THE EFFECT OF VARIETY AND INTENSITY OF CULTIVATION ON THE EXPLOITATION OF WHEAT FOR PRODUCTION OF STARCH AND GLUTEN

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In three-year period we evaluated a selected set of varieties of winter wheat in view of suitability and efficiency for starch-making purposes. The aim of the research was to judge the effect of variety and intensity of cultivation on the content of starch and wet gluten in grain dry matter, and on the total production of starch and gluten per hectare. Totally significant effect of higher intensity of cultivation followed from the results of comparison of ecological and conventional cultivation – i.e. with application of fertilisers and pesticides on the yield of grain and wet gluten that is a valuable co-product in production of wheat starch. In intensive cultivation compared with ecological one (without fertilisers and pesticides) the content of starch in grain was slightly falling due to the increase of crude protein content. The total production of starch per 1 ha was significantly higher owing to much higher yields of grain. It manifests that certain degree of intensity of cultivation is necessary for economically acceptable cultivation of starch-making wheat. In our experiments it was N-fertilisation ranging from 90 and 110 kg $N.ha^{-1}$, corresponding dose of P and K and the use of pesticides. The varieties Asta, Astella, Siria, Contra and Estica excelled in our experiments in the content of starch both in intensive and in ecological cultivation systems. These varieties were distinguished also by favourable content of wet gluten of a good quality and above all by high yields of grain and hence also by total production of starch and gluten per hectare. All these varieties are ranked among the groups B and C and except Astella, they can be cultivated with success even in marginal regions.

wheat for production of starch; varieties; starch content; intensity of cultivation; cultivation locality

INTRODUCTION

The starch can be considered as one of the strategic materials of the future. Its consumption is still increasing for food industry and non-food utilisation as well.

In the recent years, the interest in the utilisation of wheat as starch-making material has been growing in Europe, particularly in the countries with soil-weather conditions comparable with those in the Czech Republic. The reason consists in good conditions for intensive cultivation of wheat, long-term unfavourable prices of imported maize and an effort of the use of the local material sources, the problem of local over-production of cereals and the possibility of solution by searching for new sales areas, not low profits from sale of vital gluten which is an important co-product in production of wheat starch.

As it follows from experience of German starch factories, the choice of suitable variety for starch-making processing brings a significant increase of the profit. In the Czech Republic, however, the formulation of quality criteria for starch-making wheat and characterisation of starch-making varieties of wheat is still in the initial stages. In cultivation of starch-making wheat, it is necessary to take into account the yields of grain and hence also total production of starch and gluten per hectare. Therefore, there is a necessity to pay an attention to the intensity of cultivation that should be suitable for production of starch-making wheat.

The aim of our study, financed by the grant from the National Agency for Agricultural Research of the Ministry of Agriculture of the Czech Republic No. 7222 "Wheat in marginal regions for starch production", was to evaluate the set of winter wheat varieties of the domestic and foreign provenance in view of the suitability and efficiency for starch-making purposes, to characterise the effect of variety on the starch and gluten content and to assess an effect of different intensity of cultivation on the grain yields and thus also the production of starch and gluten per hectare.

The possibilities to use the starch have no competition compared with other materials. As reported by Lillford and Morrison (1997) the starch consumption is fast growing in industrial processing where its annual increment amounts to as much as 6.5%. The greatest utilisation is in paper, textile and chemical industries, where it serves for production of many products. The modification is needed for recognition of its polymeric qualities that can be achieved by chemical or physical route.

An extensive utilisation of modified starches is expected in industry of synthetic polymers, what will allow their decomposability (Munck et al., 1988). According to Doane (1989) the starch in technological aspect should be used as a material for production of majority of products till now obtained from crude oil. This does from starch an ecological and renewable material and

evidently the starch production from starch-bearing crops will be developed further in agriculture as a perspective utility orientation.

Main starch-bearing crops include starch-bearing grain crops, potatoes and tapioca. In the world-wide sense the most important source of starch is maize. The percentage of maize starch amounts to 50%, in Europe potatoes (approximately 25%) and in wheat also about 25%.

The most dynamic production can be seen in production of wheat starch, what has been confirmed by Bergthaller et al. (1998) by the data on extending capacities of starch factories in France and Germany. Based on evaluation of the costs of starch-making production of different materials, Wintzer et al. (1993) reported that more expensive production of potato starch is on decline, together with imported maize will be substituted by cheaper wheat. Another fact is important that processing of wheat for starch can be denominated as a quasi non-waste technological process. In the European Union during the last five years the production of wheat starch rose by 30%.

Food wheat has been mainly used for starch production up to now. Flour for starch-making purposes is prepared by an ordinary milling, e.g. in Germany the flour T550 with ash content 0.6% is used.

Kodet and Babor (1991) report average values for flour processed in starch factories: 0.6% of ash, starch content 68.5% and protein content 13.5% (high-quality food varieties prevailed in those times).

German authors Lindhauer and Zwingelberg (1997) consider that flour with lower content of proteins in dry matter is suitable for starch-making processing. Furthermore, the authors think that wheat varieties for starch production should be of low durability of endosperm, low content of pentosans and good quality of starch – higher falling number and higher values of amylographic maximum.

MATERIAL AND METHODS

Based on the preliminary, orientation analyses, which were carried out in 1996, a set of winter wheat varieties was chosen, that was analysed in detail in the years 1997 to 1999.

The research was concentrated both on the selection of a suitable wheat variety for starch-making processing and for analysis of the effect of cultivation on the starch content and further indicators of technological quality.

To obtain samples of winter wheat from various intensity of growing variety trials for the List of Recommended Varieties (LDO), which were established at the Experimental Station of the Faculty of Agronomy of the Czech University of Agriculture at Uhříněves in ecological system of cultivation, that is in harmony with the Methodological Directives for Ecological Agriculture of the Ministry of Agriculture of the Czech Republic and in congruency with the principles of the international organisation IFOAM (International Federation of Organic Agriculture Movements). The Station is certified for these experiments. The experimental station Uhříněves is situated in the beet-growing region, at an altitude of 295 m, with average annual temperature 8.3 °C, annual sum of precipitation 575 mm. The soil is clay luvisol with production potential of 84 points.

The samples of identical varieties were obtained from variety trials of the Breeding Station Stupice, which is placed almost in the same soil and climatic conditions. The experiments were conducted in two intensities of cultivation: basic intensity – nitrogen fertilisation 90–100 kg $N.ha^{-1}$, 60 kg $P_2O_5.ha^{-1}$ and 60 kg $K_2O.ha^{-1}$,

I. Weather pattern in experimental years 1997–1999 (Stupice, Uhříněves)

Year	1996–1997		1997–1998		1998–1999		Long-term average	
Month	average temperature (°C)	sum of precipitation (mm)	average temperature (°C)	sum of precipitation (mm)	average temperature (°C)	sum of precipitation (mm)	average temperature (°C)	sum of precipitation (mm)
9	10.7	48.9	13.7	41.5	17.3	57.6	14.0	49.0
10	9.8	23.1	7.2	34.1	9.3	24.3	8.6	41.0
11	5.2	28.6	3.3	38.1	2.9	22.6	3.2	34.0
12	–4.4	21.5	1.9	46.4	1.7	33.1	–0.5	34.0
1	–4.4	21.4	1.6	12.9	1.5	34.1	–2.1	28.0
2	3.4	22.5	4.4	14.1	–0.2	29.2	–0.8	27.0
3	5.2	44.8	4.7	38.1	5.9	26.9	3.4	31.0
4	6.3	35.1	11.1	9.9	10.1	18.5	8.2	46.0
5	14.6	25.7	15.0	27.0	15.1	54.1	13.4	65.0
6	17.0	84.1	18.1	107.7	18.1	66.8	16.3	74.0
7	17.8	110.2	18.0	89.0	19.8	78.1	18.2	74.0
8	19.5	60.5	18.2	30.3	17.7	33.9	17.5	72.0
Annual average of temperature and sum of precipitation	8.4	526	9.8	489	9.9	479	8.3	575

a herbicide was applied during vegetation; higher intensity – identical doses of fertilisers, herbicide, fungicide, insecticide and growth regulator were applied during vegetation. Table I presents weather pattern in experimental years.

In 1997 the varieties Asta, Astella, Estica, Hana, Samantha, Siria, Torysa were used at Stupice and Uhříněves; in the year 1998 there were the varieties Astella, Estica, Hana, Samanta, Siria, Contra, Saskia, Šárka and Versailles, in 1999 the varieties Astella, Estica, Samanta, Siria, Contra, Saskia, Šárka and Versailles were used.

After the harvest of wheat the yields of grain were recorded and about 2 kg of grain sample were taken from experimental areas in four repetitions. They were dispatched for laboratory assessment to the Department of Crop Production, Faculty of Agronomy, Czech University of Agriculture in Prague.

The grain was purified and ground on the laboratory mill Falling Number 120. In produced meal the starch content in dry matter (%) was recorded – the Czechoslovak Standard ČSN 56 0512-16 (the method according to Ewers), to determine analyte-polamate A was used, and except it the content of wet gluten in dry matter (%) – ČSN 56 0512-10 (Glutomatic was used for determination).

Analysis of variance of simple classification was used for statistical evaluation. Statistically significant differences in the starch content and wet gluten in grain dry matter and in the yields of grain, starch and wet gluten per hectare among the variants of different intensity of cultivation were tested by Scheffe's test, the level of significance $\alpha = 0.05$.

RESULTS

The effect of variety and intensity of cultivation on the starch and wet gluten in wheat grain (Stupice, Uhříněves)

The results of the starch content and wet gluten content in grain of selected wheat varieties from ecological system of cultivation (Uhříněves) and from both intensive variants (Stupice) are presented in Tables II–IV.

II. The effect of different intensity of cultivation on the content of starch and wet gluten in grain dry matter of selected wheat varieties (Stupice, Uhříněves – harvest of 1997)

Site	Stupice (basic intensity)		Stupice (higher intensity)		Uhříněves (ecological system)		**Average of varieties**	
Variety	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)
Asta	68.62	28.64	66.71	29.37	68.70	20.66	**68.01**	**26.22**
Astella	66.11	25.66	67.91	30.03	68.72	24.15	**67.58**	26.61
Estica	66.88	30.68	64.19	32.16	66.87	20.34	**65.98**	27.73
Hana	64.72	35.67	65.80	36.51	66.08	27.32	**65.53**	33.17
Samanta	66.65	30.72	63.94	32.65	65.39	22.70	**65.32**	28.69
Siria	67.42	31.76	65.19	31.99	69.64	19.90	**67.42**	27.88
Torysa	69.42	27.90	70.50	31.55	67.80	20.99	**69.24**	26.92
Average of sites	67.12	30.15	66.32	32.04	67.60	22.29	67.01	28.17

III. The effect of different intensity of cultivation on the content of starch and wet gluten in grain dry matter of selected wheat varieties (Stupice, Uhříněves – harvest of 1998)

Site	Stupice (basic intensity)		Stupice (higher intensity)		Uhříněves (ecological system)		**Average of varieties**	
Variety	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)
Astella	67.82	25.22	66.05	27.36	67.34	22.35	**67.07**	**24.98**
Estica	66.33	32.40	66.51	33.95	66.87	26.49	**66.57**	30.95
Hana	62.71	31.89	62.92	39.31	63.00	27.62	**62.88**	32.94
Samanta	63.81	30.53	64.87	39.01	65.11	26.90	**64.60**	32.15
Siria	68.64	30.67	67.52	35.19	69.12	23.60	**68.43**	29.82
Contra	67.08	32.79	65.94	36.38	69.21	23.76	**67.41**	30.98
Saskia	63.67	30.27	64.50	31.62	64.23	21.68	**64.13**	27.86
Šárka	63.91	29.85	62.00	26.80	64.78	21.51	**63.56**	26.05
Versailles	66.67	30.79	65.81	33.11	68.70	20.98	**67.06**	28.29
Average of sites	65.63	30.49	65.12	33.64	66.48	23.88	65.75	29.34

Statistically significant differences in starch content and wet gluten among variants with different intensity of cultivation are given in Table V.

In all three experimental years the average starch content in grain dry matter was slightly higher in ecological system cultivation in the experiments conducted at Uhříněves and Stupice. On the contrary, the content of wet gluten was much lower in ecological cultivation compared with intensive cultivation.

It followed from statistical evaluation that in the years 1998 and 1999 the difference between ecological and intensive cultivation was statistically significant. In 1997 higher intensity was statistically significant from lower intensity and ecological cultivation. Differences in the starch content between intensive variants and ecological cultivation ranged between 1 and 3%. Both of the intensive variants differed in the starch content between each other less, what means that application of fungicide, insecticide and growth regulator almost did not affect the starch content in wheat grain.

On the other hand, higher intensity of cultivation increased the content of wet gluten in dry matter of wheat grain – statistically significant differences were found between all evaluated variants of intensity of cultivation (basic intensity, higher intensity, ecological system) in all three studied years. At the same time, 10% difference was recorded in the content of wet gluten in grain dry matter between ecological cultivation and higher intensity (that is a very interesting difference even for practical reasons). The difference between basic and higher intensity ranged between 2 and 3%, what means that an application of fungicide, insecticide and growth regulator affected the content of wet gluten only little.

The varieties Asta and Torysa were above average in 1997 in the starch content in intensive cultivation. In ecological cultivation the varieties Asta, Astella and Siria dominated. In 1998 in intensive cultivation the varieties Siria, Astella and Contra were marked by the highest content of starch, in ecological cultivation – the varieties Contra and Versailles. In 1999 the varieties Astella, Siria, Estica and Šárka had the highest starch content in intensive cultivation and Contra, Siria, Estica and Šárka in ecological cultivation.

The varieties Hana, Siria, Samanta and Estica were distinguished by the highest content of wet gluten in grain dry matter in 1997, Hana and Astella in ecological

IV. The effect of different intensity of cultivation on the content of starch and wet gluten in grain dry matter of selected wheat varieties (Stupice, Uhříněves – harvest of 1999)

Site	Stupice (basic intensity)		Stupice (higher intensity)		Uhříněves (ecological system)		**Average of varieties**	
Variety	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)	starch content (%)	wet gluten content (%)
Astella	67.54	28.07	65.47	30.50	67.11	19.53	**66.71**	**26.03**
Estica	66.94	28.32	64.99	30.62	69.72	16.00	**67.22**	**24.98**
Samanta	66.77	27.16	64.00	32.16	67.38	19.21	**66.05**	**26.18**
Siria	66.85	27.52	66.22	30.55	69.17	14.81	**67.41**	**24.29**
Contra	64.36	28.93	65.46	28.97	69.98	16.60	**66.60**	**24.83**
Saskia	65.06	27.25	65.86	29.83	67.68	19.12	**66.20**	**25.40**
Šárka	64.69	25.80	66.19	26.09	69.08	18.06	**66.65**	**23.32**
Versailles	64.73	28.72	64.02	28.39	66.57	12.93	**65.11**	**23.35**
Average of sites	**65.87**	**27.72**	**65.28**	**29.64**	**68.33**	**17.03**	**66.49**	**24.80**

V. Analysis of variance of simple classification and statistically significant differences in the content of starch and wet gluten in grain dry matter among variants with different intensity of cultivation (Scheffe, $\alpha = 0.05$)

Year	Intensity of cultivation	Average content of starch (%)	Variance – among groups – inside groups	*F*-test	Homogeneity	Average content of wet gluten (%)	Variance – among groups – inside groups	*F*-test	Homogeneity
1997	Stupice (basic intensity)	67.12	1.673 0.007	250.9	A	30.15	106.943 0.005	999.9	A
	Stupice (higher intensity)	66.32			B	32.04			B
	Uhříněves (ecological system)	67.60			A	22.29			C
1998	Stupice (basic intensity)	65.63	1.888 0.005	416.6	A	30.49	99.248 0.005	999.9	A
	Stupice (higher intensity)	65.12			A	33.64			B
	Uhříněves (ecological system)	66.48			B	23.88			C
1999	Stupice (basic intensity)	65.87	10.468 0.003	999.9	A	27.72	184.650 0.025	999.9	A
	Stupice (higher intensity)	65.28			A	29.64			B
	Uhříněves (ecological system)	68.33			B	17.03			C

cultivation. In 1998 the highest content of wet gluten was found again in the varieties Hana, Samanta, Siria in intensive cultivation, but also in the variety Contra; Hana, Samanta and Estica in ecological cultivation. In 1999 the varieties Samanta, Estica and Siria had the highest content of wet gluten in intensive cultivation, Astella and Samanta in ecological cultivation.

Grain yields and the production of starch and wet gluten per 1 hectare

When the effect of cultivation intensity is studied, it is necessary to consider not only the content of starch and wet gluten in wheat grain, but also the total production of starch and gluten per 1 hectare. Grain yields of distinct wheat varieties under different cultivation intensity are presented in Table VI. Yields of starch and wet gluten per hectare (theoretical calculations) are given in Tables VII and VIII. Statistically significant differences in the yield of grain, starch and wet gluten per 1 ha between variants of different intensity are in Table IX.

A strong effect of both intensity cultivation systems on the grain yield can be seen from the results compared with ecological cultivation, where no fertiliser and no pesticide were applied. Differences in grain yield ranged on average of three-year results between 3 and 4 $t.ha^{-1}$ between basic intensity and ecological cultivation and about 1 $t.ha^{-1}$ between basic and higher intensity of cultivation.

VI. Grain yield ($t.ha^{-1}$) under different intensity of cultivation (Stupice, Uhříněves, harvest of 1997–1999)

Year	1997			1998			1999			**Average of varieties**		
Site/Variety	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)
Asta	9.94	10.66	5.90	–	–	–	–	–	–	9.94	10.66	5.90
Astella	9.44	9.83	7.09	8.25	9.25	6.32	10.32	11.50	7.50	9.33	10.19	6.97
Estica	9.48	9.95	6.43	8.35	9.40	6.79	10.57	11.07	7.79	9.46	10.14	7.00
Hana	8.68	8.92	5.17	7.68	8.72	5.20	–	–	–	8.18	8.82	5.19
Samanta	9.04	9.41	6.61	8.28	8.96	5.90	10.28	11.08	7.69	9.20	9.81	6.73
Siria	9.50	10.71	5.33	8.35	9.28	6.35	10.79	11.36	7.24	9.54	10.45	6.30
Torysa	9.31	10.74	6.28	–	–	–	–	–	–	9.31	10.74	6.28
Contra	–	–	–	8.10	9.35	6.28	10.69	11.73	7.39	9.39	10.54	6.83
Saskia	–	–	–	8.14	9.40	6.52	10.38	10.86	7.80	9.26	10.13	7.16
Šárka	–	–	–	8.21	9.16	5.89	10.25	11.56	7.32	9.23	10.36	6.60
Versailes	–	–	–	8.05	9.12	6.01	10.28	11.39	7.20	9.16	10.25	6.60
Average of sites	**9.34**	**10.03**	**6.12**	**8.16**	**9.18**	**6.14**	**10.45**	**11.32**	**7.47**	**9.27**	**10.19**	**6.51**

VII. Yield of starch ($t.ha^{-1}$) under different intensity of cultivation. Theoretical calculation (Stupice, Uhříněves, harvest 1997–1999)

Year	1997			1998			1999			**Average of varieties**		
Site/Variety	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)
Asta	6.82	7.11	4.05	–	–	–	–	–	–	6.82	7.11	4.05
Astella	6.24	6.68	4.87	5.60	6.11	4.26	6.97	7.53	5.03	6.27	6.77	4.72
Estica	6.34	6.39	4.30	5.54	6.25	4.54	7.08	7.19	5.43	6.32	6.61	4.75
Hana	5.62	5.87	3.42	4.82	5.49	3.28	–	–	–	5.22	5.68	3.35
Samanta	6.03	6.02	4.32	5.28	5.81	3.84	6.86	7.09	5.18	6.05	6.30	4.44
Siria	6.40	6.98	3.71	5.73	6.27	4.39	7.21	7.52	5.01	6.44	6.92	4.37
Torysa	6.46	7.57	4.26	–	–	–	–	–	–	6.46	7.57	4.26
Contra	–	–	–	5.43	6.17	4.35	6.88	7.68	5.17	6.15	6.92	4.76
Saskia	–	–	–	5.18	6.06	4.19	6.75	7.15	5.28	5.96	6.60	4.74
Šárka	–	–	–	5.25	5.68	3.82	6.63	7.65	5.06	5.94	6.66	4.94
Versailes	–	–	–	5.37	6.00	4.13	7.37	7.29	4.79	6.37	6.64	4.46
Average of sites	**6.27**	**6.66**	**4.13**	**5.36**	**5.98**	**4.09**	**6.97**	**7.39**	**5.12**	**6.18**	**6.71**	**4.44**

The varieties Samanta and Contra excelled in intensity cultivation, in ecological (low input) cultivation – the varieties Estica, Astella, Saskia and Contra.

Starch production per hectare can be calculated theoretically from the obtained grain yield and starch content in grain. Differences in starch production per hectare in different cultivation systems study basically the values of the difference in the grain yield. They are logically lower with respect to certain differences in the starch content in different varieties. The varieties Siria, Ver-

VIII. Yield of wet gluten (t.ha^{-1}) under different intensity of cultivation. Theoretical calculation (Stupice, Uhříněves, harvest 1997–1999)

Year	1997			1998			1999			**Average of varieties**		
Site/Variety	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)	Stupice (basic intensity)	Stupice (higher intensity)	Uhříněves (ecological system)
Asta	2.85	3.13	1.22	–	–	–	–	–	–	2.85	3.13	1.22
Astella	2.42	2.95	1.71	2.08	2.53	1.41	2.90	3.51	1.46	2.47	3.00	1.53
Estica	2.91	3.20	1.31	2.71	3.19	1.80	2.99	3.39	1.20	2.87	3.26	1.44
Hana	3.10	3.26	1.41	2.45	3.43	1.44	–	–	–	2.78	3.35	1.43
Samanta	2.78	3.07	1.50	2.53	3.50	1.59	2.79	3.56	1.48	2.70	3.38	1.52
Siria	3.02	3.43	1.06	2.56	3.27	1.50	2.97	3.47	1.07	2.85	3.39	1.21
Torysa	2.60	3.39	1.32	–	–	–	–	–	–	2.60	3.39	1.32
Contra	–	–	–	2.66	3.40	1.49	3.09	3.40	1.23	2.88	3.40	1.36
Saskia	–	–	–	2.46	2.97	1.41	2.83	3.24	1.49	2.65	3.11	1.45
Šárka	–	–	–	2.45	2.45	1.27	2.64	3.02	1.32	2.55	2.74	1.30
Versailes	–	–	–	2.48	3.02	1.26	2.95	3.23	0.93	2.72	3.13	1.10
Average of sites	**2.81**	**3.20**	**1.36**	**2.49**	**3.08**	**1.46**	**2.90**	**3.35**	**1.27**	**2.73**	**3.21**	**1.36**

IX. Analysis of variance of simple classification and statistically significant differences in the yield of grain, starch and wet gluten per 1 ha among variants with different intensity of cultivation (Scheffe, $\alpha = 0.05$)

Year	Intensity of cultivation	Average yield of grain (t.ha^{-1})	Variance – among groups – inside groups	*F*-test	Homogeneity	Average yield of starch (t.ha^{-1})	Variance – among groups – inside groups	*F*-test	Homogeneity	Average yield of wet gluten (t.ha^{-1})	Variance – among groups – inside groups	*F*-test	Homogeneity
1997	Stupice (basic intensity)	9.34	1.672 0.007	250.9	A	6.27	4.642 0.287	16.2	A	2.81	3.435 0.020	168.4	A
	Stupice (higher intensity)	10.03			B	6.66			A	3.20			B
	Uhříněves (ecological system)	6.12			C	4.13			B	1.36			C
1998	Stupice (basic intensity)	8.16	9.602 0.018	531.8	A	5.36	3.713 0.016	230.5	A	2.49	2.689 0.020	134.4	A
	Stupice (higher intensity)	9.18			B	5.98			B	3.08			B
	Uhříněves (ecological system)	6.14			C	4.09			C	1.46			C
1999	Stupice (basic intensity)	10.45	16.125 0.032	509.2	A	6.97	5.835 0.017	350.1	A	2.90	4.791 0.020	239.5	A
	Stupice (higher intensity)	11.32			B	7.39			B	3.35			B
	Uhříněves (ecological system)	7.49			C	5.12			C	1.27			C

sailles and Estica excelled even in this evaluation at the basic intensity of cultivation. The varieties Siria, Contra and Astella excelled at higher intensity and Contra, Estica, Astella and Saskia in ecological cultivation. As it can be seen these are the same varieties like in evaluation of the yields. The variety Hana is a certain exception with the lowest yield of starch per 1 hectare. However, we should emphasise again that it is only theoretical calculation, because a real yield in starch factories is fluctuating about 370 kg per 1 tonne of grain for the starch of the quality group "A", 67 kg of gluten can be gained at 14% moisture. It can be estimated from this more real aspect on the starch production from three-year average of yields that the production from basic intensity of cultivation should be approximately 3.45 tonnes of the starch "A", from higher intensity – about 3.78 tonnes of the starch "A" and 2.50 tonnes per 1 hectare of the starch "A" from ecological cultivation. Hence the differences in production speak for the benefit of intensive cultivation systems that amounts to 0.95 tonnes of starch at the basic intensity and 1.28 tonnes of starch at higher intensity compared with ecological cultivation. Therefore, we have to emphasise that despite the effect of cultivation intensity on the starch content in grain, the total production of starch per 1 hectare is much affected by both fertilisation and treatment with fungicides, insecticides and growth regulators. The difference between basic and higher intensity of cultivation was about 330 kg of starch per 1 hectare, what amounts to about 3630 CZK and covers the costs of the treatments in experiments.

The production of wet gluten per 1 hectare can be calculated theoretically in a similar way. Significant effect of fertilisation and treatment with fungicides, insecticides and growth regulators on the total production of wet gluten per hectare has been confirmed even in this case. This production was higher at higher intensity of cultivation at Stupice and was more than double when compared with ecological cultivation.

Results of statistical evaluation correspond to these facts when statistically significant differences were found both in the yields of starch and wet gluten per 1 hectare in all three experimental years and among all variants of cultivation intensity. The only exception was the yield of starch per hectare in 1997 when no statistically significant difference was recorded between both intensive variants at Stupice.

DISCUSSION

Significant influence of higher intensity of cultivation (i.e. with application of fertilisers and pesticides) on the yield of grain followed from three-year results of evaluation of the starch content and wet gluten content in grain dry matter and yields of grain, starch and wet gluten per 1 ha in selected set of wheat varieties. It was shown further that the content of starch in grain in intensive cultivation is slightly falling and the content of gluten rises in intensive cultivation compared with ecological system (without fertilisers and pesticides). The total starch production per 1 ha in intensive cultivation is significantly higher due to significantly higher grain yields.

Petr et al. (1998a) present on the basis of their results that particularly N-fertilisation caused marked changes in the structure of wheat stands – higher number of spikes per area unit, higher productivity of spike and TKW. Stands were thinner in ecological cultivation and the time of filling of caryopses was shorter when assimilation apparatus of upper part of plant was ageing earlier.

This all proves that certain degree of intensity of cultivation is necessary for economically available cultivation of starch wheat. In our trials it was N fertilisation ranging from 90 to 110 kg $N.ha^{-1}$, corresponding to the doses of P and K and the usage of herbicide in basic intensity of cultivation and when herbicide, fungicide, insecticide and growth regulator were applied at higher intensity of cultivation.

The fact that the content of gluten is significantly higher in intensive cultivation is very important. This gluten can be separated during starch production as a worthy side product with good application. According to Gröbl (1996) it is the so-called vital gluten valued on world markets many times more than the starch alone.

In varieties recommended for starch production it is necessary to take into account also further qualities, among other facts, a good washing out of gluten (Kodet, 1999). A good washing out of gluten depends both on a variety and on intensity of cultivation, particularly with nitrogen. The Trane variety is an example of low quality of gluten with good starch content, but with bad separation ability. This variety has been excluded from our observations just for these problems connected with washing out of gluten (Petr et al., 1998b).The gluten is washing out with more difficulties if the wheat is cultivated under low intensity, i.e. without fertilisation and treatment with pesticides (Petr et al., 1999). We can mention that higher intensity of cultivation affected significantly positively also other quality criteria (crude protein content, SDS-test, falling number) (Petr et al., 2000) according to our further results of complex evaluation of technological quality of wheat.

The varieties Asta, Astella, Siria, Contra and Estica excelled in the starch content in our experiments both in intensive and ecological cultivation. At the same time, these varieties were distinguished by favourable content of high-quality gluten and particularly by high grain yields and hence by high total production of starch and gluten per hectare. All these varieties are among the quality groups B and C, and except Astella, they can be cultivated with success even in marginal regions, when they reach good yields under adequate intensity of cultivation. Also Rosenberg and Hubík (1996) found significant differences in yields of grain during evaluation of a set of winter wheat varieties. According to their results the highest yields were obtained by the varieties of quality group B and C, while quality varieties (A) and elite (E) varieties gave lower yields.

Results presented in this study come from the trials conducted under conditions of intensive sugar-beet

growing region, with production potential of soils 84 points (Stupice, Uhříněves). The results of further experiments can be presented for comparison with the same winter wheat varieties, carried out with identical intensity of cultivation at several variety testing stations of the Central Institute for Supervising and Testing in Agriculture in marginal regions (Variety Testing Station Domanínek, Hradec nad Svitavou, Trutnov, Stachy, Lípa near Havlíčkův Brod, Chrastava). Even under these conditions (cereal- and potato-growing region) identical knowledge like at Stupice and Uhříněves have been confirmed – higher intensity of cultivation characterised mainly by N-fertilisation and treatment with pesticides were manifested significantly in increased grain yields and hence also total production of starch and gluten per hectare. Results showed that as to both the site and weather pattern and naturally, to intensity of cultivation, the content of starch in grain was an indicator among the evaluated quality traits which showed lowest fluctuation and least differences among years, sites and variants with different intensity of cultivation. Compared with the starch content, the content of wet gluten was considerably variable.

It followed from results that evaluated wheat varieties in cooler conditions of cereal- and potato-growing regions were distinguished by higher starch content and lower content of crude protein and gluten. The difference was not, however, notable to declare that starch-making wheat should be cultivated exclusively in these regions. Even in fertile regions cultivation of starch-making wheat can be very efficient. However, food quality that is better valued in prices can be reached here with a greater certainty. In marginal regions the certainty of reaching parameters of quality of food wheat is much lower. Therefore, it should be possible to direct the production to starch-making utilisation that should be valued better than it was up to now (P e t r et al., 1999).

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Vliv odrůdy a intenzity pěstování na využitelnost pšenice pro produkci škrobu a lepku.

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Značný rozvoj produkce pšeničného škrobu klade nové nároky na škrobárenskou surovinu. Její jakost je vymezena především odrůdou, která zaručuje požadovanou výtěžnost a též kvalitu škrobu, danou vysokým podílem velkých škrobových zrn kategorie „A“. Významným koproduktem při produkci pšeničného škrobu je vitální lepek, užívaný

zejména v potravinářství. Významnou roli pro dosažení požadovaných jakostních parametrů škrobárenské pšenice hraje i intenzita pěstování a půdně-klimatické podmínky místa pěstování.

V tříletém období jsme hodnotili vybraný soubor odrůd ozimé pšenice z hlediska vhodnosti a využitelnosti pro škrobárenské účely. Cílem výzkumu bylo posoudit vliv odrůdy a intenzity pěstování na obsah škrobu a mokrého lepku v sušině zrna a dále na výnos zrna a celkovou produkci škrobu a lepku z hektaru.

Z výsledků srovnání ekologického a konvenčního způsobu pěstování vyplynul zcela průkazný vliv vyšší intenzity pěstování, tj. s aplikací průmyslových hnojiv a pesticidů, na výnos zrna a mokrého lepku. V intenzivním způsobu pěstování se ve srovnání s ekologickým (bez průmyslových hnojiv a pesticidů) mírně snižoval obsah škrobu v zrnu, protože stoupal obsah N-látek. Díky podstatně vyšším výnosům zrna byla však celková produkce škrobu z 1 ha výrazně vyšší.

Ukazuje to, že pro ekonomicky přijatelné pěstování škrobárenské pšenice je určitá míra intenzity pěstování nezbytná. V našich pokusech šlo o hnojení N v rozmezí 90–110 kg $N.ha^{-1}$, odpovídající dávky P a K a užití pesticidů.

V obsahu škrobu vynikly v našich pokusech jak v intenzivním, tak v ekologickém způsobu pěstování odrůdy Asta, Astella, Siria, Contra a Estica. Tyto odrůdy se současně vyznačovaly uspokojivým obsahem mokrého lepku dobré kvality a zejména vysokými výnosy zrna a tím i celkovou produkcí škrobu a lepku z hektaru. Všechny tyto odrůdy patří do jakostních skupin B a C a lze je, s výjimkou Astelly, s úspěchem pěstovat i v marginálních oblastech.

pšenice pro produkci škrobu; odrůdy; obsah škrobu; obsah lepku; intenzita pěstování; pěstitelská lokalita

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