Modification of crop management and its influence on the structure of yield and quality of spring barley grain

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ABSTRACT

In 1998–2000, in a multi-factorial field experiment established by the method of split blocks and subplots, we studied the effect of three systems of beet tops management, two sowing rates and two levels of N fertilization and the effect of interactions of the factors on production and qualitative indicators of spring barley varieties Amulet and Kompakt. The evaluation shows the dominant effect of the particular year on the variability of all characters. The proportion of the effect of the year on the variability of characters ranged from 2.1 (number of plants per m^2) to 80.1% (yield). The variability of quality parameters was also considerably affected by the genetic factor of the variety (grain over 2.5 mm sieve 40.4%, TGW 20.5%). The level of characters was greatly variable in relation to the course of climatic conditions of the year. The highest grain yield was achieved in 1999 (7.21 t/ha), the lowest one in 2000 (5.25 t/ha). The best quality parameters were shown by grain from the 1998 harvest (yield 6.20 t/ha) with significantly highest TGW (47.76 g), a high proportion of grain over 2.5 mm sieve (92.01%, 5.54 t/ha) and a favourable content of N substances in the grain (10.60%). Ploughed down beet tops supported the creation of the yield, the average differences between variants were, however, minimal being heavily affected by the course of weather in particular years. More favourable conditions for the creation of the yield (6.17 t/ha) and for the formation of mechanical properties of the spring barley grain (TGW 45.55 g, grain over 2.5 mm sieve 85.86%) were produced by variants with late ploughing down beet tops, the smallest accumulation of N substances occurred in variants with harvested beet tops (11.83%). Sowing rate significantly affected values of all studied characters. Variants sown 4.5 MGS (6.27 t/ha) gave higher average grain yields, grain of better quality was obtained from the stands sown 3.5 MGS (TGW 45.22 g, grain over 2.5 sieve 84.41%, N substances 11.93%). Between particular varieties, significant differences were found both in the economic yield and the grain quality. The Kompakt variety showed on average 4.7% higher yield (6.37 t/ha) than the Amulet variety which, however, reached the higher average TGW values as well as the proportion of grain over 2.5 mm sieve (45.87 g, 88.24%). The grain quality of the Amulet variety was negatively affected by the increased accumulation of N substances in the grain (12.49%). As compared with control, N fertilization at the rate of 30 kg/ha showed significant increase in the yield in 1998 only (by 7.5%) while in other years, an increase in the yield was not noticed. In all years under investigation, the TGW values and the proportion of grain over 2.5 mm sieve decreased and the content of N substances in grain increased after application of N at the rate of 30 kg/ha.

Keywords: spring barley; beet tops; yield; yield structure; grain quality; N fertilization; sowing rate

Sugar beet belongs traditionally to the best foregoing crops for the creation of yield as well as malt quality of spring barley in the production regions of its growing. Present technologies of sugar beet harvesting with the subsequent ploughing down of beet tops, however, represent considerable amounts of organic matter and nutrients that enter the soil. The course of mineralization of ploughed down matter of beet tops when release of nutrients occurs significantly affects the production process of spring barley and its quality (Zimolka et al. 1999).

Mineralization of the organic matter of beet tops and its intensity are dependent above all on the course of weather conditions at the time after ploughing down into soil and in the course of the growing season. Provazník et al. (2000) mention that mineralization of ploughed down beet tops gives theoretically the following average amounts of nutrients into soil: 102 kg N, 12 kg P, 148 kg K, 33 kg Ca and 18 kg Mg. The shift of mineralization to later stages of the production process (shooting, grain formation and ripening) is the reason for uncontrolled release of nitrogen and marked changes of its dynamics in soil with negative effects on lodging, health conditions and worsening of grain quality parameters. The cause of the retardation or even cessation of mineralization processes in soil is early and long-term freezing of soil during winter and dry and cold weather in spring after sowing spring barley. Possibilities of affecting the processes are related to problems of the term of beet tops ploughing down and optimization of spring barley nutrition. Stress is particularly laid on the rationalization of N nutrition (Tóth 2000).

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Table 1. Agrochemical soil properties before the establishment of the experiment, depth 0–250 mm (Provazník et al. 2000)

Year	pH/KCl	Available nutrients – Mehlich II (mg/kg)			
		P	K	Ca	Mg
1998	6.9	67	209	4 430	323
1999	7.0	102	254	5 228	352
2000	6.84	91	263	3 935	318

MATERIAL AND METHODS

The effects of sugar beet tops management on selected quantitative and qualitative parameters of spring barley were studied in the plant production experimental station of the Agricultural Training Enterprise Žabčice near Brno, Mendel University of Agriculture and Forestry, Brno, in 1998–2000. The station is situated in the maize agricultural production region, sub-region K2, at an average altitude of 185 m. The region that is part of the Dyje-Svratka valley basin is characterized as warm, slightly dry with moderate winters.

The soil type was classified as Gley Fluvisol (FL_G) developed on the Svratka river alluvium. As for soil texture, it is a moderately- to heavy-textured clay-loam to clay soil with the content of clay particles amounting to 55–65%. The groundwater table occurs about 1.8 m under the soil surface. The agrochemical properties of the soil are given in Tables 1 and 2. The course of weather in particular years is given in Table 3.

In a series of experiments with perpendicular-split blocks and subplots, the following factors were evaluated: three systems of beet tops management (a – early ploughing down of bet tops, b – late ploughing down of bet tops, c – harvested beet tops) under two levels of mineral N fertilization (0 kg/ha N, 30 kg/ha N) with the differentiated sowing rate of 3.5 and 4.5 MGS. Each of the variants was in 4 repetitions with an area of trial plots 12.5 m^2. In the experiments, the top-ranking malt varieties Amulet and Kompakt were studied. Barley was grown during all years under investigation after sugar beet fertilized by manure at a rate of 40 t/ha in the crop rotation

Table 2. Content of N_{an} in soil (mg/kg) before establishing the experiment according to variants of beet tops management, depth 0–500 mm, 1998–2000

Year	Variants of beet tops management					
	a		b		c	
	0–250	250–500	0–250	250–500	0–250	250–500
1998	17.66	17.93	17.11	8.49	20.58	8.74
1999	18.17	17.51	13.81	14.33	14.58	18.23
2000	20.27	20.58	15.11	14.60	11.78	22.42

Table 3. Average monthly temperatures (°C) and monthly sums of precipitation (mm)

Month	Average monthly temperatures (°C)					Monthly sums of precipitation (mm)				
	30-year average (1961–1990)	1997	1998	1999	2000	30-year average (1961–1990)	1997	1998	1999	2000
1	–2.0	–3.7	1.2	–0.7	–1.9	24.8	14.3	12.0	5.0	29.6
2	0.2	1.8	3.6	–0.1	3.1	24.9	18.6	2.8	10.6	22.7
3	4.3	4.6	4.8	6.5	5.4	23.9	25.6	15.3	20.8	60.4
4	9.6	7.5	12.3	11.7	14.0	33.2	20.8	39.3	49.8	1.6
5	14.6	16.1	15.8	15.8	17.4	62.8	51.6	20.2	34.2	39.7
6	17.7	19.2	20.1	18.2	20.3	68.6	63.8	71.4	81.6	16.0
7	19.3	18.7	20.6	21.2	18.6	57.1	268.8	53.8	82.4	113.3
8	18.6	20.9	20.7	19.5	21.2	54.3	35.6	37.6	10.4	45.5
9	14.7	14.7	14.7	18.6	14.6	35.5	17.0	133.2	35.6	42.5
10	9.5	7.3	9.3	10.2	12.6	31.8	25.6	95.0	11.2	21.4
11	4.1	4.4	1.1	3.4	7.5	36.8	68.6	27.4	42.2	56.6
12	0.0	2.0	–2.0	–0.2	1.5	26.3	43.2	10.8	5.6	39.0
$\bar{x}/\Sigma$	9.2	9.5	10.2	10.4	11.2	480.0	653.5	518.8	389.4	488.3

Table 4. Characteristics of incorporated beet tops

Year	Yield (t/ha)	Dry matter (%)	Content of main macroelements (% in dry matter)				
			N	P	K	Ca	Mg
1997	23.96	21.15	2.12	0.28	4.15	0.88	0.41
1998	18.80	14.55	3.55	0.37	3.16	0.76	0.54
1999	21.20	16.90	3.33	0.264	4.75	0.44	0.47

of pea – winter wheat – sugar beet – spring barley. In the variant a, beet tops were crushed after sugar beet harvesting (mid-October), they were evenly layered and ploughed down to a depth of 250–280 mm. In the variant b, beet tops were similarly ploughed down a month later (mid-November) and in the variant c, beet tops were removed (ploughing carried out in terms of the variant b). Table 4 gives the average values of chemical analyses of the beet tops and their amounts ploughed down in 1997, 1998 and 1999.

In spring, the pre-seeding treatment of soil was carried out (smoothing harrow + harrow). Nitrogen was applied as a single measure before sowing in the form of SYNFERTA combined fertilizer (12% N, 11% P, 11% K) at a rate of 0 and 30 kg/ha N. The treatment of crops, using pesticides to control weeds, diseases and pests, was carried out according to standard methods for the plant protection.

In each repetition, the number of plants per unit area was determined from an area of 0.25 m^2 after full heading as well as the number of created and fertile tillers on a plant (Table 5). Before the harvest, the number of spikes per m^2 was evaluated, as well as the number of grains per spike and the accumulation potential of the stands. The total economic yield of grain was determined from the harvested plots after drying (14%) and preliminary cleaning. The percentage and yield of grain over 2.5 mm sieve were also determined as well as the weight of 1000 grains (TGW) and the content of N substances in the grain (%).

The results were processed by the multi-factorial analysis of variance using the STATISTICA computer program. To test average differences, the test according to Tukey was used on a 5 and 1% significance level. Homogeneity of variances was verified using Bartlett's test.

RESULTS AND DISCUSSION

The statistical evaluation of the effect of particular factors on characters under study including their interaction from a half experimental series in 1998 to 2000 is summarized in Table 6. Table 7 gives the differences between the particular levels of factors.

The results show that all factors under the study affected highly significantly or significantly the general level of the economic yield and the parameters of the spring barley grain quality. The particular year (80.1%) in the course of the three-year study appeared as having a dominant effect on the total yield variability, the proportion of other factors ranged from 0.6% (sowing rate) to 5.7% (variety). In case of quality characters, the year-class affected most the variability of the content of N substances in the grain (79.6%) and TGW (62.3%), the variability of quality parameters was also highly affected by the genetic factor of the variety (grain over 2.5 mm

Table 5. Proportion of factors on total variability of examined characters (%)

Examined characters/ sources of variability	Proportion of variability					
	years	variant of beet tops management	variety	sowing rate	N fertilization	interaction
Number of plants (per m^2)	2.1	1.1	0.1	90.7	0.4	5.6
Number of tillers per plant	27.1	0.8	0.0	55.6	3.0	13.5
Number of fertile tillers per plant	6.8	2.5	7.5	63.6	2.2	14.8
Number of spikes (per m^2)	35.2	0.7	18.1	18.5	1.5	26.0
Number of grains per spike	62.3	0.3	19.0	4.0	0.1	14.3
Number of grains (per m^2)	55.2	0.6	26.4	1.1	0.9	15.8
Yield (t/ha)	80.1	2.5	5.7	0.6	1.4	9.7
TGW (g)	62.3	5.6	20.5	0.6	1.6	9.4
Grain > 2.5 mm sieve (%)	38.2	5.5	40.4	0.1	1.4	14.4
Content of proteins in grain (%)	79.6	4.3	5.9	2.8	3.3	4.1

Table 6a. Analysis of variance for examined characters in 1998 to 2000

Source of variability	*df*	Number of plants (per m^2)		Number of tillers per plant		Number of fertile tillers per plant		Number of spikes (per m^2)		Number of grains per spike	
		MS									
Y: year	2	13 962.3	**	15.10	**	2.29	*	353 610.0	**	475.63	**
e(R, Y)	9	1 416.1		0.36		0.30		13 443.2		1.77	
A: variety	1	452.5	NS	0.02	NS	2.54	**	182 156.4	**	145.35	**
Y × A	2	897.6	NS	0.46	NS	0.06	NS	4 883.3	NS	59.49	**
e(A)	9	1 469.1		0.30		0.22		11 200.5		2.74	
B: beet tops	2	7 228.5	**	0.42	NS	0.83	*	6 673.4	NS	1.99	NS
Y × B	4	655.8	NS	0.26	NS	0.50	*	35 579.4	**	3.67	NS
e(B)	18	829.9		0.16		0.14		6 657.1		1.34	
A × B	2	1 847.5	NS	0.35	NS	0.10	NS	2 021.3	NS	4.37	NS
Y × A × B	4	504.3	NS	0.56	NS	0.07	NS	6 305.9	NS	3.23	NS
e(A × B)	18	1 099.4		0.31		0.10		6 171.5		1.59	
C: sowing rate	1	616 882.8	**	30.98	**	21.49	**	185 186.8	**	30.81	**
Y × C	2	11 642.5	**	1.43	**	1.87	**	34 494.6	**	4.69	NS
A × C	1	108.8	NS	0.16	NS	0.22	NS	3 479.2	NS	0.07	NS
B × C	2	673.3	NS	0.01	NS	0.04	NS	6 591.1	NS	0.38	NS
Y × A × C	2	356.6	NS	0.30	NS	0.16	NS	31 536.1	**	1.22	NS
Y × B × C	4	1 668.9	NS	0.23	NS	0.09	NS	4 608.3	NS	0.81	NS
A × B × C	2	1 400.7	NS	0.00	NS	0.06	NS	105.8	NS	2.44	NS
Y × A × B × C	4	1 520.9	NS	0.21	NS	0.04	NS	2 445.4	NS	2.18	NS
e(C)	54	624.9		0.20		0.07		3 894.0		1.74	
D: fertilization	1	2 514.6	NS	1.68	**	0.73	**	15 007.8	NS	0.48	NS
Y × D	2	0.7	NS	0.09	NS	0.09	NS	4 313.9	NS	0.66	NS
A × D	1	547.3	NS	0.01	NS	0.00	NS	4 991.7	NS	1.59	NS
B × D	2	1 362.1	NS	0.16	NS	0.11	NS	1 634.1	NS	3.57	NS
C × D	1	45.9	NS	0.07	NS	0.40	*	12 495.2	NS	0.96	NS
Y × A × D	2	77 907.0	NS	0.60	*	0.02	NS	1 039.5	NS	0.63	NS
Y × B × D	4	588.1	NS	0.06	NS	0.07	NS	2 057.8	NS	0.43	NS
Y × C × D	2	1 881.9	NS	0.07	NS	0.15	NS	3 674.4	NS	0.55	NS
A × B × D	2	17.8	NS	0.31	NS	0.00	NS	1 759.9	NS	0.08	NS
A × C × D	1	525.4	NS	0.00	NS	0.26	NS	11 237.5	NS	0.23	NS
B × C × D	2	1 199.8	NS	0.06	NS	0.06	NS	2 357.9	NS	1.40	NS
Y × A × B × D	4	1 000.0	NS	0.09	NS	0.15	NS	9 223.9	NS	1.78	NS
Y × A × C × D	2	401.3	NS	0.08	NS	0.12	NS	7 392.0	NS	0.76	NS
Y × B × C × D	4	972.1	NS	0.19	NS	0.07	NS	2 894.0	NS	2.27	NS
A × B × C × D	2	2 369.9	NS	0.17	NS	0.19	NS	13 305.0	NS	0.88	NS
Y × A × B × C × D	4	219.2	*	0.08	NS	0.09	NS	4 032.1	NS	0.55	NS
e(D)	108	658.5		0.18		0.08		5 163.0		1.25	
Total	287										

NS = not significant, * $P \leq 0.05$, ** $P \leq 0.01$

sieve 40.4%, TGW 20.5%). Similar results are also mentioned by Cerkal et al. (2001), Ehrenbergerová et al. (1999), Flašarová and Onderka (1997) etc. The significant effect of the year was also demonstrated by interactions of particular year-classes with other experimental factors.

The level of studied characters was considerably variable in relation to the intensity of particular factors (Table 7). Between years, significant differences were found in the creation, reduction and compensation of yield-forming elements, in the yield and quality of grain. The significantly highest yield of grain was achieved in 1999 (7.21 t/ha). On the other hand, the lowest yield level was achieved in 2000 (5.25 t/ha) when the precipitation deficit and the occurrence of highly above-average tempera-

Table 6b. Analysis of variance for examined characters in 1998 to 2000

Source of variability	*df*	Number of grains (per m^2)		Yield (t/ha)		TGW (g)		Grain > 2.5 mm sieve (%)		Content of proteins in grain (%)	
		MS									
Y: year	2	690 519 168	**	92.12	**	527.125	**	4 495.221	**	418.097	**
e(R, Y)	9	7 761 413		0.67		4.267		29.235		0.919	
A: variety	1	330 617 984	**	6.56	**	173.600	**	4 758.814	**	31.244	**
Y × A	2	50 888 392	*	1.48	*	4.632	NS	652.498	**	1.642	**
e(A)	9	7 230 569		0.35		2.212		34.199		0.077	
B: beet tops	2	7 876 653	NS	0.93	*	47.053	**	644.699	**	22.763	**
Y × B	4	15 980 263	*	5.18	**	40.459	**	563.992	**	1.165	**
e(B)	18	3 981 345		0.18		0.923		2.972		0.044	
A × B	2	1 693 185	NS	0.26	NS	1.561	NS	71.688	**	4.164	**
Y × A × B	4	4 821 792	NS	0.12	NS	0.591	NS	9.504	NS	1.561	**
e(A × B)	18	3 771 273		0.18		1.461		4.605		0.204	
C: sowing rate	1	14 040 010	*	0.67	**	4.651	**	15.914	*	14.842	**
Y × C	2	18 781 246	**	0.11	NS	2.765	*	88.998	**	0.662	**
A × C	1	37 212	NS	0.00	NS	0.125	NS	0.098	NS	0.085	NS
B × C	2	947 492	NS	0.14	NS	0.880	NS	13.652	*	0.008	NS
Y × A × C	2	10 737 307	NS	0.11	NS	0.841	NS	11.809	NS	0.017	NS
Y × B × C	4	2 577 780	NS	0.07	NS	0.213	NS	3.066	NS	0.015	NS
A × B × C	2	1 503 703	NS	0.00	NS	1.408	NS	26.928	**	0.379	*
Y × A × B × C	4	2 648 654	NS	0.06	NS	0.563	NS	15.303	**	0.902	**
e(C)	54	3 390 876		0.09		0.606		3.844		0.114	
D: fertilization	1	10 679 632	NS	1.63	**	13.347	**	164.863	**	17.150	**
Y × D	2	2 718 961	NS	2.02	**	5.206	**	27.142	**	1.150	**
A × D	1	5 728 464	NS	0.02	NS	0.023	NS	1.983	NS	0.631	**
B × D	2	5 124 451	NS	0.13	NS	0.207	NS	11.956	NS	0.045	NS
C × D	1	1 597 653	NS	0.00	NS	0.201	NS	0.113	NS	0.194	NS
Y × A × D	2	1 297 993	NS	0.10	NS	1.031	NS	32.425	**	1.044	**
Y × B × D	4	1 801 600	NS	0.08	NS	1.224	NS	19.174	*	0.070	NS
Y × C × D	2	3 179 822	NS	0.12	NS	0.596	NS	1.147	NS	0.396	*
A × B × D	2	592 541	NS	0.13	NS	0.161	NS	2.443	NS	0.369	*
A × C × D	1	6 807 774	NS	0.03	NS	0.233	NS	4.376	NS	0.304	NS
B × C × D	2	3 532 599	NS	0.09	NS	0.013	NS	0.491	NS	0.619	**
Y × A × B × D	4	5 629 533	NS	0.14	NS	0.553	NS	1.637	NS	0.204	NS
Y × A × C × D	2	4 981 644	NS	0.20	NS	0.306	NS	0.412	NS	1.094	**
Y × B × C × D	4	4 074 040	NS	0.12	NS	0.762	NS	9.435	NS	0.763	**
A × B × C × D	2	8 600 961	NS	0.00	NS	3.527	**	10.968	NS	1.200	**
Y × A × B × C × D	4	2 558 462	NS	0.05	NS	1.546	NS	29.400	**	1.053	**
e(D)	108	3 267 596		0.08		0.708		5.572		0.090	
Total	287										

NS = not significant, * $P \leq 0.05$, ** $P \leq 0.01$

tures at the time of flowering (Table 3) negatively affected the productivity of spikes (17.40 grains) contributing generally to the formation of the lowest accumulation capacity of stands (13 917 grains/m^2). Persisting unfavourable weather conditions in the period of grain formation and ripening were also the cause of the high content of N substances in grain (14.53%). Conditions for the attainment of high economic yield in 1999 were formed already in the course of tillering (3.43 tillers) with a subsequent maintenance of the high number of productive tillers (1.64) with the highest number of grains per spike (21.85). Although the significantly highest accumulation potential (18 809 grains/m^2) was not sufficiently fulfilled (TGW 43.35 g), it was fully sufficient for achiev-

Table 7. Differences between factors in 1998 to 2000

Level of factors		n	Number of plants (per m²)		Number of tillers per plant		Number of fertile tillers per plant		Number of spikes (per m²)		Number of grains per spike		Number of grains (per m²)		Yield (t/ha)		TGW (g)		Grain > 2.5 mm sieve (%)		Content of proteins in grain (%)	
			mean	dif.	mean	dif.	mean	dif.	mean	dif.	mean	dif.	mean	dif.	mean	dif.	mean	dif.	mean	dif.	mean	dif.
Year	1998	96	318.2	b	3.09	b	1.41	b	738.5	b	19.56	b	14457	b	6.20	b	47.76	a	92.01	a	10.60	c
	1999	96	334.5	a	3.43	a	1.64	a	859.9	a	21.85	a	18809	a	7.21	a	43.35	b	79.36	b	11.34	b
	2000	96	341.8	a	2.64	c	1.35	b	796.5	a	17.40	c	13917	b	5.25	c	44.17	b	81.15	b	14.53	a
Variety	Amulet	144	332.8	a	3.06	a	1.38	b	773.2	b	18.89	b	14657	b	6.07	b	45.87	a	88.24	a	12.49	a
	Kompakt	144	330.2	a	3.05	a	1.56	a	823.5	a	20.31	a	16799	a	6.37	a	44.32	b	80.11	b	11.83	b
Variant of	a	96	330.2	ab	3.09	a	1.49	ab	801.4	a	19.57	a	15752	a	6.33	a	44.29	b	81.19	b	11.93	b
beet tops	b	96	323.5	b	3.10	a	1.55	a	804.7	a	19.76	a	16002	a	6.17	b	45.55	a	85.86	a	12.72	a
management	c	96	340.8	a	2.98	a	1.37	b	788.9	a	19.48	a	15430	a	6.15	b	45.45	a	85.48	a	11.83	c
Sowing rate	3.5 MGS	144	285.2	b	3.38	a	1.74	a	773.0	b	19.93	a	15507	b	6.17	b	45.22	a	84.41	a	11.93	b
	4.5 MGS	144	377.8	a	2.72	b	1.20	b	823.1	a	19.28	b	15949	a	6.27	a	44.97	b	83.94	b	12.38	a
N fertiliz-	0 kg/ha	144	334.5	a	2.98	b	1.42	b	791.1	a	19.56	a	15536	a	6.14	b	45.31	a	84.93	a	11.91	b
ation	30 kg/ha	144	328.5	a	3.13	a	1.52	a	805.5	a	19.64	a	15921	a	6.29	a	44.88	b	83.42	b	12.40	a

a – early ploughing down, b – late ploughing down, c – beet tops removed; means with different letters are statistically significant at $P \leq 0.05$

Minimum significant differences

Year	$\alpha = 0.05$	15.2	0.24	0.22	46.7	0.54	1123	0.33	0.83	2.18	0.39
	$\alpha = 0.01$	20.9	0.33	0.30	64.3	0.74	1544	0.45	1.14	3.00	0.53
Variety	$\alpha = 0.05$	10.2	0.15	0.12	28.2	0.44	717	0.16	0.40	1.56	0.07
	$\alpha = 0.01$	14.7	0.21	0.18	40.6	0.63	1030	0.23	0.57	2.14	0.11
Variant of beet tops management	$\alpha = 0.05$	10.6	0.15	0.14	30.1	0.43	735	0.16	0.35	0.64	0.08
	$\alpha = 0.01$	13.8	0.19	0.18	39.1	0.56	957	0.20	0.46	0.83	0.10
Sowing rate	$\alpha = 0.05$	5.9	0.11	0.06	14.8	0.31	437	0.07	0.18	0.47	0.08
	$\alpha = 0.01$	7.9	0.14	0.09	19.7	0.42	582	0.10	0.25	0.62	0.11
N fertilization	$\alpha = 0.05$	6.0	0.10	0.07	16.8	0.26	423	0.06	0.20	0.55	0.07
	$\alpha = 0.01$	7.9	0.13	0.09	22.2	0.35	559	0.09	0.26	0.73	0.09

Table 8. Values of yield components, yield and grain quality in 1998 to 2000

Factors/parameters		Variant of beet tops management			Variety		Sowing rate		N fertilization	
		a	b	c	Amulet	Kompakt	3.5 MGS	4.5 MGS	0 kg/ha	30 kg/ha
Number of plants (m^2)	1998	317.8	304.8	332.0	322.5	313.9	268.7	367.7	321.2	315.2
	1999	333.5	327.9	342.1	332.7	336.3	279.2	389.8	337.5	331.5
	2000	339.3	337.9	348.2	343.1	340.5	307.8	375.8	344.6	338.9
Number of tillers per plant	1998	3.09	3.16	3.04	3.15	3.03	3.47	2.72	3.01	3.18
	1999	3.52	3.52	3.25	3.47	3.40	3.85	3.01	3.33	3.54
	2000	2.67	2.61	2.65	2.57	2.71	2.83	2.45	2.60	2.69
Number of fertile tillers per plant	1998	1.48	1.55	1.20	1.31	1.51	1.77	1.05	1.33	1.49
	1999	1.62	1.80	1.52	1.58	1.71	1.99	1.30	1.59	1.70
	2000	1.36	1.31	1.40	1.24	1.47	1.47	1.24	1.34	1.37
Number of spikes (per m^2)	1998	762.1	754.9	698.6	720.4	756.6	734.1	743.0	724.6	752.4
	1999	846.8	887.5	845.4	834.9	884.8	829.7	890.1	852.6	867.2
	2000	795.2	771.8	822.7	764.2	828.9	755.1	838.0	796.1	797.0
Number of grains per spike	1998	19.82	19.70	19.15	19.56	19.56	20.01	19.10	19.43	19.69
	1999	21.86	21.75	21.93	21.28	22.42	22.31	21.39	21.88	21.82
	2000	17.04	17.82	17.34	15.84	18.96	17.47	17.33	17.37	17.43
Number of grains (per m^2)	1998	15 108	14 891	13 374	14 095	14 820	14 711	14 204	14 077	14 838
	1999	18 554	19 318	18 556	17 775	19 844	18 515	19 103	18 669	18 949
	2000	13 595	13 796	14 361	12 100	15 735	13 295	14 539	13 861	13 974
Yield (t/ha)	1998	6.81	6.02	5.77	6.18	6.22	6.11	6.28	5.96	6.44
	1999	7.07	7.33	7.22	7.04	7.37	7.16	7.25	7.22	7.20
	2000	5.11	5.16	5.47	4.98	5.52	5.23	5.27	5.26	5.24
TGW (g)	1998	47.56	47.85	47.86	48.63	46.89	47.86	47.65	47.79	47.73
	1999	41.06	44.50	44.50	43.88	42.83	43.66	43.05	43.83	42.88
	2000	44.24	44.29	43.97	45.10	43.24	44.14	44.20	44.31	44.03
Grain > 2.5 mm sieve (%)	1998	91.03	92.90	92.09	95.00	89.02	92.11	91.90	92.38	91.64
	1999	70.86	83.46	83.76	81.53	77.19	80.62	78.10	80.72	78.00
	2000	81.68	81.21	80.58	88.19	74.12	80.50	81.81	81.69	80.61
Content of proteins in grain (%)	1998	10.40	11.24	10.15	10.97	10.23	10.36	10.83	10.28	10.92
	1999	11.27	11.71	11.05	11.53	11.16	11.04	11.65	11.23	11.46
	2000	14.10	15.20	14.28	14.96	14.09	14.39	14.67	14.24	14.82

ing the relatively highest yield. The proportion of grain (over 2.5 mm sieve) utilizable for malt purposes was, however, significantly lowest (79.36%) amounting to 5.72 t/ha. From the viewpoint of malt quality, the content of N substances was still favourable (11.34%). The grain from the 1998 harvest (yield 6.20 t/ha) showed the best parameters with significantly highest TGW (47.76 g), the high proportion of grain over 2.5 mm sieve (92.01%) and the favourable content of N substances in grain (10.60%).

The ploughed down beet tops supported the creation of yield, however, the average differences between variants were not marked (Table 7) being heavily affected by the course of weather conditions in the particular years. The variants with the late ploughing down of beet tops created more favourable conditions for the yield of the spring barley grain. The late ploughing down of beet tops influenced positively the process of tillering and the subsequent formation of tillers (3.10 and 1.55 tillers). The spike productivity was also favourably affected (19.76 grains) thus creating conditions for the formation of stands with a high accumulation potential (16 002 grains/m^2). The average yield of 6.17 t/ha grain, however, did not correspond to the stand condition. The highest yield of grain within the evaluated period (on average) was obtained from the variants in the early ploughed down beet tops (6.33 t/ha). As compared with other variants, the grain showed, however, the significantly lowest values of mechanical properties (TGW 44.29 g, grain over 2.5 mm sieve 81.19%), the content of N substances in grain (11.93%) was significantly lower than in the variants with the highest content of N substances in the late ploughed down beet tops (12.72%). The lowest yield level (6.15 t/ha) in the variants with harvested beet tops was a response to the generally lowest accumulation capacity of stands

(15 430 grains/m), the low level of tiller formation participating in it first of all (1.37). The yield of grain over 2.5 mm sieve and TGW were lower as compared with late ploughing down (85.48% and 45.45 g), the content of nitrogen in grain was significantly lowest (11.83%).

Between the particular varieties, significant differences were found both in the economic yield and grain quality. The Kompakt variety was on average 4.7% better as for yield (6.37 t/ha) than the Amulet variety that, however, achieved higher average values of TGW and the proportion of grain over 2.5 mm sieve (45.87 g, 88.24%). The quality of grain of the Amulet variety was negatively affected by the increased accumulation of N substances in grain (12.49%). The higher economic yield of the Kompakt variety was based on significantly higher numbers of created tillers (1.56) supported by the significantly higher productivity of spikes (20.31 grains).

The sowing rate amount significantly affected the values of all parameters under investigation. Variants sown 4.5 MGS have higher average yields of grain. The self-regulation capacity of stands established using 3.5 MGS sowing rates was positively reflected in the higher numbers of formed and realized tillers (3.38, 1.74), the higher numbers of grains per spike (19.93), TGW (45.22 g) and the higher proportion of grain over 2.5 mm sieve (84.41%). The number of plants per unit area decided, however, on the general productivity of stands. The deficit of plants in 3.5 MGS sowing rate became the reason of the low accumulation capacity of stands (15 507 grains/m^2). The average yield difference as against variants sown 4.5 MGS (6.27 t/ha) amounted to 0.1 t/ha. The accumulation of N substances in the spring barley grain developed more intensively in stands sown by denser sowing rates (12.38%). Kopecký (1983) also gives similar results in his paper.

The nitrogen fertilization at the rate of 30 kg/ha was demonstrated through the statistically significant increase in the yield (by 0.15 t/ha) but significantly worsened technological parameters of the barley grain. These trends were also corroborated by Flašarová and Onderka (1997), Kandera (1994) and Tichý et al. (1991) who noted that the effect of N fertilization was particularly related to the year-class and a number of other factors.

The effect of various methods of beet tops management on the creation of yield and grain quality in the course of the particular years is summarized in Table 8. With respect to the fact that the organic matter of beet tops contains considerable amounts of nutrients in dry matter (Table 4), mineralization of post-harvest residues can affect the growth and development of barley as well as its quality (Provazník et al. 2000, Cerkal et al. 2001). The course of weather ranks to the greatest extent among factors that regulate effects of ploughed down beet tops. Under relatively favourable precipitation conditions (1998, 1999) when the allocation of precipitation contributes to the sufficient water supply for plants from the beginning of vegetation, the ploughed down beet tops support the formation and realization of tillers, thereby creating conditions for establishing a higher accumulation capacity of stands. On the other hand, in years with a dry spring and above-average temperatures (2000), the ploughing down can be depressive for yield. In order to obtain a quality yield with maximum TGW values and relatively the highest proportion of grain over 2.5 mm sieve, it is more suitable to leave beet tops to wither and to plough them down later. With respect to the lower accumulation of N substances in grain, however, variants with early ploughing down and removed beet tops appear to be more suitable.

The variety, which guarantees the technological quality of grain with exactly defined parameters of yield, appears to be an important factor. Each variety used an individual mechanism of genetic potential, implementation of which was shown in the course of establishing, formation and reduction of each yield-forming component. In the Kompakt variety, the basis of the higher yield potential and actual yield was based on the higher level of tillering and on the higher number of grains per spike. The Amulet variety showed a capability to compensate for the lower accumulation potential by higher TGW values and by the higher proportion of grain over 2.5 mm sieve. These variety differences demonstrate limiting factors of biological material in the production process. It has been shown that typical, genetically fixed properties of varieties can fully manifest themselves under favourable weather conditions of a particular year only (Ehrenbergerová et al. 1999).

According to Tichý et al. (1991), the unsuitable choice of the sowing rate can cause a depression in the yield of grain thus affecting its general quality. Experiments showed that differences between 3.5 MGS and 4.5 MGS sowing amounts were decisive from the viewpoint of the grain yield and quality. The number of plants per unit area appeared to be an important regulation element of the productivity of stands. In the stands from 3.5 MGS sowing rates, the compensation of missing plants by higher numbers of fertile tillers or higher productivity of spikes did not occur, however, grain with better quality parameters was obtained.

The level of yield-forming elements and quality parameters of grain was also affected by N fertilization in the particular years (Table 8). Nitrogen applied at the rate of 30 kg/ha at the pre-sowing preparation of soil supported the formation and realization of tillers and favourably affected the productivity of stands and spikes. The economic yield of grain was increased by N fertilization in 1998 only, the yield increase was not noticed in other years. In all years under investigation, TGW values decreased after N application at the rate of 30 kg/ha, as well as the proportion of grain over 2.5 mm sieve and an increased accumulation of N substances in the grain occurred. The effects of N fertilization on the grain quality parameters were also shown in interactions with other factors (Table 6b). Problems of optimization of nitrogen fertilization rates in relation to the yield and quality of grain were discussed by Kandera (1994), Ložek et al. (1991), Provazník et al. (2000) et al.

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ABSTRAKT

Modifikace pěstitelských opatření ve vztahu k zaorávce chrástu a jejich vliv na strukturu výnosu a kvalitu zrna jarního ječmene

V polyfaktoriálním polním pokusu, založeném metodou dělených bloků a poddílců, byl v letech 1998–2000 sledován vliv tří systémů hospodaření s řepným chrástem, dvou výsevků a dvou úrovní dusíkatého hnojení a vliv interakcí těchto faktorů na produkční a kvalitativní ukazatele jarního ječmene odrůd Amulet a Kompakt. Z hodnocení vyplývá dominantní vliv ročníku na variabilitu všech sledovaných znaků. Podíl ročníku na variabilitě znaků byl od 2,1 % (počet rostlin na m^2) do 80,1 % (výnos), na variabilitách jakostních parametrů měl vysoký podíl také genetický faktor odrůdy (PPZ 40,4 %, HTZ 20,5 %). Úroveň znaků byla značně variabilní v závislosti na průběhu povětrnostních podmínek ročníku. Nejvyšší výnos zrna byl dosažen v roce 1999 (7,21 t/ha), nejnižší v roce 2000 (5,25 t/ha). Nejlepší kvalitativní parametry vykázalo zrno ze sklizně 1998 (výnos 6,20 t/ha) s průkazně nejvyšší HTZ (47,76 g), vysokým podílem předního zrna (92,01 %, 5,54 t/ha) a s příznivým obsahem N látek v zrnu (10,60 %). Zaorávaný chrást podporoval tvorbu výnosu, průměrné diference mezi jednotlivými variantami byly však minimální a silně ovlivněné průběhem povětrnosti ročníků. Vhodnější podmínky pro tvorbu výnosu (6,17 t/ha) a formování mechanických vlastností zrna jarního ječmene (HTS 45,55 g, PPZ 85,86 %) vytvářely varianty s pozdní zaorávkou chrástu, nejmenší akumulace dusíkatých látek byla zjištěna na variantách se sklizeným chrástem (11,83 %). Výsevek ovlivnil průkazně hodnoty všech sledovaných znaků, vyšší průměrný výnos zrna poskytovaly varianty seté 4,5 MGS (6,27 t/ha), kvalitativně lepší zrno bylo získáno z porostů setých 3,5 MKZ (HTZ 45,22 g, PPZ 84,41 %, N látky 11,93 %). Mezi odrůdami byly zjištěny průkazné rozdíly v hospodářském výnosu i v kvalitě zrna. Odrůda Kompakt byla v průměru o 4,7 % výnosově lepší (6,37 t/ha) než odrůda Amulet, která však dosahovala vyšších průměrných hodnot HTZ a podílu předního zrna (45,87 g, 88,24 %). Jakost zrna odrůdy Amulet negativně ovlivnila zvýšená akumulace dusíkatých látek v zrnu (12,49 %). Hnojení dusíkem v dávce 30 kg/ha se proti kontrole projevilo statisticky významným zvýšením výnosu pouze v roce 1998 (o 7,5 %), v ostatních letech nebyl přírůstek výnosu zaznamenán. Ve všech sledovaných letech se po aplikaci dusíku v dávce 30 kg/ha snížily hodnoty HTZ i podílu předního zrna a došlo ke zvýšení obsahu dusíkatých látek v zrnu.

Klíčová slova: jarní ječmen; řepný chrást; výnos; struktura výnosu; kvalita zrna; dusíkaté hnojení; výsevek

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