Agronomy Research **8** (Special Issue III), 595–602, 2010

Effect of fertilization and conditions of year on some characteristics of spring wheat and barley

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Abstract. Spring wheat and barley are the most cultivated spring cereals in Estonian farming. Six-year (2003–2008) field trial was conducted at the Jõgeva Plant Breeding Institute to estimate the effect of fertilization and weather conditions of the tested years on characteristics of spring wheat and barley. Four levels of fertilization (N0 – untreated control $N_0P_0K_0$ kg ha^{-1}; N1 – $N_{60}P_{13}K_{23}$; N2 – $N_{100}P_{22}K_{39}$; N3 – $N_{140}P_{31}K_{54}$) were applied using the complex fertilizer Kemira Power ($N_{18}P_4K_7$). The weather data during the tested years were variable. Year as factor influenced the length of growing period of both cereals the most (wheat 98.0%; barley 98.5%). Wheat had longer growing period than barley (difference 11 days). Spring wheat was more sensitive to environmental conditions; its yield was more affected by year (32.3%) than barley (3.3%). Moreover, from variation of yield of barley 82.0% was explained by fertilization and the same for wheat was 52.9%. The lodging resistance of both crops was influenced by fertilization, year conditions and their interaction (Y x F). The year conditions and Y x F interaction influenced 1000 kernel weight of both cereals, but fertilization had only a marginal effect on this parameter. The protein content of both crops depended on the fertilization and year as factor. Wheat showed higher level of this characteristic in all the years and fertilizer doses.

Key words: spring wheat, spring barley, fertilization, weather conditions

INTRODUCTION

Spring wheat and barley are the most cultivated spring cereals in Estonian farming. High grain yield and quality are important for food and feed production, where wheat is used for food and feed, barley for feed mostly.

The yield of wheat and barley is influenced by environmental conditions during vegetation period, particularly light interception, air and soil temperature, plant water stress and the available nutrient absorption (Araus, 2002; McMaster & Wilhelm, 2003). Furthermore, the crop management effects have been investigated for purpose to increase yield capacity and achieve better quality of spring cereals (Metho et al., 1997; Peltonen-Sainio et al., 1997; Oscarsson et al., 1998; Jermuss & Vigovskis, 2008). In recent years, there has been major interest focused on long-term investigations about the effect of climate changes on crop adaptation and productivity (Marton, 2008; Peltonen-Sainio et al., 2009).

The aim of this work was to estimate the influence of fertilization and weather conditions of the years on some characteristics of spring wheat and barley during six-year period.

MATERIALS AND METHODS

The trial was carried out at the Jõgeva Plant Breeding Institute during the years 2003–2008. The soil of the experimental site was *Calcaric (Eutric) Cambisol* (FAO classification), with pH_{KCl} 5.5, C organic content 1.8%, available P 200 mg kg^{-1}, K 219 mg kg^{-1} and Ca 1669 mg kg^{-1}. The field trial was established on 9 m^2 plots in three replications using a randomized block design. The plots were sown with two wheat and barley varieties at density of 600 (wheat) and 500 (barley) germinating seeds per m^2 in early May. Four levels of fertilization (N0 – untreated control $N_0P_0K_0$ kg ha^{-1}; N1 – $N_{60}P_{13}K_{23}$; N2 – $N_{100}P_{22}K_{39}$; N3 – $N_{140}P_{31}K_{54}$) were applied using the complex fertilizer Kemira Power ($N_{18}P_4K_7$) before sowing.

The length of growing period, grain yield, lodging resistance, 1000 kernel weight and protein content were measured as the characteristics. Grain yield (kg ha^{-1}) of dried and cleaned seeds was weighted and expressed on the basis of 14% moisture content. Lodging resistance was evaluated in the field using scale of 1–9 points, where 9 points means no lodging. Grain protein content was determined by total nitrogen using the Kjeldahl method (N x 6.25).

Data were analyzed by factorial analysis of variance using the Agrobase II statistics software. The significance of the differences between the averages (*LSD, p* < 0.05), variation and coefficients were calculated. The correlations between the characteristics and fertilizers doses were found.

Field meteorological station Metos Compact recorded the weather data during the six-year period. The weather data were variable (Table 1). In 2004 and 2005 the weather conditions were quite favourable for cultivating spring cereals. The average air temperature during the vegetation period (May–August) of 2004 was close to the long-term average, but the sum of precipitation somewhat higher.

Table 1. The average temperature and sum of precipitation for growing seasons 2003–2008 and long-term average (1922–2008) at Jõgeva.

Year	Avg. air temperature °C					Sum of precipitation mm				
	Month					Month				
	May	June	July	August	May-August	May	June	July	August	May-August
2003	11.3	13.0	19.5	15.0	14.7	100	59	53	187	399
2004	10.0	13.1	16.3	16.5	14.0	16	183	68	113	380
2005	10.6	14.0	17.8	16.0	14.6	80	51	60	116	307
2006	10.5	16.0	18.1	16.8	15.4	36	40	10	74	160
2007	11.7	15.7	16.8	17.6	15.5	61	43	85	64	253
2008	10.4	14.2	15.6	15.3	13.9	21	107	56	195	379
Long-term average*	10.3	14.5	16.7	15.3	14.2	55	75	88	95	313

* – average of the years 1922–2008

Monthly period of early drought before heading was observed in 2006 and 2007. The average temperature of these years was higher and sum of precipitation lower than average. The grain harvest period was wet and rainy in 2003 and 2008. The average air temperature in 2008 turned out to be somewhat lower than long-term average.

RESULTS AND DISCUSSION

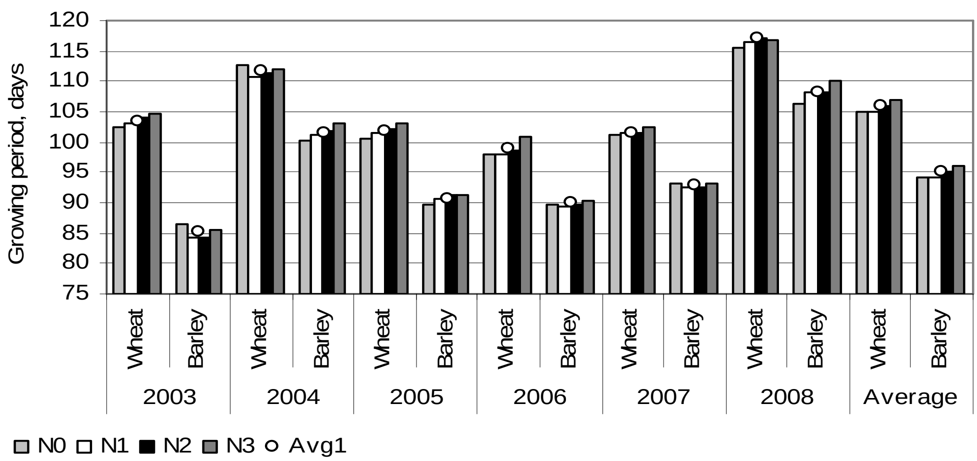
The presented factors (year conditions, fertilizer dose, their interaction) affected the variation of characteristics of spring wheat and barley (Table 2).

The length of growing period was influenced by year as factor the most (wheat 98.0%; barley 98.5%). The growing period was the shortest for wheat in 2006 (99 days) and for barley in 2003 (85 days) (Fig. 1).

Table 2. The characteristics of wheat and barley at different variation sources (%).

Source of variation	Growing period	Grain yield	Lodging resistance	1000 kernel weight	Protein content
Wheat					
Year (Y)	98.0***	32.3***	20.5***	79.5***	41.2***
Fert.dose (F)	0.9***	52.9***	36.4***	4.0***	50.9***
Y x F	0.9***	12.4***	34.1***	14.5***	7.3***
Barley					
Year (Y)	98.5***	3.3***	33.5***	62.6***	38.6***
Fert.dose (F)	0.5***	82.0***	22.5***	6.3***	51.0***
Y x F	0.6***	12.6***	40.5***	26.9***	8.8***

*** significant at $p < 0.001$



Avg1 – average of fertilizer doses

Figure 1. The length of growing period at different fertilizers doses in the tested years (2003 – $LSD_{0,05}$ = 0.7; 2004 – $LSD_{0,05}$ = 0.8; 2005 – $LSD_{0,05}$ = 0.7; 2006 – $LSD_{0,05}$ = 0.6; 2007 – $LSD_{0,05}$ = 0.7; 2008 – $LSD_{0,05}$ = 0.9; average –$LSD_{0,05}$ = 0.7).

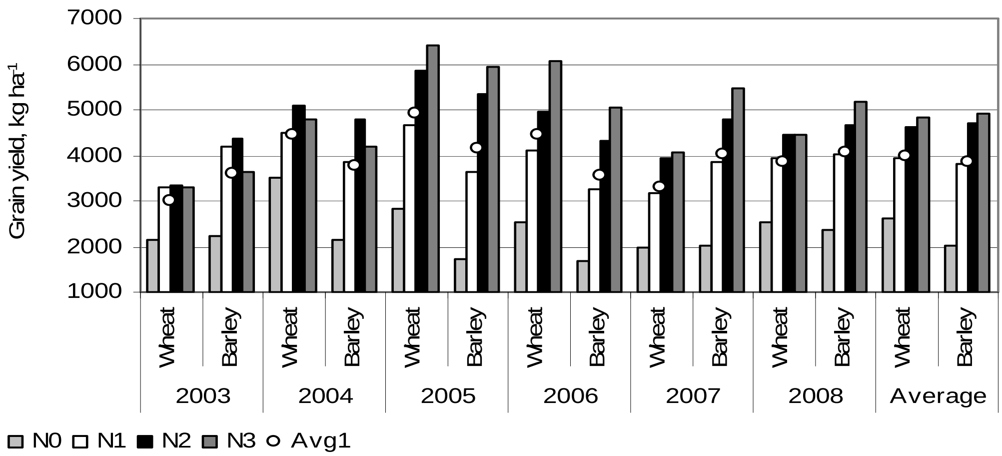
Dominated high air temperature shortened the length of growing period of these years. Furthermore, on the contrary, the cool and wet weather conditions in 2008 prolonged the length of growing period of both cereals – wheat 117 and barley 108 days.

In average of the years the growing period of wheat was 11 days longer than barley. This is in accordance with the results of White (1995) concluding that barley has shorter life cycle than wheat.

The influence of fertilization to the length of growing period of both cereals was low. In six-years average, higher fertilizer dose (N3) prolonged the growing period of wheat for two days and barley one day.

Grain yield. Results revealed, that grain yield of barley highly related with fertilization (82.0%), while fertilization (52.9%), year (32.3%) and Y x F interaction (12.4%) influenced wheat yield. Furthermore, in average of six-year period, the variation of barley yield was affected by year conditions only by 3.3% and Y x F interaction was 12.6%. Somewhat different results were reported by Oscarsson, et al. (1998), where there was indicated the major importance of Y x F interaction for yield of barley. Better tillering capacity made barley less sensitive to growing conditions in different years.

The grain yield of wheat varied in average of tested years between 3,020–4,930 kg ha^{-1} (*CV* 18.7%) and barley 3,570–4,160 kg ha^{-1} (*CV* 6.5%) (Fig. 2). Barley showed higher yield stability than wheat. For both spring cereals the year 2005 was the best for high yield formation, but unfavourable in 2003 for wheat and 2003, 2006 for barley.



Avg1 – average of fertilizer doses

Figure 2. The grain yield at different fertilizer doses in the tested years (2003 – $LSD_{0,05}$ = 331; 2004 – $LSD_{0,05}$ = 504; 2005 – $LSD_{0,05}$ = 394; 2006 – $LSD_{0,05}$ = 357; 2007 – $LSD_{0,05}$ = 380; 2008 – $LSD_{0,05}$ = 264; average – $LSD_{0,05}$ = 268).

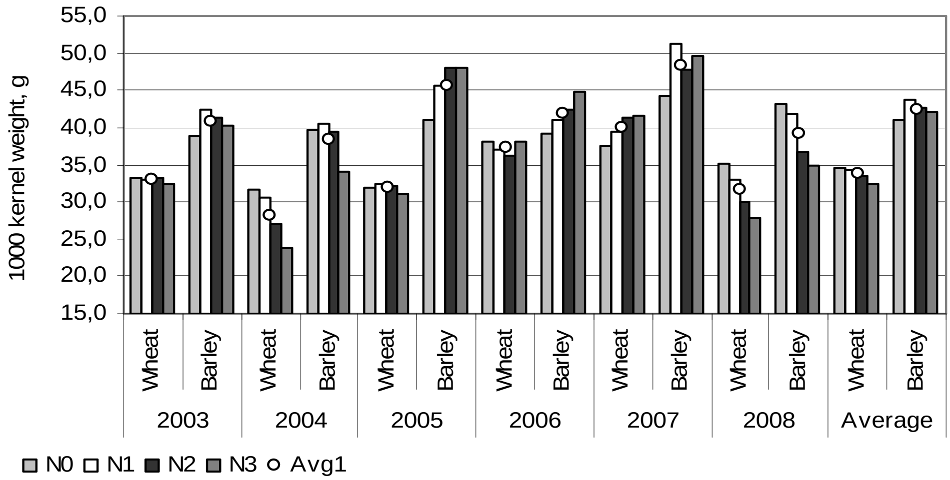
In 2006, the drought caused stress-situation in plants. Stress can reduce the duration of photosynthetic area, which limits yield of biomass (Araus, 2002). The contribution of assimilates to final grain yield depends on environmental conditions during grain-filling period (Simmons, 1987; Moral et al., 2002; Zahedi & Jenner, 2003), but the weather conditions in 2003 were not in favour of high yield productivity. Warm and humid weather conditions during grain harvesting caused the sprouting of kernels in 2003. Lodging contributed the pre-harvest sprouting of cereals under favourable weather conditions (Detje, 2008).

In average the both crops reacted positively to the increase of N dose. The lowest yield of the both cereals was obtained in N0 dose and the highest in N3. The biggest difference appeared in N0 dose. In three out of six years (2004, 2005, 2006), barley was less yielding than wheat. Barley had difficulties in booting stage. The ears were kept in sheath of flag leaf and the length of ear remained shorter, which decreased seed formation. The differences between grain yields of the crops were small in the rest of the N doses. In average of years, the both crops had significant differences *($p < 0.05$)* between the yields obtained by different fertilizer doses.

Lodging resistance. Our results showed, that the fertilizer dose (36.4%), Y x F interaction (34.1%) and year conditions (20.5%) determined the variation of lodging resistance of wheat. The lodging resistance of barley was more influenced by Y x F interaction (40.5%), year conditions (33.5%) and fertilization (22.5%). In three years (2003, 2005, 2008) out of six, there were significant differences in lodging resistance between two cereals. Wheat had 8.5 points and barley 9.0 points in 2005 ($LSD_{0,05} = 0.3$). Nevertheless this, there was heavy lodging of barley observed in fertilizer dose N3 (2003 3.0 and 2008 2.5 points). Wheat experienced only moderate lodging during these years. In average of fertilizer doses wheat had 8.0 (2003), 8.5 (2008) points and barley 6.6 (2003, 2008) points ($2003 - LSD_{0,05} = 0.7; 2008 - LSD_{0,05} = 1.3$), accordingly. Our results confirmed that wheat was more resistant to lodging than barley (Berry et al., 2006). In the years of drought (2006, 2007) no lodging occurred.

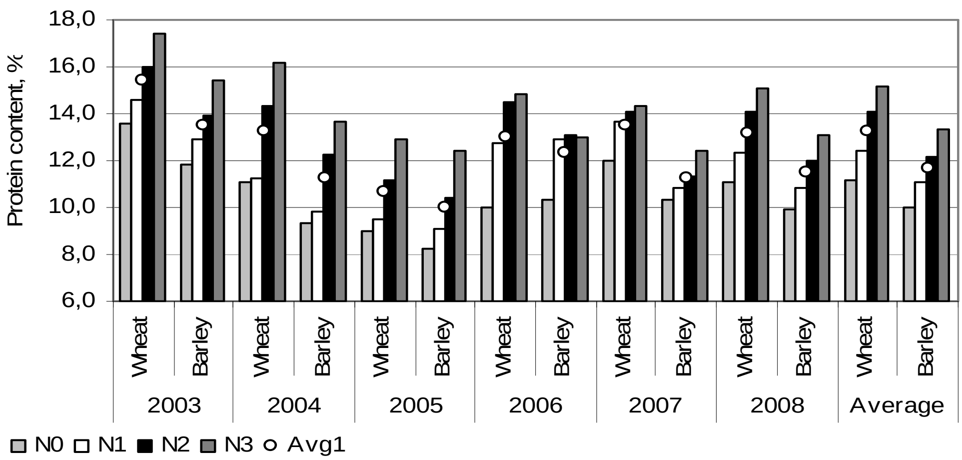
1000 kernel weight. Six-year data revealed, that the variation of 1000 kernel weight of wheat and barley was mostly influenced by year as factor (wheat 79.5%, barley 62.6%). The impact of Y x F was 14.5% for wheat and 26.9% for barley. The influence of fertilization turned out to be lower. Our results agree with those of Oscarsson et al. (1998), where environmental factor was of special importance for 1000 kernel weight and fertilization had only a marginal effect on this parameter. As shown in Fig. 3, generally, there were significant differences ($p < 0.05$) in average 1000 kernel weight of barley between the tested years. Wheat reacted differently – there were no significant differences between the averages of 1000 kernel weight of wheat in two years (2005 and 2008). The smallest kernels developed in 2004 (for wheat 28.3 g; for barley 38.4 g) and the biggest in 2007 (for wheat 40.0 g; for barley 48.2 g). The differences between these years in 1000 kernel weight were 11.7 g for wheat and 9.8 g for barley. Over the years in average of fertilizer doses, 1000 kernel weight of barley had somewhat higher stability (*CV* 9.1%) than wheat (*CV* 12.7%). 1000 kernel weight of barley (42.4 g) was significantly higher than wheat (33.7 g) in average of the years ($LSD_{0,05} = 1.3$). At higher fertilizer doses (N2 and N3), smaller kernels of the both crops were produced. Metho et al. (1997) obtained similar conclusions.

Protein content. The main significant impact on protein content of both crops had fertilization (wheat 50.9%, barley 51.0%) followed by year effect (wheat 41.2%, barley 38.6%). Metho et al. (1997), Oscarsson et al. (1998) and Åssveen (2009) found similar results**.** Protein content was higher at higher fertilizer doses (Fig. 4). All the differences between the doses were significant ($p < 0.05$). In average of six-years, the wheat kernels contained considerably more protein (13.2%) than barley (11.7%), difference was 1.5% ($LSD_{0,05} = 0.5$). The same results were found in publications of Orth & Shellenberger (1988) and Kangor et al. (2007). The highest average protein content formed in 2003 (wheat 15.4% and barley 13.5%) and the lowest in 2005 (wheat 10.7% and barley 10.0%).



Avg1 – average of fertilizer doses

Figure 3. 1000 kernel weight at different fertilizer doses in the tested years (2003 – $LSD_{0,05} = 1.2$; 2004 – $LSD_{0,05} = 1.7$; 2005 – $LSD_{0,05} = 1.1$; 2006 – $LSD_{0,05} = 1.4$; 2007 – $LSD_{0,05} = 1.6$; 2008 – $LSD_{0,05} = 2.1$; Average – $LSD_{0,05} = 1.3$.



Avg1 – average of fertilizer doses

Figure 4. Protein content at different fertilizer doses in the tested years (2003 – $LSD_{0,05} = 0.5$; 2004 – $LSD_{0,05} = 0.3$; 2005 – $LSD_{0,05} = 0.3$; 2006 – $LSD_{0,05} = 1.0$; 2007 – $LSD_{0,05} = 0.6$; 2008 – $LSD_{0,05} = 0.6$; Average – $LSD_{0,05} = 0.5$).

The maximum differences between the years were 4.7% (wheat) and 3.5% (barley). The protein contents of wheat and barley varied quite similarly between the years (*CV* 11.6% for wheat and *CV* 10.1% for barley).

CONCLUSIONS

The six-year results (2003–2008) indicate that the influence of fertilization and year on characteristics of spring wheat and barley were variable. The impact of year as factor was the biggest to the variation of length of growing period. Wheat had considerably longer growing period than barley. Our results indicated that by using higher fertilizer dose (N3) the growing period of wheat prolonged somewhat more.

We found that the yield of wheat was affected substantially more by year conditions than barley. Yield of barley depended more on fertilization.

The variation of lodging was influenced by fertilization, year conditions and their interaction. Wheat had better lodging resistance than barley, especially at higher fertilizer doses.

The impact of fertilization to 1000 kernel weight was lower compared to year conditions and Y x F interaction. Furthermore, barley had higher 1000 kernel weight than spring wheat.

The main significant impact on protein content of both crops had fertilization followed by year effect. Protein content was higher at higher fertilizer doses. Spring wheat had higher protein content than barley.

ACKNOWLEDGEMENTS. We thank the regional Kemira GrowHow Authority that supported this trial financially.

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