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Winter wheat grain baking quality depending on environmental conditions and fertilizer

I. Skudra[1,2,*] and A. Ruza[1]

[1]Latvia University of Agriculture, Faculty of Agriculture, Institute of Agrobiotechnology, St. Liela 2, LV3001 Jelgava, Latvia
[2]Latvian Rural Advisory and Training centre, St. Rigas 34, LV3018 Ozolnieki region, Ozolnieki parish, Ozolnieki, Latvia
[*]Correspondence: ilze.skudra@llkc.lv

Abstract. Yield and quality of wheat grain depends on many factors such as environmental conditions, soil quality, genetic parameters and fertilization, especially nitrogen fertilizer which is one of the most important factor influencing quality parameters of winter wheat. Field experiments were done at the Research and Training Farm Vecauce of the Latvia University of Agriculture during 2013 till 2015. The aim of our study was to determine effect of nitrogen fertilization and environmental conditions on winter wheat (*Triticum aestivum* L.) variety 'Kranich' grain quality parameters. The investigated factors were six different nitrogen application norms (0 – control, 85, 153, 175+S21, 187 N kg ha^{-1}) and differential nitrogen norm according to chlorophylmeter (Konica Minolta Ltd.) data 180 N kg ha^{-1} in 2013, 150 N kg ha^{-1} in 2014 and 205 N kg ha^{-1} in 2015. One more variant was added – 175 N kg ha^{-1} in 2015. During the study years the meteorological conditions were significantly different. Our trials results showed that protein content suitable for bread making was obtained in variants N175+S21, 180 and 187 in year 2013, in all N application forms in 2014, but in 2015 – in all applications except N0, N175+S21, N85. The meteorological conditions had factor influence (η^2) 46% on protein content, but fertilizer application – 35%. Strong significant relationship at the 0.01 probability level between protein content and gluten content (r = 0.99), sedimentation value (r = 0.97) and falling number (r = 0.74) was found.

Key words: winter wheat, protein content, gluten content, fertilizers.

INTRODUCTION

Wheat is an important cereal in Latvia national economy providing human population with bread. The best available technology should be used for fertiliser and pesticide handling and used in a way to provide the maximum effectiveness with the minimal negative side effect on crop and environment (Alam, 2014). Nitrogen application is one of the crucial factors for successful implementation of crop management practices used in wheat production system. Lack of nitrogen (N) in plants was related to grain filling, which required greater nitrogen amounts to be applied later. To maximize the use of fertilizer N by crops, N should ideally be applied as it is required by the crop plants. The proportion of applied nitrogen taken up by the crop is affected by many factors including crop species, climate and soil conditions. A simple and reliable method for field determination of wheat nitrogen status is using of

chlorophyllmeter. It can be used to make quick and easy measurements of leaf greenness, which is positively related to leaf chlorophyll content (Murdock et al., 2004 & Marsh, 2014). More and more farmers looking for simple method which to help determine the crop N status. In Latvia there is no investigations about chlorophyllmeter usage in winter wheat.

There is limited demand for wheat with a low (< 12.0%) protein content in Latvia. Values less than 12.0% demonstrate nitrogen insufficiency reaching yield potential (Mašauskiene et al., 2006). Improvements in nitrogen management are needed to produce superior quality grain and satisfy market demands for baking quality. The baking quality of winter wheat depends greatly on variety, soil fertility, climatic conditions, crop density and fertilization (Johansson, 2002; Otteson et al., 2008; Linina & Ruža, 2014). The temperature, especially during the grain filling period, is the most important weather parameter. Johansson & Svensson (1998) have shown that 34% of variation temperature influenced protein content. Dupont & Altenbach (2003) conclude that genetic and environmental factors affect wheat quality mainly through their effects on grain protein content and composition.

The aim of our study was to determine effect of nitrogen fertilization and environmental conditions on winter wheat (*Triticum aestivum* L.) variety 'Kranich' grain yield and baking quality parameters.

MATERIALS AND METHODS

Field trials were carried out in the Research and Training Farm 'Vecauce' of the Latvia University of Agriculture during 2013 till 2015. The 2012/2013 and 2013/2014 experiments were carried out on the fields with winter oilseed rape as the previous crop, but in 2014/2015 – spring wheat. The soil at the site was loam, Endostagnic Phaeozem (Loamic) (WRB, 2014) with humus content 17–25 g kg^{-1}, soil pH KCl – 6.6–7.2, plant available potassium content average, phosphorus content – average to high, sulphur content – low. Winter wheat variety 'Kranich' was used. The variety is characterized by good winter hardiness, high yield potential and A Class food grain quality. It is one of the most suitable for growing in the Baltic conditions by using intensive technology. Sowing was done in optimal time for Latvia's conditions, and used seed rate was 450 viable seeds per m^2. At sowing depending on the year winter wheat was fertilized with compound fertilizer rate N – 15, P – 20, K – 62 kg ha^{-1} in 2012, N – 18, P – 34, K – 75 kg ha^{-1} in 2013 and N – 11, P – 21, K – 45 kg ha^{-1} in 2014.

The investigated factors were six different nitrogen application norms (0 – control, 85, 153 (85+68), 175+S21 (85+60(S14)+30(S7)), 187 (85+68+34) N kg ha^{-1}) and differential nitrogen norm according to chlorophylmeter (Konica Minolta Ltd.) data 180 (85+50+45) N kg ha^{-1} in 2013, 150 (85+50+15) N kg ha^{-1} in 2014 and 205 (85+70+50) N kg ha^{-1} in 2015 (further N-test). One more variant was added – 175 (85+60+30) N kg ha^{-1} in 2015. The first dose of nitrogen was given in spring at the beginning of wheat regrowth, the second time at the stem elongation and the third time – at the beginning of heading. Treatments were arranged in four replicated randomized blocks.

Grain yield was determined at 100% purity and 14% humidity after the grains was dried. After harvesting, grain samples per each plot were taken according to standard LVS – 270. Grain protein content, gluten content, sedimentation value or Zeleny index and starch content were determined by grain analyzer Infratec 1241 (Foss Tecator AB,

Sweden). The Hagberg falling number was measured by the Hagberg – Perten method using a Perten Instruments (Sweden) 'Falling number 1500' was assessed to LVS EN ISO 3093.

The meteorological conditions were significantly different in all research years. In 2013 and 2015 wheat overwintered succesfully, but in 2014 January and February were not favourable for plant overwintering and some of winter wheat did not survive. In 2013 vegetation started very late – at the end of April. In 2014 and 2015 in April air temperature was higher by 2.7 °C and 1.9 °C than the average for many years (Fig. 1). In 2013 May air temperature was 3°C higher than long-term and precipitation three times more than norm. In 2013 and 2015 June meteorological condition were very dry: precipitation was lower than long–term mean by 22.6 and 21.6 mm accordingly. In 2014 and 2015 June air temperature was lower than norm and in 2013 and 2015 was recorded sufficient precipitation. Air temperature in grain filling period – July – was close to the long–term mean in 2013 and 2015, but 3 °C higher than norm in 2014. August weather was favorable for harvesting in all research years.

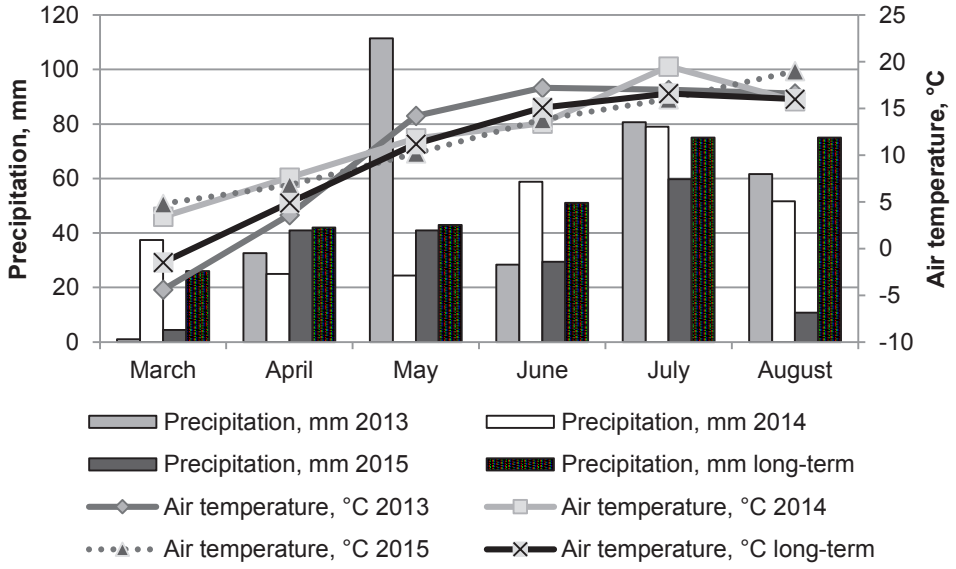

Figure 1. Meteorological conditions in 2013–2015 winter wheat vegetation period.

ANOVA procedures, the test of statistically significant differences at Fischer's criterion, impact factors influence (η^2) and correlation analyses were used for experimental data processing. The software MS Excel was used for data analyses.

RESULTS AND DISCUSSION

Split topdressings of nitrogen fertilizer after spring green-up may improve nitrogen efficiency and increase yield and grain quality (Jarvan et al., 2012; Alam, 2014). In our research according chlorophyllmeter readings nitrogen norm for plant growth and development were differ year by year (180, 150 and 205 kg ha^{-1} N) and provided baking

quality grain. Environmental conditions and plant supply with nutrients greatly influenced demand for nitrogen each year.

Wheat grains with protein content more than 12.0% are suitable for bread making. Our trials results showed that protein content suitable for bread was obtained in variants N175+S21, N-test and N187 ($LSD_{0.05}$ = 0.39) in year 2013, in all N application forms ($LSD_{0.05}$ = 0.29) in 2014, but in 2015 – in all N applications except N0, N175+S21, N85 ($LSD_{0.05}$ = 0.76) (Table 1). The baking quality parameters were influenced by environmental conditions (trial site, soil type, meteorological conditions) in trial years and nitrogen fertilizer. A significant impact ($P < 0.05$) of nitrogen application (35%) and meteorological conditions (46%) were noted on protein content. Similar results have been reported for winter wheat meteorological conditions significant impact to protein content (Cociu & Alionte, 2011; Linina & Ruža, 2014).

Table 1. Effect of nitrogen fertilizer on winter wheat grain quality parameters, 2013–2015

Year	Nitrogen fertilizer rates							
	N0	N85	N153	N175	N175+S21	N–test	N187	$LSD_{0.05}$
Protein content, %								
2013	9.10	9.70	11.40	x	12.50	12.00	12.60	0.39
2014	12.43	12.50	14.50	x	15.23	15.38	15.85	0.29
2015	9.70	9.97	12.55	12.92	10.80	14.02	13.62	0.76
Average	10.41	10.72	12.82	12.92	12.84	13.80	14.02	x
Gluten content, %								
2013	16.08	17.65	22.65	x	25.65	24.43	25.98	1.29
2014	25.20	25.65	30.60	x	32.55	33.15	34.68	0.89
2015	18.20	19.00	26.35	27.77	21.60	30.77	29.40	2.28
Average	19.83	20.77	26.53	27.77	26.60	29.45	30.02	x
Sedimentation value, mL								
2013	20.33	23.83	35.50	x	41.90	39.73	42.78	2.92
2014	35.43	39.63	58.10	x	62.65	62.98	63.38	3.94
2015	23.57	25.67	46.80	51.67	32.27	61.27	59.02	7.04
Average	26.44	29.71	46.80	51.67	45.61	54.66	55.06	x
Falling number, s								
2013	371	341	379	x	364	365	370	19.36
2014	354	371	383	x	385	381	391	9.77
2015	334	343	369	359	375	388	379	14.41
Average	353	352	377	359	374	378	380	x

The use of nitrogen fertilizer increased gluten content in all trial years. The highest gluten content (34.68%) was obtained in year 2014 by using nitrogen fertilizer norm 187 kg ha^{-1}, also all N norms provided suitable gluten content for baking quality grains (25.20– 4.68%). Meteorological conditions (40%) and nitrogen fertilizer (51%) showed significant impact ($P < 0.05$) on this parameter.

Sedimentation value or Zeleny index is the most important protein quality character trait. In all trial years sedimentation value increased with increasing nitrogen fertilizer norm. Nitrogen fertilizer influence on sedimentation value was found also in other scientist trials (Mašauskiene et al., 2006; Linina et al., 2012). Three year average sedimentation value above nitrogen fertilizer norm 153 kg ha^{-1} obtained second class quality (45.61–55.06 mL). These grains were useful for direct baking or mixing up with

comparatively weak flour. Meteorological conditions (30%) and nitrogen fertilizer norm (57%) showed significant influence ($P < 0.05$) on sedimentation value.

An important parameter of wheat grain quality is Hagberg falling number, which shows α-amylase activity and measure how far the break-down of starch has progressed in the kernel through enzymatic activities. Optimal falling number for good bread preparing according grain processor Dobeles dzirnavnieks (Dobele Miller) requirements is more than 230 s (Elite and A class > 280 s, I group > 270, II group > 250, III group > 230) (Dobeles Dzirnavnieks, 2015). Falling number higher than 280 s (334–391 s) was obtained in all trial years and standard – Elite was reached. High falling number indicated low α-amilase activity (Lunn et al., 2001) and is affected by the precipitation during grain maturation (Johansson, 2002). Our results showed significant impact ($P < 0.05$) of nitrogen fertilizer (43%) and meteorological conditions (11%) on falling number. In all investigated years precipitation at grain harvesting period were lower than long-term mean (Fig.1) and provided high falling number – to comply with bread baking quality requirements put forward by processors.

Different grain yields were obtained depending on trial year meteorological conditions and nitrogen application norms. Grain yield in 2013 varied from 4.07–7.84 t ha^{-1}, in 2014 – 2.79–5.20 t ha^{-1}, and in 2015– 4.23–10.20 t ha^{-1}. The highest winter wheat yield (10.20 t ha^{-1}) was obtain in 2015 with N application N175+S21, but – with low protein content (10.80%), it could be explained by lack of nitrogen for obtaining food grain quality. This is in accordance with results of other studies (Jarvan et al., 2012) where with increasing yields the protein and wet gluten concentrations in grain decreased. Correlation between grain yield and quality parameters was not found. Results connected with Linina & Ruza (2014) and Kaya & Akcura (2014) reports. Correlation analyses of qualitative parameters of wheats shows a strong significant relationship at the 0.01 probability level between protein content and gluten content r = 0.99 (Table 2), sedimentation value r = 0.97 and falling number = 0.74 ($\alpha_{0.01} = 0.60$, $n = 19$). Similar results were found by Kaya & Akcura, 2014 and Cioineag & Cristea, 2015. Close significant negative correlation at the 0.01 probability level was found between protein content and starch content (r = -0.98). Close significant correlation was found also between gluten content and sedimentation value, and falling number.

Table 2. Correlation between winter wheat grain quality parameters

Parameter	Grain yield	Protein content	Gluten content	Sedimentation value	Falling number
Protein content	-0.11				
Gluten content	-0.06	0.99	1.00	x	x
Sedimentation value	0.02	0.97	0.98	1.00	x
Falling number	0.06	0.74	0.74	0.75	1.00
Starch content	0.02	-0.98	-0.98	-0.98	-0.77

Probability level $\alpha_{0.01} = 0.60$, $n = 19$.

Similar researches in future have to be done in winter wheat for high grain yield and baking quality obtaining under different nitrogen management strategies. The usage of chlorophyllmeter is increasing in farms that are why more research has to be done in future.

CONCLUSIONS

The baking quality parameters (protein content, gluten content, sedimentation value and falling number) were significantly ($P < 0.05$) influenced by environmental conditions (trial site, soil type, meteorological conditions) in trial years and application of nitrogen fertilizer. Protein content suitable for bread was obtained in variants with nitrogen fertilizer more than 153 kg ha^{-1}, except in year 2013 – N153 kg ha^{-1} and 2015 – N175+S21 kg ha^{-1}. Nitrogen fertilizer increased gluten content and sedimentation value in all trial years. Correlation between grain yield and quality parameters was not found. Strong significant relationship at the 0.01 probability level between protein content and gluten content, sedimentation value and falling number was found. Further research on N fertilizer usage efficiency in winter wheat is needed.

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