2012 4th International Conference on Agriculture and Animal Science
IPCBEE vol.47 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2012. V47. 2

Quality and Yield Rate of Wheat Grown in Organic Farming

Petr Konvalina[1] and Ivana Capouchová[2]

[1] University of South Bohemia, Studentská 13, 37005 České Budějovice, CZ, konvalina@zf.jcu.cz

[2] Czech University of Life Sciences, Kamýcká 120, 165 21 Praha, CZ, capouchova@af.czu.cz

Abstract. Bread wheat (*Triticum aestivum* L.) is the most frequent cereal species in the Czech Republic grown in accordance with the organic farming principles. The range of cultivars is wide there; the organic farmers deal with a problem - how to understand it and orientate themselves in it. Our research aimed at an evaluation of the yield rate and the basic parameters of the baking quality of different winter wheat cultivars. The trial plants were grown in accordance with the organic farming principles between 2006 and 2011. The research outputs have shown that the organic growing of wheat is connected with a reduction of the yield rate, as well as the technological quality. The proportion of proteins in grain, just as the baking quality of proteins, decreases (the reduced values of the Zelenyho test). Our research has, however, shown a favorable yield rate and a good protein content of the following cultivars: Akteur, Ludwig or Element.

Keywords: Bread wheat, Selection of cultivars, Organic farming, Yield, Quality

1. Introduction

Bread wheat (*Triticum aestivum* L.) is the most frequent cereal species grown within the Czech organic farming system (Moudrý, 2004; Moudrý et al., 2005). In 2010, it represented almost 25 percent of the organic farming land (Hrabalová, 2011). Nowadays, there are neither bread wheat cultivars nor any other crop cultivars available in the Czech Republic, which have been bred with the organic farming target (Moudrý et al., 2007a, 2007b). Conventional bred and tested cultivars which have become overabundant within the organic farming conditions are usually grown in practice. Modern top cultivars are less suitable for organic farming because they have been bred in order to reach the genetic base favourable for intensive farming (using a considerable amount of easily accessible industrial fertilizers, pesticides and regulators of growth) (Wolfe et al., 2008).

Growing of the conventional cultivars with the purpose of their subsequent application within the organic farming system is deducible from the outputs of cultivar trials executed within a lower farming intensity. Anyway, it embodies certain risks. Grain yield rate (Murphy et al., 2007), and quality of grain yield, (Wolfe et al., 2008) expressed by the proportion and the composition of proteins in grain (Săulescu et al., 2005) are the logical indicators of the suitability of a cultivar for the particular farming system. Being grown within the organic farming system, bread wheat achieves a very low yield rate (Moudrý et al., 2006); the mean yield rate reaches 62 percent of the wheat being grown in accordance with the conventional farming conditions (Hrabalová, 2011). Foreign authors usually mention a higher yield rate of the organic wheat crop stand: 80 percent of the conventional wheat yield rate (Ingver et al., 2008).

Studies which have been introduced so far show that the conventional cultivars do not have all the features necessary to be grown in accordance with the organic farming principles (Wolfe et al., 2008). This article aims at the presentation of the results of the bread wheat cultivar trials which were carried out by the authors of the article for the particular period of time. It also aims at a demonstration of the necessity to establish an efficient system of certification of the organic cultivars.

2. Experiments and Results

2.1. Materials and Methods

Small-plot trials were established on the trial parcels of the University of South Bohemia in České Budějovice (CB), and the Czech University of Life Sciences (CZU). Ten cultivars of bread wheat were included in the CB trial (2006 – 2008) and fourteen varieties of bread wheat were included in the CZU trial (2007 – 2009). Furthermore, a comparative trial was executed in 2011; it aimed at the comparison of the conventional and organic farming systems (CZU, fourteen varieties of bread wheat). A list of the varieties included in the trials makes part of Tables 1 and 2. The trial crop stands were treated with a standard small-plot mechanisation, the treatment complied with the binding legislation on the organic farming. The character of the trial parcels is as follows: a) CB: climate – mid-warm; soil type – pseudo gley cambisol; soil class (sort) – loamy-sand soil; altitude – 338 meters above sea level. b) CZU: climate – warm and mid-dry; soil type – brown soil; soil class (sort) – loamy-sand soil; altitude – 295 meters above sea level. Analyses of the baking quality were executed in accordance with the standard procedure: a proportion of nitrogenous elements in grain dry matter (ČSN ISO 1871), proportion of wet gluten in grain dry matter (ČSN ISO 5531) and gluten index, Zelenyho test (ČSN ISO 5529), and falling number (ČSN ISO 3093).

2.2. Results and Discussion

The bread wheat grown on the CB parcel achieved the yield rate of 5.17 $t.ha^{-1}$ (the average value of ten cultivars being taken into account). As for CZU, the bread wheat achieved the yield rate of 6.68 $t.ha^{-1}$ (the average value of fourteen cultivars being taken into account). In 2011, the comparative trial was executed; it aimed at the comparison of the conventional bread wheat and organic growing (Table 3). The organic wheat achieved the yield rate of 7.5 $t.ha^{-1}$; the conventional wheat achieved the yield rate of 9.9 $t.ha^{-1}$ (Fig. 1). Akteur and Ludwig, two foodstuff cultivars grown in Prague-Uhříněves, achieved extraordinary above-average yield rates. As for non-foodstuff cultivars (C-qualitative class), e.g. Etela and Biscay achieved high values of the yield rate. The ascertained yield rate values, being compared to the usual yield rate, which amounts to 3.26 $t.ha^{-1}$ (Hrabalová, 2011), are considered as extraordinary and above-average. Analysing the most frequent and serious reasons for the low yield rate of the organic wheat plants, we have to name an insufficient absorption of nitrogen by plants in particular (Wolfe et al., 2008). A reduced hectare protein yield rate also bears relation to the deficiency of accessible nitrogen in the soil; it amounted to 0.56 $t.ha^{-1}$ on the CB parcel and to 0.81 $t.ha^{-1}$ on the CZU parcel (organically grown plants), or 1.16 $t.ha^{-1}$ on the CZU parcel as well (conventionally grown plants). On the other hand, the deficiency of the accessible nitrogen in the soil also encourages the resistance to lodging and improves the health state of the organically grown plants (e.g. it contributes to a reduction of mildew emergence).

As for the wheat used in the baking industry, the minimum limit required for the proportion of proteins in grain amounts to 11.5 percent. Element, an Austrian cultivar exceeded this limit, being grown on the CB parcel (Table 1). As for the CZU parcel, the average value of the proportion of proteins in grain also exceeded this limit of 11.5 percent (Table 2). However, there were considerable differences between the cultivars being grown on the CZU parcel; Akteur (12.5 percent) and Ludwig (12.1 percent) appeared as the most perspective cultivars. In 2011, as for the organically grown plants, they did not exceed the limit. There were three exceptions: Akteur, Ludwig and Florett (C-qualitative class). As for the conventionally grown plants, the value of the proportion of proteins in grain amounted to 12.6 percent (Fig. 2). Our research has proved a smaller difference between the organic and conventional growing than the other authors ever cited (e.g. Săulescu et al., 2005).

Furthermore, the value of the Zelenyho sedimentation test was also studied and ascertained; the minimum limit required for the baking wheat amounts to 30 ml. This qualitative indicator characterizes features of the wheat grain protein complex and it indicates a suitability of the particular wheat grains for the baking process. It is genetically conditioned but also influenced by an intensity of growing (Krejčířová et al., 2008). As for the CB station, the average value of the Zelenyho sedimentation test amounted to 39 ml, just as it did on the trial parcel being located in Prague-Uhříněves. The organic and conventional cultivars being compared to each other, they showed considerable differences in 2011. The average amount of sedimentation achieved 32 ml within the organic farming system (Glubus, Ludwig, Cubus and Akteur achieved the highest

values of the sedimentation rate). On the other hand, three conventional cultivars did not meet the minimum limit either; they were involved in the category of cultivars being unsuitable for the baking process.

Wet gluten content is supposed to be an additional qualitative indicator; the previous ČSN 461100-2 norm (foodstuff wheat) stipulated the minimum limit of the wet gluten content in wheat grain dry matter to be 24 percent (the limit was binding for the baking wheat). Any of the tested cultivars being grown on the CB parcel did not achieve the above-mentioned limit (Element – 23.6 percent). We noticed better findings on the parcel located in Prague-Uhříněves; all the cultivars exceeded the limit, except for one cultivar. Ludwig (28.4 percent) and Akteur (28 percent) achieved the highest values of the wet gluten content in grain. The conventional cultivars also exceeded the allowed limit of the wet gluten content in 2011 (27 percent and three cultivars did not exceed the limit – they almost achieved the value of 24 percent). They surpassed the values achieved by the organically grown cultivars (23 percent; six cultivars did not exceed the limit – they almost achieved the value of 24 percent). A possible effect of the farming system on the falling number was also studied and evaluated on the parcel located in Prague-Uhříněves in 2011. There were negligible differences, which correlated with the results presented by Trethowan (1995).

2.3. Conclusions

Any official testing of the utility value of the organic cultivars is not executed in the Czech Republic. Selecting the cultivars, we have to work with the findings made by the closest testing stations (the results of the low-intensity farming), or we contact the organic farmers working in similar conditions. The preference of cultivars forming their yield rate via their high thousand grain weight more than the total weight of spike, is generally accepted. The cultivars forming less tillers, higher plants, and the cultivars resistant to lodging, are also in demand. As for the other parametres, which should be also taken into account, the suitability for the particular land and climatic conditions, the competitiveness to weeds, the strong and rich root system, the formation of a sufficient amount of straw (if necessary), just as the qualitative parametres derived from the farming system, also belong to the significant ones. The selection of modern and efficient cultivars (the qualitative cultivars belonging to E-class, the elite ones) is generally recommended with the purpose of achieving as high a baking quality as possible, if these cultivars are grown in accordance with the organic farming principles. Such cultivars are able to form a sufficient yield rate, just as a sufficient quality standard, if being grown in the favourable land and climatic conditions.

3. Acknowledgements

This article was supported by the project of the National Agency for Agricultural Research of the Ministry of Agriculture of the Czech Republic, NAZV QI111B154.

Table 1: Basic statistical analysis of yield rate and quality of wheat winter cultivars (three replications in the period of 2006 and 2008), locality České Budějovice

Cultivar	Grain yield ($t.ha^{-1}$)	Crude protein yield ($t.ha^{-1}$)	Crude protein content (%)	Wet gluten content (%)	Zelenyho test (ml)
Ludwig	5.32	0.57	10.8	20.4	39
Eurofit	5.27	0.57	11.0	19.1	38
Erivan	4.80	0.49	10.4	18.1	41
Element	4.50	0.54	12.4	23.6	50
Clever	4.42	0.45	10.0	19.5	30
Capo	5.60	0.63	11.3	21.9	47
Econom	5.02	0.53	10.3	19.6	37
Epsilon	5.60	0.59	10.6	20.0	36
320/05	5.85	0.60	10.4	19.2	37
304/05	5.29	0.60	11.3	20.8	42
Mean ± CD	5.17 ±1.76	0.56 ±0.19	10.8 ±1.3	20.2 ±3.1	40 ±15
Remarks: CD = conclusive deviation					

Table 2: Basic statistical analysis of yield rate and quality of wheat winter cultivars (three replications in the period of 2007 and 2009), locality Praha-Uhříněves

Cultivar	Grain yield ($t.ha^{-1}$)	Crude protein yield ($t.ha^{-1}$)	Crude protein content (%)	Wet gluten content (%)	Zelenyho test (ml)
Akteur (E)	7.38	0.92	12.5	28.0	50
Ludwig (E)	7.41	0.90	12.1	28.4	53
Cubus (A)	6.73	0.80	12.0	26.6	44
Darwin (A)	6.53	0.79	12.0	27.0	43
Eurofit (A)	6.61	0.79	11.9	27.0	44
Buteo (B)	6.14	0.71	11.6	24.9	35
Globus (B)	7.11	0.82	11.5	26.0	40
Hedvika (B)	6.40	0.74	11.7	26.3	40
Meritto (B)	6.38	0.73	11.5	25.8	41
Biscay (C)	6.90	0.76	11.0	24.4	27
Dromos (C)	6.55	0.72	11.0	23.9	32
Etela (C)	7.51	0.84	11.3	24.7	30
Florett (C)	5.43	0.62	11.4	24.7	30
Simila (C)	6.48	0.73	11.3	24.4	30
Mean ± SD	6.68±0.70	0.78±0.09	11.6±0.5	25.9±1.5	39±8
Remarks: SD = Standard deviation; qualitative categories: elite baking quality (E), baking quality (A), bread baking quality (B), unsuitable for the baking process (C)					

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Table 3: Outputs of the evaluation of yield rate and quality of wheat winter cultivars, classified into the qualitative categories (2011, Praha-Uhříněves), two growing systems - organic farming (OF) and conventional farming (OF)

Qualitative category of cultivar (baking quality)	Grain yield rate (t.ha^{-1})		Crude protein yield (t.ha^{-1})		Crude protein content (%)	
	OF	CF	OF	CF	OF	CF
Elite quality (E)	8.9	10.2	1.05	1.25	12	12
Good-quality (A)	7.0	9.6	0.77	1.14	11	12
Bread quality (B)	7.7	9.7	0.79	1.13	10	12
Unsuitable (C)	7.1	10.0	0.76	1.16	11	12
Mean ± SD	7.5±1.5	9.9±0.8	0.81±0.1	1.16±0.1	10.8±0.7	11.8±0.7
Qualitative category of cultivar (baking quality)	Wet gluten content (%)		Zelenyho test (ml)		Falling number (s)	
	OF	CF	OF	CF	OF	CF
Elite quality (E)	25	32	41	47	305	280
Good-quality (A)	22	26	34	45	250	247
Bread quality (B)	22	28	33	37	276	270
Unsuitable (C)	25	25	25	26	226	245
Mean ± SD	24±1.0	27±3.4	32±7.7	37±10.0	257±66.3	258±61.6
Remarks: SD = standard deviation; OF = organic farming, CF = conventional farming						

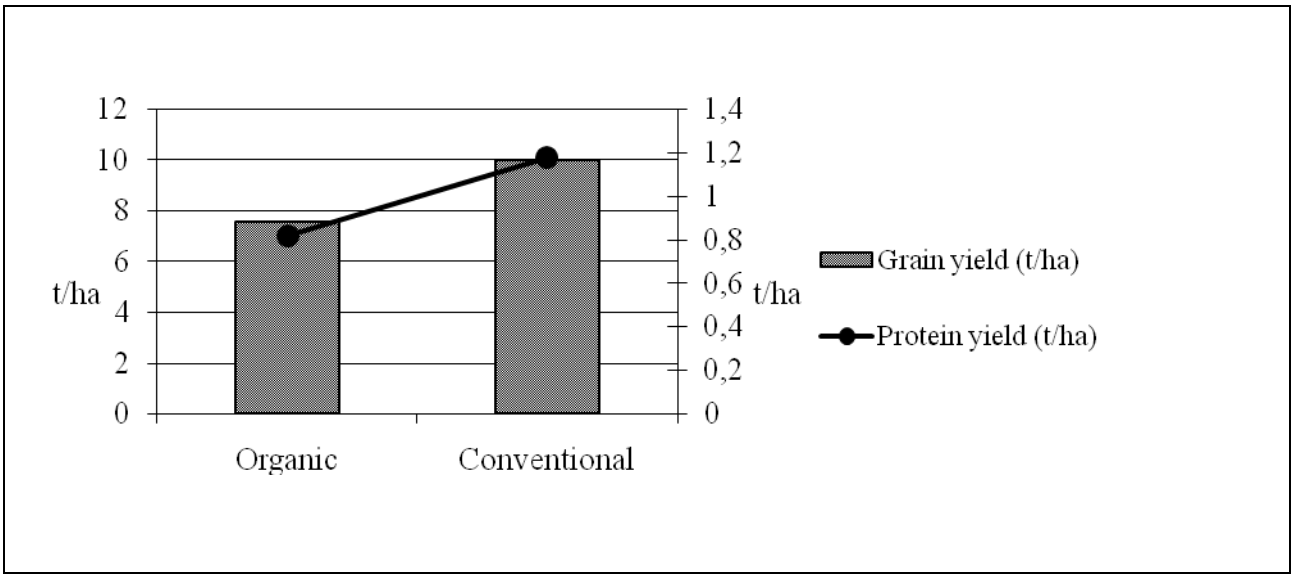

Fig. 1: Comparison of grain and protein yield in different growing systems (mean of 14 varieties)

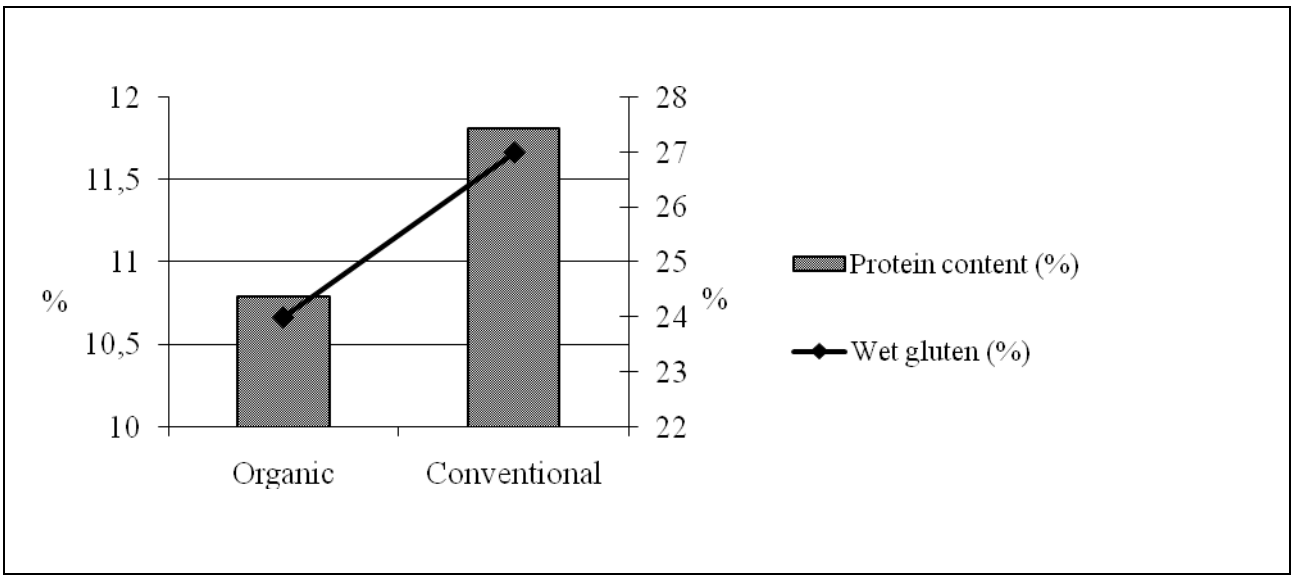

Fig. 2: Comparison of protein and wet gluten content (mean of 14 varieties)