30 kg N/ha in AN
2	30 kg N/ha in AN	50 kg N/ha in AN	50 kg N/ha in AN
3	30 kg N/ha in AN + FF in Zadoks stage 31	50 kg N/ha in AN + FF in Zadoks stage 31	50 kg N/ha in AN + FF in Zadoks stage 31
4	30 kg N/ha in AN + FF in Zadoks stage 49	50 kg N/ha in AN + FF in Zadoks stage 49	50 kg N/ha in AN + FF in Zadoks stage 49

AN – ammonium nitrate (34% N), FF – foliar fertiliser (14% N, 10.5% P)

with water soluble phosphorus (14% N, 10.5% P) in a dose of 5 kg/ha.

RESULTS AND DISCUSSION

The effect of the conditions of the year

Yield variability and variability in the protein content of grain in the course of the experimental years were most affected by the weather conditions (82.3 and 76.2% share in the total variability, respectively). Cerkal et al. (2001) and Ehrenbergerová et al. (1999) also confirmed the dominant effect of the weather conditions of the year on barley yields of the studied locality. As a consequence of unfavourable weather conditions, the lack of precipitation in May and June in the year 2001 (Table 2) and later establishment of stands (in early April), the time of vegetation was shortened, yields were considerably reduced and the content of protein in the grain (12.8%) was above the norm for the purchase of malting barley. The weather conditions of the year 2002 at the experimental locality were ideal for the growth of spring barley; the average yield was 6.49 t/ha and the protein content was 10.3%. In the year 2003 the yields dropped due to poor precipitation to 5.88 t/ha and the protein content in the grain increased to 12.1%. Faměra and Beber (1989) and Frančáková (1985) confirmed the negative effects of high temperatures and a deficit of precipitation at the time of grain formation on the protein content in the grain.

The effect of the fore-crops

In the years 2001 and 2002 the sugar beet was the best fore-crop for spring barley, and the yields were 4.84 and 7.42 t/ha, respectively (Figure 1). In 2003, due to the lack of rainfall during vegetation, the best fore-crop was maize (6.17 t/ha). In terms of the protein content in the grain a good fore-crop was also sugar beet (12.2, 10.5 and 11.0%, Figure 1) and maize (13.0, 9.5 and 11.9%). In the years of insufficient rainfall the content of crude protein after winter wheat was higher than the norm for the purchase of malting barley. Kulík (1985) and Kopecký (1985) drew attention to the unfavourable effect of wheat on the protein content in grain.

In the first two years the plants after sugar beet took up more nutrients than after wheat and maize as the consequence of a more intensive plant growth, which was in relation to good mineralization of

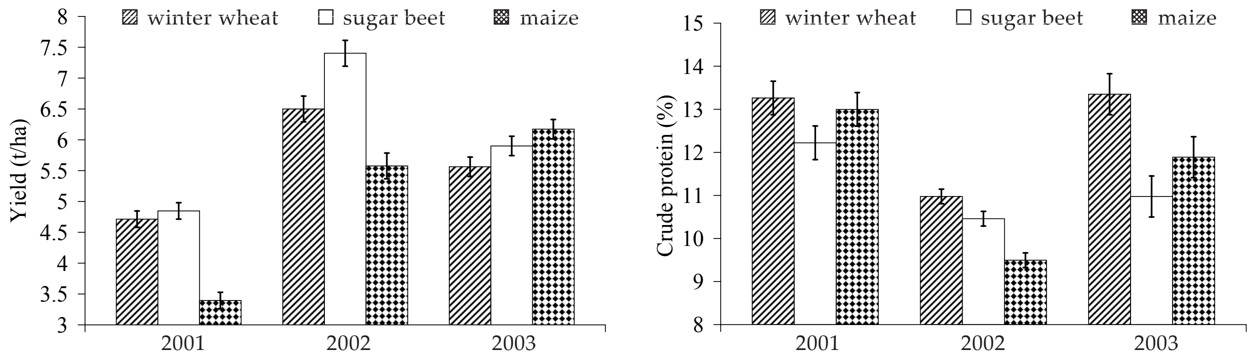

Figure 1. Analysis of variance for yield and crude protein after forecrops (Tukey $P \leq 0.05$, average values of all variants of fertilisation)

Table 4. Contents of nutrients (%) and dry matter (DM) of one plant (g) in the main stages of plant development on the 2nd treatment

Year	Zadoks stage	Sugar beet						Winter wheat						Maize					
		DM	N	P	K	Ca	Mg	DM	N	P	K	Ca	Mg	DM	N	P	K	Ca	Mg
2001	23	0.18	5.15	0.58	4.44	0.89	0.26	0.14	4.97	0.58	4.24	0.91	0.24	0.10	5.23	0.51	4.30	0.89	0.30
	31	0.82	4.40	0.45	3.39	0.84	0.22	0.71	3.52	0.41	3.24	0.68	0.18	0.42	4.01	0.44	3.64	0.82	0.24
	49	1.38	2.78	0.39	3.30	0.62	0.20	1.64	3.01	0.34	3.00	0.65	0.21	1.00	3.18	0.41	2.91	0.63	0.24
2002	23	0.08	4.84	0.47	3.46	0.69	0.15	0.07	5.18	0.52	3.71	0.81	0.22	0.05	4.60	0.48	3.98	0.85	0.21
	31	0.48	3.97	0.41	4.25	0.67	0.18	0.31	3.86	0.43	3.66	0.64	0.20	0.31	3.62	0.36	3.97	0.71	0.16
	55	1.77	1.72	0.19	2.44	0.42	0.14	1.75	1.34	0.23	2.03	0.48	0.17	0.96	1.39	0.28	1.93	0.48	0.16
2003	23	0.10	4.60	0.54	4.72	0.88	0.28	0.11	4.90	0.44	4.54	0.81	0.25	0.12	4.79	0.57	4.83	0.95	0.25
	31	0.78	3.41	0.43	3.53	0.69	0.17	0.60	3.64	0.30	3.46	0.60	0.17	0.73	3.81	0.42	3.76	0.65	0.18
	55	2.01	1.43	0.25	2.26	0.41	0.14	1.99	1.79	0.26	2.24	0.33	0.16	2.08	1.71	0.26	2.20	0.36	0.14

post harvest plant residues (beet tops) and thus the increased content of N_{min} in the soil (Table 1). The initial growth of stands after sugar beet was faster and the plants had more tillers (2–3 tillers), while the growth and tillering of stands after maize and wheat lagged behind (1–2 tillers). Kopecký (1985) reported a reduced intensity of tillering and higher reduction of tillers after wheat; he also considered sugar beet to be a better forecrop for spring barley. At the beginning of vegetation in the year 2003 the stands after sugar beet were more developed (had more tillers). For this intensively growing stand it was more difficult to resist drought than for the stand after maize, which developed better in the later stages.

The effects of fertilisation

After wheat the response of barley to intensive nitrogen fertilisation (50 kg N/ha) was the lowest; this dose did not increase the yields in any of the years. In the years 2001 and 2003 this treatment resulted in a negative increase in the protein content (Table 5). Hence a lower dose of nitrogen (30 kg N/ha) appears to be sufficient for barley after wheat. Tichý et al. (1991) came to the same conclusions, i.e. reduced yields in years of minimal yield level or slight increase in yields in the years of maximal yield level with the application of 60 kg N/ha. Kandera (1994) achieved the best yields after the application of 60 kg N/ha before sowing, but this dose increased the protein content in grain to 12.5%. In his experiments split nitrogen fertilisation after wheat did not give good results. Frančáková (1985) reported a lower malting quality of barley after winter wheat and silage maize under the effect of increasing doses of nitrogen (0, 50, 75 and 100 kg N/ha).

After sugar beet the response of spring barley to 30 kg N/ha was positive. Foliar fertilization in the years 2001 and 2002 was not successful because of

Table 5. Analysis of variance for yields (t/ha) and crude protein (%)

Forecrop	Year	2001				2002				2003			
	factor/variant	1	2	3	4	1	2	3	4	1	2	3	4
Winter wheat	yield (t/ha)	4.71^{A}	4.51^{A}	4.78^{A}	4.86^{A}	6.49^{A}	6.19^{A}	6.83^{A}	6.49^{A}	5.55^{A}	5.30^{A}	5.61^{A}	5.78^{A}
	protein (%)	13.1^{A}	13.9^{A}	13.2^{A}	12.8^{A}	10.9^{A}	10.7^{A}	10.8^{A}	11.5^{B}	12.6^{A}	14.0^{B}	13.5^{B}	13.4^{AB}
Sugar beet	yield (t/ha)	4.77^{A}	4.98^{A}	4.67^{A}	4.96^{A}	7.38^{A}	7.48^{A}	7.40^{A}	7.35^{A}	5.62^{A}	5.81^{AB}	6.30^{B}	5.87^{AB}
	protein (%)	12.1^{A}	12.2^{A}	12.4^{A}	12.3^{A}	10.1^{A}	10.5^{AB}	10.7^{B}	10.6^{B}	10.5^{A}	10.7^{A}	11.5^{A}	11.3^{A}
Maize	yield (t/ha)	3.33^{A}	3.47^{A}	3.39^{A}	3.38^{A}	5.14^{A}	5.50^{AB}	6.28^{B}	5.38^{AB}	6.01^{A}	6.21^{A}	6.27^{A}	6.20^{A}
	protein (%)	12.7^{A}	13.0^{A}	13.4^{A}	12.9^{A}	9.9^{A}	9.4^{B}	9.3^{B}	9.3^{B}	11.8^{A}	11.5^{A}	12.2^{A}	12.1^{A}

Statistically significant difference is between letters A and B; Tukey $P \leq 0.05$

Table 6. Average correlation between content of nutrients (mg/plant), yields (t/ha) and crude protein (%); 2001–2003

Zadoks code (stage)	Nutrient	Correlation with yield	Correlation with proteins	Nutrient	Correlation with yield	Correlation with proteins
23		0.529	0.097		0.544	0.071
31		0.595	0.137		0.492	0.108
33	N	0.742	0.129	Ca	0.823	–0.087
49–55		0.429	–0.065		0.444	–0.287
71–73		0.615	0.261		0.333	0.098
23		0.767	0.159		0.365	0.239
31		0.709	0.161		0.559	0.130
33	P	0.840	0.007	Mg	0.644	–0.207
49–55		0.337	–0.266		0.115	–0.222
71–73		0.402	0.098		0.254	0.149
23		0.621	0.036		0.564	0.280
31		0.674	0.164		0.518	0.554
33	K	0.823	–0.119	S	0.682	0.386
49–55		0.643	–0.181		0.304	0.340
71–73		0.519	0.062		0.456	0.356

a higher content of nitrogen and phosphorus in the soil. Baier et al. (1990) discovered that high yields could be achieved thanks to the mobilisation of nutrient reserves as a consequence of sufficient organic fertilisation in the crop rotation. In the year 2003, a year of poor rainfall, foliar fertilisation worked well.

Increased yields of spring barley after maize were observed as a reaction to fertilisation. Application of leaf fertilisers at the beginning of stem elongation was the best and increased yields by 1.8, 22.2 and 4.3% compared to the first treatment (Table 5). In the years 2001 and 2003 the protein content in grain increased statistically insignificantly after fertilisation.

The results of plant analyses

During the year 2001 the average content of nitrogen per plant increased from 7.3 mg (5.0%) in the tillering stage to 41.6 mg (3.0%) in the stage of head emergence. The high uptake of nitrogen by the plants during vegetation and the low production of dry matter in the second half of vegetation (1407 mg of dry matter of one plant in Zadoks stage 49, Chang et al. 1974) influenced by the lack of precipitation plus the impaired health conditions (leaf diseases) had a negative effect on yields and grain quality.

In the year 2002 the average content of nitrogen in the tillering stage was 3.3 mg per plant (4.9%). At this stage the content of dry matter (68 mg) was considerably lower than in the year 2001 (144 mg). At the stage of head emergence the dry matter of one plant was 1758 mg and the content of nitrogen increased to only 24.8 mg (1.4%). Such a low nitrogen content in the plant resulted in a lower content of nitrogen in the grain and the higher dry matter content had a positive effect on yields.

At the beginning of the vegetation (stage 23) in the year 2003 the average N content was 5.1 mg (4.7%) and at the stage of head emergence it was 31.4 mg (1.6%). At the stage of head emergence the dry matter content in one plant increased from 107 mg to 1962 mg. Due to the drought in June, which hit the stand after the stage of head emergence, the shoots dried up and the protein content in the grain increased.

During vegetation the N:K ratio narrowed from 1.0–1.3 in the tillering stage to 0.7–1.0 in the stage of head emergence; the uptake of N predominated over K only in the tillering stage and the N:P ratio narrowed during vegetation from 8.9–10.0 to 5.8–7.8. Baier et al. (1990) confirmed similar results, i.e. the N:P ratio narrowing from 9.5 to 7.3.

Correlation coefficients between nutrient uptake and yields and between nutrient uptake and protein content in the grain were calculated on the basis of

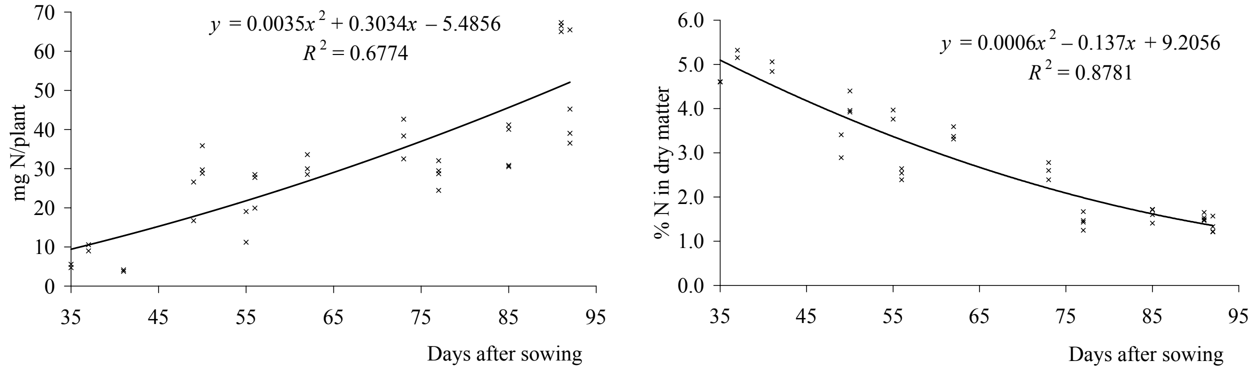

Figure 2. Dynamics of N content in barley plants after sugar beet in the course of the growing season

a three-year chemical analyses of plants in the main stages of development (Table 6). There is a positive correlation between yields and the N and K content in the plant during the entire period of vegetation, particularly in the stage of the 3rd node (stage 33). In the early stages of vegetation (up to stage 33) there is a positive correlation between yields and the P and Ca content. Mg correlation is the highest in the period of stem elongation (stage 31–33), i.e. in the period of leaf area formation. Compared to the other nutrients, the highest correlation is between the content of crude protein in grain and sulphur.

In the three-year-period the highest average yields (6.05 t/ha) and the lowest content of crude protein (11.22%) of all the fore-crops were achieved after sugar beet; due to this fact model curves of the N concentration in mg per plant and in per cent were drawn as the three-year results of the sampling of the aboveground parts of the plants (Figure 2). According to these model curves the concentration of nitrogen in the tillering stage (37th day after sowing) is counted to 5.0% (10.5 mg) and in the stage of ear formation (78th day after sowing) it is 2.2% (40.0 mg). Increasing the dry matter weight of one plant reduced the percentage content of nitrogen in the plant.

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ABSTRAKT

Vliv hnojení a předplodin na výnos a obsah bílkovin v zrnu jarního ječmene

V průběhu let 2001–2003 byl v polních pokusech sledován vliv ročníku, předplodin (ozimá pšenice, cukrovka, kukuřice na zrno) a optimalizace výživného stavu na výnos a obsah bílkovin v zrnu jarního ječmene. Z provedených rozborů rostlin vyplývá, že produkce sušiny a koncentrace živin v rostlině byly ovlivněny zejména ročníkem a předplodinou. Po cukrovce bylo dosaženo intenzivního nárůstu sušiny a vyšších koncentrací živin na rostlinu již v počátečních fázích vegetace, zatímco porosty po pšenici a po kukuřici na počátku vegetace zaostávaly v růstu. Nejvhodnější předplodinou byla v letech 2001 a 2002 cukrovka. V roce 2003 byla díky extrémnímu nedostatku srážek nejlepší předplodinou kukuřice. Zatímco dávka dusíku 50 kg/ha zvýšila výnos jarního ječmene po kukuřici, po pšenici působila snížení výnosu a zvýšení obsahu bílkovin v zrnu.

Klíčová slova: jarní ječmen; hnojení; chemické rozbory rostlin; předplodina; výnos; hrubé bílkoviny

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