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THE EFFECT OF SELECTED FACTORS OF PRODUCTION ON YIELDS AND CONTENTS OF N-SUBSTANCES IN MALT BARLEY GRAIN

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Abstract

BABIÁNEK, P., VAVROUŠOVÁ, P., RYANT, P., HŘIVNA, L., CERKAL, R.: *The effect of selected factors of production on yields and contents of N-substances in malt barley grain.* Acta univ. agric. et silvic. Mendel. Brun., 2010, LVIII, No. 2, pp. 19–26

The objective of the three-year small-plot trial was to assess the effect of the weather of the year, forecrop, variety, form of sulphur (elementary and sulphate) and additional nitrogen fertilising on the yields and the content of N-substances of the malt barley varieties Jersey and Sebastian. The trial was carried out in 2006–2008 at the experimental site of the Mendel University of Agriculture and Forestry in Brno, the Žabčice locality. The Jersey and Sebastian varieties were grown after three different forecrops – winter wheat with ploughed down straw, sugar beet with ploughed down tops and maize for grain with ploughed down straw. The fertilising treatments differed in the form of sulphur (elementary and sulphate) and date of the additional nitrogen fertilising. As the sulphate form we chose ammonium sulphate (40 $kg.ha^{-1}$ N and 45.6 $kg.ha^{-1}$ S) and the same amount was supplied in the form of elementary sulphur; nitrogen was in the form of urea. A dose of 30 $kg.ha^{-1}$ of ammonium nitrate with limestone (ANL) was applied as additional nitrogen fertilising. The results show that the weather conditions of the respective years had an almost 94 % effect on yields. The very strong effect of the weather overshadowed the effect of the forecrop (3.8 %); the effect of the variety was only half that of the forecrop (1.8 %). The form of additionally applied sulphur and nitrogen during cultivation had a relatively little effect on the yields (0.2 %). The forecrop affected the content of N-substances most of all (47.3 %). The quality of barley grain is markedly dependent on the course of the weather of the year (40.1 %); the effect of the variety on the content of N-substances was relatively low (1.6 %). Applications of various forms of sulphur had a small effect on the grain quality (0.01 %), while the effect on additional nitrogen fertilising on the content of N-substances was 8.5 %.

spring barley, fertilisation, forms of sulphur, grain yields, content of N-substances

In order to ensure highly productive stands of spring barley, one must consider a number of factors which determine the potential yields of the main product – the grain. The final economic yields, their structure and quality are the result of a collaboration of these factors during growth and development of the stand (PETR *et al.*, 1980).

In terms of the yield formation and yield stability of spring barley the important factor is the forecrop (CERKAL *et al.*, 2001; PŘÍKOPA *et al.*, 2005). With the decrement of areas of root crops in the structure of crop production the selection of forecrops suitable for spring barley is limited. Areas where root crops are grown are decreasing and barley is grown after cereals and oil plants (ZIMOLKA *et al.*, 2006).

Barley grain yields and quality are greatly affected by the crop management practices, an integral part of which is nutrition and fertilisation. At the present time, a considerable attention is being devoted to nitrogen and sulphur nutrition. Sulphur deficient soil is caused, above all, by the reduction of atmospheric deposits all over Europe (SCHERER, 2001). On as much as 94 % of the area of the Czech Republic, sulphur fall-out is less than 10 $kg.ha^{-1}$ (HŮNOVÁ *et al.*, 2008). Sulphur deficit is beginning to be seen in yields and also in the quality of production (MC

GRATH *et* ZHAO 1996, ZHAO *et al.*, 2006); the plants are forming fewer spikes with a smaller number of grains in them (HANEKLAUS *et* SCHNUG, 1992).

Interaction between nitrogen and sulphur uptake was proved by a number of authors. MCGRATH *et* ZHAO (1996), HŘIVNA *et al.* (2001) discovered that sulphur deficit may reduce the effect of nitrogen fertilisation. On the other hand, excessive nitrogen fertilisation in combination with sulphur may have a negative effect on the quality of barley. Luxury uptake of nitrogen results in grain high in nitrogen. At the same time, nitrogen content negatively correlates with the content of the extract in malt dry matter and decreases the value of Kolbach's number (KOSAŘ *et al.*, 1997; ŠPUNAROVÁ *et* PROKEŠ, 1998).

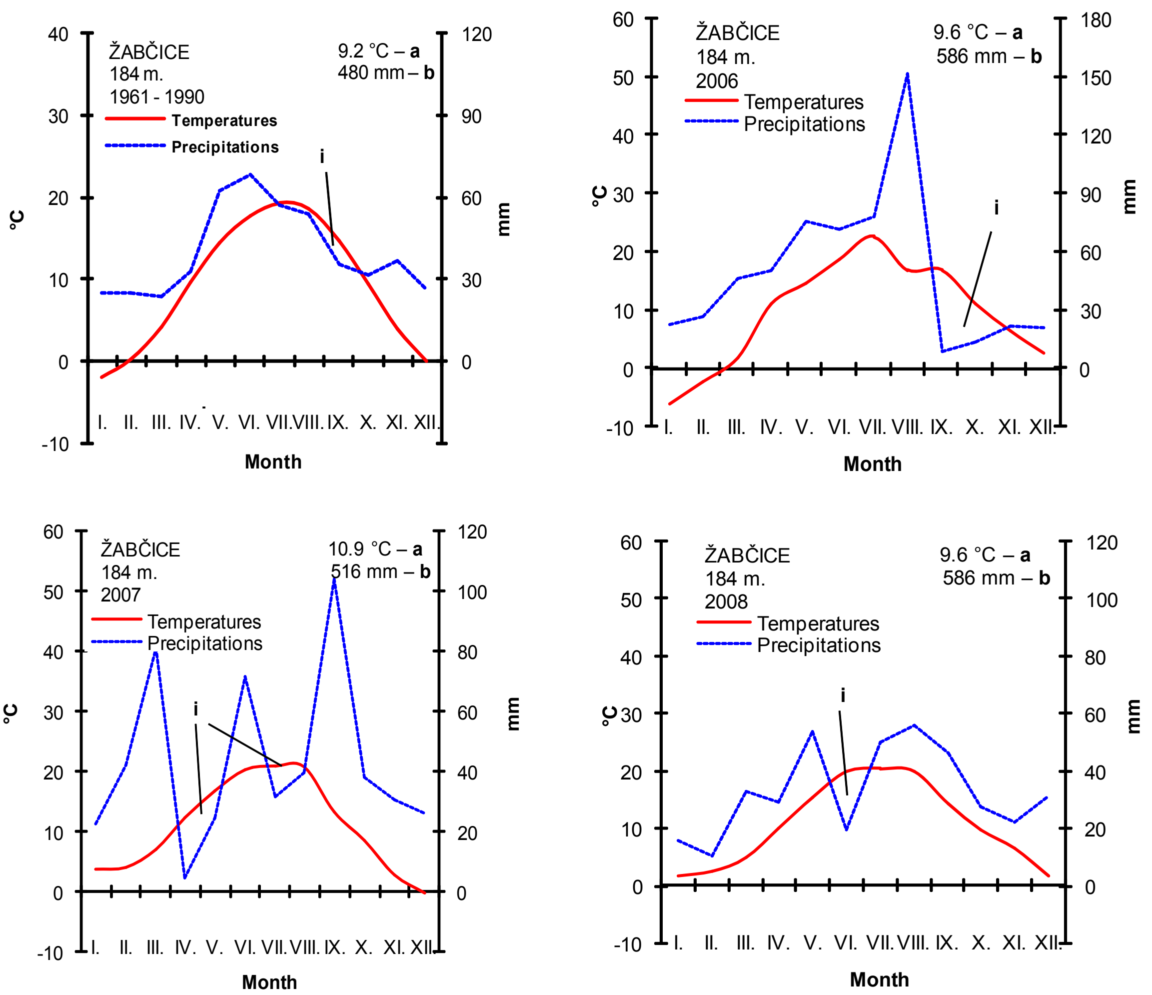
As a rule, the yield and quality of malt barley is most of all affected by the weather conditions of the year; the effect of the forecrop, variety and standard of cultural practice are also important. This study evaluates the effect of the individual factors.

MATERIAL AND METHODS

The three-year trial was set up as a small-plot trial in 2006–2008 at the experimental site of the Mendel University in Brno on the Žabčice locality (16° 37' long. and 49° 01' lat.). The locality is situated in the maize-production region, sub-region K2, average altitude of 184 m. The soil of the experimental site is classified as fluvial gley (FLg) (NĚMEČEK *et al.*, 2001). The soil is medium heavy to heavy, soil type clay loam to loam.

The locality is characterised as warm, moderately dry, with warm winters. The average monthly air temperatures/sum of precipitation ratios expressed in the form of a climate diagram define the periods threatened by drought; on the Žabčice locality it is usually from mid-July to early October.

Fig. 1 shows the weather conditions from 2006 to 2008 and the long-term normal for 1961–1990. The meteorological data were obtained from the Department for Agricultural Systems and Bioclimatology of Mendel University of Agriculture and Forestry in Brno.



1: *Climate diagrams of average monthly temperatures and sums of precipitation in 2006–2008 and the long-term normal for 1961–1990*

I: *Plan of the experiment*

Treatment	Variety	Form of sulphur	Additional nitrogen
1	Jersey	Sulphate	without
2			at sowing
3			**3 tillers detectable (DC 23)**
4			**beginning of stem elongation (DC 31)**
5		Elementary	without
6			at sowing
7			**3 tillers detectable (DC 23)**
8			**beginning of stem elongation (DC 31)**
9	Sebastian	Sulphate	at sowing
10			**3 tillers detectable (DC 23)**
11			**beginning of stem elongation (DC 31)**
12		Elementary	at sowing
13			**3 tillers detectable (DC 23)**
14			**beginning of stem elongation (DC 31)**

II: *Measures carried out during spring barley vegetation*

Measure	Year		
	2006	2007	2008
Sowing	21 Apr.	17 Mar.	11 Mar.
Nitrogen added at DC 23	21 May	25 Apr.	25 Apr.
Nitrogen added at DC 31	25 May	3 May	13 May
Treated with herbicide Sekator 250 g.ha^{-1} in 200 l.ha^{-1} of water	24 May	X	X
Treated with fungicide Falcon 0.6 l.ha^{-1} in 200 l.ha^{-1} of water	2 June	X	X
Harvest	12 Aug.	15 July	15 July

Barley varieties Jersey and Sebastian were grown after three different forecrops – winter wheat with ploughed down straw, sugar beet with ploughed down tops and maize for grain again with ploughed down straw. The seeding rate of the stands was 4.0 million germinative seeds per ha. The fertilising treatments differed in the form of sulphur and the date of additional nitrogen fertilising. Prior to sowing, basic fertilisation by nitrogen and sulphur was carried out, and during the vegetation, the stand was supplemented with nitrogen at various growth stages (Tab. I). Ammonium sulphate at a rate of 40 kg.ha^{-1} of nitrogen and 45.6 kg.ha^{-1} of sulphur was chosen as the sulphate form. The same amount of sulphur was applied in the form of elementary sulphur and nitrogen was replenished in the form of urea. A dose of 30 kg.ha^{-1} of ammonium nitrate with limestone (ANL) was used as the additional nitrogen fertiliser (Tab. I). Each fertilisation treatment was carried out in three repetitions.

Tab. II shows the measures carried out during spring barley vegetation. Barley grain was harvested at full ripening with the harvester-thresher SAMPO – ROSENLEW.

Immediately after the harvest, the grain yields per ha were assessed and the content of N-substances in the grain was determined by Kjeldahl's method (ZBÍRAL *et al.*, 2005). The effects of the individual factors were evaluated statistically by the Statistica 8.0 programme using analysis of variance followed by Tukey tests at a 99 % level of significance.

RESULTS AND DISCUSSION

Tab. III displays the average hectare yields of barley grain in relation to the individual factors. The results show that the weather conditions were important for the formation of the grain yield. For example, CHMIELEWSKI *et* KOHN (1999) reported up to 60 % effect of the weather on the yield formation. In our experiment, the decisive effect of the weather conditions was even stronger and affected the variability of the values in up to 94 %. The dominant effect of the year and particular weather extremes on the Žabčice locality were confirmed also by EHRENBERGEROVÁ *et al.* (1999) and CERKAL *et al.* (2001). The yield was significantly the lowest (3.41 t.ha^{-1}) in 2006; in 2007, it increased to 4.07 t.ha^{-1}, and in 2008, the average yield per ha was 7.70 t.ha^{-1} which shows a high statistically significant yield increase ($P > 0.99$) by 4.29 t.ha^{-1} and 3.63 t.ha^{-1} in 2006 and 2007, respectively, compared to 2008.

The very strong effect of the weather conditions very often considerably overshadowed the effect of the forecrop. In our case, the forecrop contributed to the total variability only in 3.8 %. The worst previous crop in our experiments was maize after which the average yields reached 4.60 t.ha^{-1}. Grain yields were higher after wheat (5.46 t.ha^{-1}) and the highest after sugar beet (5.97 t.ha^{-1}). Lower barley yields achieved after maize as the forecrop are often connected with larger amounts of ploughed down poorly decomposable post-harvest residues which may have a negative effect on the quality of establishment of the stand and initial growth of spring barley (ZIMOLKA *et al.*, 2006).

The effect of the variety on the variability of the yield was even lower; only half the effect of the forecrop. However, a higher yield potential was observed in the Sebastian variety as it was better at using the soil and climatic conditions of the site. Although the yields of Sebastian were higher than Jersey, on average by 0.5 t.ha^{-1}, the difference was not statistically significant.

If the weather is not standard, especially if the weather is dry, it is quite common that the effect of fertilization in soils well supplied with nutrients and sufficient available nitrogen is often not noticeable. This has been confirmed by KLEM *et al.* (2006) who considered the effect of the forecrop on grain yields of malt barley to be more important than the effect of the cultivation measures including nutrition. We also came to this conclusion in our experiments where the form of sulphur and nitrogen additional fertilizing applied during growth had a relatively small and statistically insignificant effect on the variability of grain yields of malt barley. Treatments with elementary sulphur containing urea were on average higher by 0.11 t.ha^{-1} than when ammonium sulphate was applied.

We assessed the effect of additional nitrogen fertilising on hectare yields of grain of both barley varieties and discovered statistically insignificant differences between the nitrogen fertilisation treatments. The worst results of the Jersey variety were achieved without additional nitrogen fertilising, i.e. on average ca 4.81 t.ha^{-1}, in the remaining three treatments with additional nitrogen fertilising; yields tended to increase if applied later. The most suitable treatment for the Sebastian variety was nitrogen correction carried out at sowing.

Tab. IV shows the average content of N-substances in relation to the individual factors.

Forecrop had the greatest effect on content of the N-substances in the grain. Among the forecrops we discovered statistically highly significant ($P > 0.99$) differences in the contents of N-substances. The content of N-substances was the highest and above the required technological quality after sugar beet (12.23 %). After wheat, it averaged 11.70 % and after maize, the content of N-substances was the lowest (11.11 %). In terms of the suitability of

III: *Average yields of barley grain in relation to the individual factors*

Factor			n	Yield (t.ha^{-1})		d. f.	AS	Share of the factor on the total variability (%)
Year		2006	84	3.41	c	2	582.2	94.0
		2007	126	4.07	b			
		2008	126	7.70	a			
Forecrop		Wheat	126	5.46	a	2	24.00	3.8
		Sugar beet	84*	5.97	a			
		Maize	126	4.60	b			
Variety		Jersey**	144	5.14	a	1	11.14	1.8
		Sebastian	144	5.54	a			
Form of sulphur		Sulphate	168	5.21	a	1	1.21	0.2
		Elementary	168	5.32	a			
Additional nitrogen fertilising	Jersey	Without	48	4.81	a	3	1.39	0.2
		At sowing	48	5.06	a			
		DC 23	48	5.15	a			
		DC 31	48	5.22	a			
	Sebastian	At sowing	48	5.59	a			
		DC 23	48	5.51	a			
		DC 31	48	5.52	a			
		Error				326	0.36	0.1
		Total				335	619.70	100.0

*fewer repetitions due to extreme weather conditions at harvest in 2006 (see Graph 1) which resulted in extensive growing through of the spikes making proper harvest of the barley stand and exact assessment of the yields impossible.

**from the evaluation we omitted treatment without additional nitrogen fertilising due to the absence of such treatment for the variety Sebastian which would be a disadvantage for the variety Jersey over Sebastian.

Note: Treatments with identica letters show statistically insignificant differences in average values ($P > 0.99$).

n – number of data, d. f. – degree of freedom, AS – average square barley grain for malting specified by Czech standard ČSN 46 1100-5 (2006), the minimal and maximal content of N-substances is 10 % and 12 %, respectively, the optimal value is aprox. 11 %. According to this standard, the most suitable grain was produced after maize as the forecrop. The poor content of N-substances after sugar beet is due to mineralization of the tops (BENADY *et al.*, 2001).

The quality of barley grain is considerably dependent on the weather conditions. The share of this factor on the total variability of the content of N-substances is 40.1 %. The significantly ($P > 0.99$) highest content of N-substances was found in 2006 (12.20 %) and the lowest in 2008 (11.14 %).

Compared to the weather conditions and forecrop, the effect of the variety on the variability of the content of N-substances was relatively small. Although the content of N-substances in the variety Sebastian was by 0.16 % lower than in Jersey and was closer to the optimal value, the difference between these varieties in the content of N-substances was not statistically significant ($P > 0.99$).

Applications of various forms of sulphur did not have much of an affect the content of N-substances in grain; the differences between the elementary sulphur and the sulphate sulphur in ammonium sulphate were not statistically significant. SKWIERAWSKA *et al.* (2008) and RICHTER *et al.* (2008) reached the same conclusions in their experiments with spring barley.

Compared to the weather and forecrop, the share of additional nitrogen fertilising in the variability of values of N-substances in the grain was smaller albeit not negligible (8.5 %). In Jersey, the average content of N-substances was significantly the lowest ($P > 0.99$) when no additional nitrogen was applied (11.36 %). The effect of the date of the individual applications on the content of N-substances in grain was not significant. This finding corresponds with the fact that additional nitrogen fertilising of barley is possible until the beginning of the stem elongation stage without a considerable increase in the N-substances in the grain. This was also described by RICHTER *et al.* (2005) and it differs from the common methods of malt barley production that state that the latest date for additional nitrogen fertilising is the stage of the 3rd to 4th leaf (DC 13–14) (BENADA *et al.*, 2001).

In the course of the 3-year trials, the contents of N-substances were relatively high, as Graph 2 shows. It means that the treatment which had the best effect on the content of N-substances was only the basic dose of 40 kg.ha^{-1} N with no further additional nitrogen fertilisation.

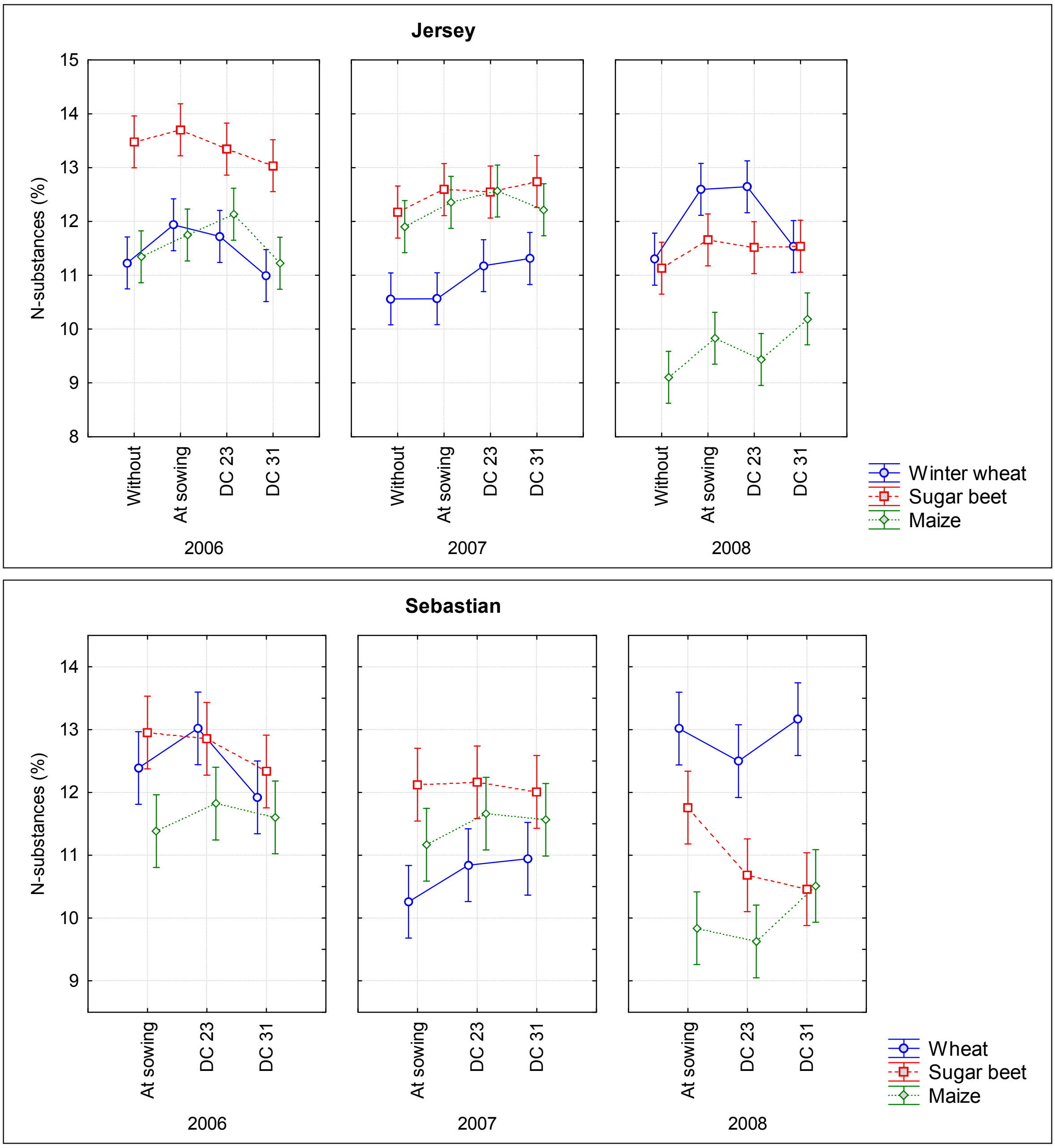
IV: *Average contents of N-substances in relation to the individual factors of cultivation*

Factor			n	N-substances (%)		d. f.	AS	Share of the factor on total variability (%)
Year		2006	126	12.20	a			
		2007	126	11.69	b	2	16.88	40.1
		2008	126	11.14	c			
Forecrop		Wheat	126	11.70	b			
		Sugar beet	126	12.23	a	2	19.89	47.3
		Maize	126	11.11	c			
Variety		Jersey*	162	11.81	a	1	0.68	1.6
		Sebastian	162	11.65	a			
Form of sulphur		Sulphate	189	11.68	a	1	0.01	0.0
		Elementary	189	11.68	a			
Additional nitrogen fertilising	Jersey	Without	54	11.36	b			
		At sowing	54	11.89	a			
		DC 23	54	11.90	a			
		DC 31	54	11.64	ab	3	3.56	8.5
	Sebastian	At sowing	54	11.65	a			
		DC 23	54	11.69	a			
		DC 31	54	11.61	a			
		Error				326	1.06	2.5
		Total				335	42.07	100.0

*treatment without additional nitrogen fertilising was left out due to the absence of this treatment in the variety Sebastian which would be a disadvantage for Jersey.

Note: Treatments with identical letters show statistically insignificant differences in average values ($P > 0.99$).

n – number of data, d. f. – degree of freedom, AS – average square



2: *Contents of N-substances in the harvested malt barley grain varieties Jersey and Sebastian in dependence on the date of additional nitrogen fertilising in the individual years and after forecrops*

SUMMARY

The objective of the three-year small-plot trial was to assess the effect of the year, the forecrop, the variety, the form of sulphur (elementary and sulphate) and the additional nitrogen fertilising on the yields and the content of N-substances of the malt barley varieties Jersey and Sebastian. The results confirmed that 94 % of the yields variability is affected by the weather conditions during individual years. The significantly lowest yields were reported in 2006 (3.41 $t.ha^{-1}$), they increased in 2007 (4.07 $t.ha^{-1}$) and in 2008, the yields were 7.70 $t.ha^{-1}$. The effect of the weather was very strong and even overshadowed the effect of the forecrop (3.8 %). In our experiments, maize as the forecrop resulted in the significantly lowest yields (4.60 $t.ha^{-1}$), higher yields were reported after wheat (5.46 $t.ha^{-1}$) and the highest after sugar beet (5.97 $t.ha^{-1}$). The effect of the variety was half that of the forecrop (1.8 %). The yield potential of the variety Sebastian was higher than the one of Jersey (by 0.5 $t.ha^{-1}$). The form of applied sulphur and nitrogen correction carried out during vegetation affected yields relatively little (0.2 $t.ha^{-1}$), even so fertilisation treatments with elementary sulphur containing urea resulted in average yields by 0.11 $t.ha^{-1}$ higher than ammonium sulphate treatments.

The forecrop had the greatest effect on the content of N-substances in the grain (47.3 %). The content of N-substances was the highest and above the required technological quality after sugar beet (12.23 %), after wheat it averaged 11.70 % and after maize, the content of N-substances was the lowest (11.11 %); however, according to the Czech standard ČSN 461100-5, it is the most favourable. The variability of the quality parameters of barley grain is markedly dependent on the weather of the given year (40.1 %). The highest content of N-substances was monitored in 2006 (12.20 %) and the lowest in 2008 (11.14 %). The variety affected the content of N-substances relatively little (1.6 %); in the variety Sebastian, the content of N-substances was by 0.16 % lower than in Jersey. The effect of applications of various forms of sulphur on grain quality was low (0.01 %), while the effect of additional nitrogen fertilising on the content of N-substances was 8.5 %.

SOUHRN

Vliv vybraných faktorů pěstování na výnos a obsah dusíkatých látek v zrnu sladovnického ječmene

Cílem tříletého maloparcelního pokusu bylo posoudit vliv ročníku, předplodiny, odrůdy, formy síry (elementární a síranová) a přihnojení dusíkem na výnos a obsah dusíkatých látek u odrůd sladovnického ječmene Jersey a Sebastian. Z výsledků je zřejmé, že průběh povětrnosti v jednotlivých ročnících ovlivňuje výnos téměř z 94 %. Průkazně nejnižší výnos byl zaznamenán v roce 2006 (3,41 t/ha), v roce 2007 došlo ke zvýšení (4,07 t/ha) a v roce 2008 byl průměrný hektarový výnos 7,70 t. Velmi silný vliv ročníku zastínil vliv předplodiny (3,8 %). Průkazně nejhorší předplodinovou hodnotu měla v našich pokusech kukuřice (4,60 t/ha), vyššího výnosu bylo dosaženo po pšenici (5,46 t/ha) a nejvyšší pak po cukrovce (5,97 t/ha). Vliv odrůdy byl ve srovnání s předplodinou poloviční (1,8 %). Výnosově vyšší potenciál měla odrůda Sebastian v porovnání s odrůdou Jersey (o 0,5 t/ha). Forma aplikované síry a korekce dusíkem prováděné během pěstování měly relativně malý vliv na výnos (0,2 t/ha), přesto varianty hnojené elementární sírou s močovinou vykazovaly o 0,11 t/ha vyšší průměrné výnosy než varianty s aplikací síranu amonného.

Na obsah dusíkatých látek v zrnu měla největší vliv předplodina (47,27 %). Nejvyšší, ale mimo technologickou kvalitu, byl obsah N-látek po cukrovce (12,23 %), po pšenici se průměrně pohyboval na úrovni 11,7 % a po kukuřici byl obsah nejnižší (11,11%), avšak podle normy ČSN 461100-5 se jevilo jako nejvhodnější. Kvalita zrna ječmene je výrazně závislá na průběhu povětrnosti daného ročníku (40,12 %), nejvyšší obsah N-látek byl stanoven v roce 2006 (12,20 %) a nejnižší v roce 2008 (11,14 %). Odrůda se odrazila na obsahu N-látek relativně málo (1,6 %), odrůda Sebastian měla o 0,16 % nižší obsah N-látek než Jersey. Vliv aplikace různé formy síry na kvalitu zrna byl malý (0,01 %), zatímco přihnojení dusíkem ovlivnilo obsah N-látek z 8,5 %.

ječmen jarní, hnojení, formy síry, výnos zrna, obsah N-látek

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