The influence of nitrogen fertilization on quality of winter wheat grain

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Abstract: The aim of this study was to evaluate winter wheat grain quality after the application of different organic and mineral fertilizers at two sites in the Czech Republic (S1 - Červený Újezd, S2 - Prague-Suchdol). For the purpose of this paper were determined dry matter yield (DM, t ha^{-1}), bulk density (BD, kg hl^{-1}), thousand kernel weight (TKW, g) and grain crude protein content (CP, %) with regard to the requirements for food quality of wheat. The highest average yields were obtained after the use of mineral nitrogen fertilizers, at S1 6.9 t ha^{-1} and at S2 6.5 t ha^{-1}. In the first year of experiment was at S1 the highest average BD for treatments with mineral nitrogen (76.8 kg hl^{-1}), but in the second year for organic fertilized treatments (79.9 kg hl^{-1}), probably due to different weather conditions. At S2 was the highest average BD for treatments with mineral nitrogen fertilizers (78.6 kg hl^{-1}) in both years. At S1 was the highest average value of TKW found for farmyard manure (51.4 g), at S2 for mineral nitrogen treatment (56 g). The highest values of CP were determined after application of nitrogen in mineral form at both sites (12.3 %). At S2 was found high correlation between parameters, better quality and higher DM yield after the use of nitrogen in mineral form compare to the organic fertilizers. At S1 was high variability between years and treatments, but values of DM yield and CP were higher for mineral nitrogen fertilizers than for organic.

Key-Words: quality, nitrogen, wheat, fertilizer, protein concentration

Introduction

Nitrogen is the most important element to achieve stable high grain yields [1, 2] and is essential for improving grain quality of wheat [3, 4, 5]. Wheat is our most grown crop, in 2013 it was grown at 31.8 % of the total sown area of the Czech Republic [6]. Both high yield and good and stable quality are important features in today´s wheat market. To reach these goals N fertilizer rates, split N application and timing of application have been the major strategies recommended to increased protein content and improved alveograph parameters [7, 8]. Wheat quality and yield is influenced by the interaction of a number of factors, including cultivar, soil, climate, cropping practices and grain storage conditions. The performance of many quality characteristics depends greatly on environmental conditions, which result in differential expression of grain quality from site to [9, 10, 11]. Predictions of grain quality for the prospective wheat harvest would be of considerable value to grain buyers in aiding purchasing decisions, and to farmers to help optimize late-season agronomy [12]. The objective of this paper was to evaluate influence of different organic and mineral fertilizers on dry matter yield, bulk density, thousand kernel weight and crude protein content in winter wheat grain.

Material and Methods

In the experiment was examined the effect of different fertilizers on selected parameters of wheat grain quality. Experiments were established at two sites of the Czech Republic with different soil and

climatic conditions: S1 (Červený Újezd), S2 (Praha-Suchdol) (table 1). A simple crop rotation contained: maize (at S1)/potatoes (at S2), winter wheat and spring barley. Treatments of fertilization were repeated in three blocks allow for growing all crops every year.

For the purpose of this paper were evaluated six treatments with winter wheat: Control, Sewage sludge (SS), Farmyard manure (FYM), N in mineral fertilizers (N), NPK and N in mineral fertilizers + spring barley straw (N+ST). For these treatments was determined: dry matter yield (DM, t ha $^{-1}$), bulk density (BD, kg hl^{-1}), thousand kernel weight (TKW, g), and grain crude protein content (CP, %). All the quality traits were assessed using two random samples from each treatment.The whole experiment was based on the same nitrogen rate 330 kg N ha^{-1} to the crop rotation (of which 140 kg N ha^{-1} to the winter wheat) except the Control treatment, which was not fertilized (table 2). For mineral nitrogen fertilization was used Calcium ammonium nitrate. The dose of nitrogen was for winter wheat divided into two doses (such as regeneration and production fertilization). Organic fertilizers were applied only on the potatoes (S1)/silage maize (S2) in the crop rotation. The amount of applied nutrients is described in Table 2. The areas of experimental plots were 60 m^2, respectively 80 m^2 on the Červený Újezd site. The grown variety of winter wheat was Alana, which is characterized as a late variety with baking quality A.

For determination of thousand kernel weight was calculated 2 x 500 seeds using the electronic calculator and weighted the seeds with a prescribed accuracy. Bulk density was determined on laboratory meter model 1938 (Meopta, Czech Republic). Grain samples for determination of total nitrogen were homogenized on a laboratory cutting mill SM 100 (Retsch, Germany) and measured following the Kjeldahl method on the device VAPODEST 50s (Gerhardt GmbH & Co. KG, Germany). The observed nitrogen content was multiplied by a coefficient (for baking wheat 5.7) to obtain a crude protein content in grain [13].

Statistical evaluation of the results was performed between treatments with data over 2 years in the STATISTICA 12.0 program (StatSoft, Tulsa, USA) with the Main effects ANOVA followed by the Tukey´s test at the level of significance $P < 0.05$. Coefficients of correlation (r) between assessed traits are presented in correlation matrix for both sites and years.

Table 1 Characteristic of experimental sites

Site	S1	S2
Location	50°4'22''N, 14°10'19''E	50°7'40''N, 14°22'33''E
Altitude (m a.s.l.)	400	286
Average annual temperature (°C)	7.7	9.1
Average annual precipitation (mm)	493	495
Soil type	haplic Luvisol	haplic Chernozem
Soil texture	silt loam	silt loam

Table 2 Rates of nutrients N-P-K (kg/ha) during crop rotation cycle

	Potatoes/Silage maize	Winter wheat	Spring barley
Control	-	-	-
SS[1]	330-207-44	-	-
FYM[1]	330-102-307	-	-
N[2]	120-0-0	140-0-0	70-0-0
NPK[2]	120-30-100	140-30-100	70-30-100
N[2]+ST[1,3]	138-6-47	140-0-0	70-0-0

[1] P and K in organic fertilizers - average dose taking into account nutrient content in organic fertilizers; [2] mineral fertilizers: N - calcium ammonium nitrate (27 % N), P - triple super phosphate (21 % P), K - potassium chloride (50 % K); [3] 5 t/ha spring barley straw

Results and Discussion

Results were collected in years 2013 and 2014. Average values of DM yield were at both sites for Control treatment about 4 t ha $^{-1}$. After organic fertilizers increased average values to 6.1 t ha $^{-1}$ at S1 and 5.5 t ha $^{-1}$ at S2. Mineral fertilization increased average yields to 6.9 t ha $^{-1}$ at S1 and 6.5 t ha $^{-1}$ at S2. Yields were highly influenced by interannual variability. According to the standard ČSN 461100-2 is the limit of bulk density for food wheat 76.0 kg hl^{-1}. Required limit was not reached in year 2013 at S1 in Control, SS and FYM treatment. In this year and site were found the lowest values in our experiment. In the year 2014 all variants at S1 exceeded the required limit.

For all fertilized treatments at S2 values of BD were higher than 76.0 kg hl^{-1} in both experimental years. The significantly highest values were observed after mineral nitrogen fertilization at both sites, except year 2014 at S1, where the highest bulk density was for treatments with organic fertilizers. Values of BD were higher in the year 2014 compare to the year 2013 at both sites (see table 3). Bulk density is highly determined by weather conditions, particularly by high temperature during the final phase of grain filling [8, 10], which probably caused differences between years.

Thousand kernel weight is one of the yield parameter. The lowest values of TKW were at S1 site observed after application of mineral nitrogen and in combination with straw. In the contrary at S2 reached these treatments the highest values of TKW (table 4). At S2 were achieved higher values compare to S1. At S1 were the highest values found for FYM and NPK treatments, at S2 for N and NPK treatments. There were lower differences between years for TKW than for BD.

In the standard ČSN 461100-2 is the minimal requirement of CP for food wheat 11.5 %. This limit was not achieved by all Control and FYM treatments at both locations and by SS treatment at S1 and NPK at S1, but only in 2013. The highest values of CP were determined after application of nitrogen in mineral form at both sites (table 5). Kozlovský et al. [14] achieved similar high values of CP after application of 150 kg N ha^{-1} as in our experiment. At S2 was recorded significant correlation between all parameters. At S1 was correlation significant only between DMY and CP and DMY and BD. According to Kučerová [15] is between CP and DM yield very strong correlation, which was confirmed in our experiment (table 6).

Table 3 Bulk density (BD, kg hl^{-1})

	S1		S2	
	2013	2014	2013	2014
Control	74.66^{a}	78.25^{a}	75.58^{a}	75.95^{a}
SS	75.71^{b}	80.76^{d}	76.94^{b}	78.04^{b}
FYM	75.47^{ab}	80.61^{d}	76.40^{ab}	78.18^{b}
N	76.82^{c}	79.89^{c}	78.38^{c}	79.10^{c}
NPK	77.01^{c}	78.92^{b}	77.88^{c}	79.24^{c}
N+ST	76.44^{bc}	78.82^{ab}	77.83^{c}	79.13^{c}

Values of BD lower than 76.0 kg hl^{-1} are marked red. Values in the column with the same letter were not significantly different at P < 0.05.

Table 4 Thousand kernel weight (TKW, g)

	S1		S2	
	2013	2014	2013	2014
Control	48.70^{ab}	49.92^{ab}	51.36^{ab}	51.19^{a}
SS	48.44^{ab}	50.86^{b}	53.86^{bc}	54.34^{b}
FYM	50.20^{a}	52.54^{c}	53.72^{bc}	54.69^{b}
N	46.01^{b}	47.03^{d}	56.01^{c}	55.93^{b}
NPK	50.22^{a}	49.25^{a}	54.97^{c}	56.04^{b}
N+ST	46.26^{b}	46.27^{d}	54.22^{abc}	55.22^{b}

Values in the column with the same letter were not significantly different at P < 0.05.

Table 5 Protein content (CP, %)

	S1		S2	
	2013	2014	2013	2014
Control	8.55[a]	8.11[a]	9.90[a]	9.47[a]
SS	9.18[b]	9.58[b]	12.00[bc]	11.49[b]
FYM	9.31[b]	9.60[b]	10.28[a]	10.84[b]
N	11.89[c]	12.94[c]	11.87[b]	12.44[c]
NPK	11.38[d]	12.86[c]	12.39[bc]	12.40[c]
N+ST	11.92[c]	12.65[c]	12.56[c]	12.28[c]

Values of CP lower than 11.5 % are marked red. Values in the column with the same letter were not significantly different at P < 0.05.

Table 6 Trait correlation

Site	Trait	DMY	BD	TKW
S1 2013	BD	0.95	-	-
	TKW	-0.30	-0.29	-
	CP	0.89	0.92	-0.54
S1 2014	BD	0.28	-	-
	TKW	-0.43	0.49	-
	CP	0.83	-0.11	-0.73
S2 2013	BD	0.96	-	-
	TKW	0.94	0.94	-
	CP	0.88	0.87	0.72
S2 2014	BD	0.98	-	-
	TKW	0.93	0.99	-
	CP	0.98	0.97	0.95

The highest coefficients of correlation (r) indicated in red were significant at P < 0.05

Conclusion

The highest DM yields by up to almost 3 t ha $^{-1}$ in treatments with mineral nitrogen were achieved. Values of bulk density were highly determined by weather conditions. Higher values of BD after mineral nitrogen fertilizing compare to the organic fertilizing were observed, except of S1 in year 2014. At S1 were higher values of TKW found for SS and FYM treatments, at S2 for treatments with mineral nitrogen. Sufficient values of CP were in N, NPK and N+ST treatments, at S2 even in FYM treatment. At S2 was found high correlation between parameters.

For mineral nitrogen treatments higher values of DM yield, BD, TKW and CP compare to organic fertilized treatments at S2 were achieved. At S1 were values of DM yield and CP in both years and BD in year 2013 higher than for organic treatments.

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