

## Spring cereals performance in organic and conventional cultivation

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**Abstract.** The field trials were carried out at the Jõgeva Plant Breeding Institute to compare grain yield and quality characteristics of spring wheat, barley and oat in organic and conventional conditions. Thirteen varieties of each cereal crop were tested during the four trial years (2005–2008). By the results turned out that all the spring crops were able to produce comparatively high yields in organic conditions after a suitable precrop. Oat as the most unpretentious crop was the highest yielding in organic trial and had the best weeds suppressing ability among the spring cereals. The most widely spread weeds were (*Chenopodium album*) and (*Viola arvensis*). Among the quality traits protein content was the most influenced by the management regime having evident decrease in organic conditions. A yield gap between organic and conventional production depended on crop, precrop and growing conditions.

**Key words:** spring wheat, barley, oat, yield, quality, weeds, organic, conventional

### INTRODUCTION

The lack of information on the relative performance of cereal crops and their modern varieties under organic conditions is a limitation for organic farmers. In Europe Vogt-Kaute (2001), Lammerts van Bueren (2003), and (Wolfe et al., 2008) have tested and summarized results of organic trials and drawn out several aspects of organic plant breeding and crop production. In the Estonian University of Life Sciences research on the effects of pure and undersowing green manures on yields of succeeding spring cereals was carried out by a group of scientists (Talgre et al., 2009). Concurrent comparison of spring cereals and their varieties in organic and conventional conditions was started in 2005 in Estonia. Preliminary results of our trials about yield and quality were published in 2007 (Tamm et al., 2007) and 2008 (Ingver et al., 2008). The trial was continued and 4 years results are summarised in the current publication.

### MATERIALS AND METHODS

The trials were carried out during 2005–2008 at the Jõgeva Plant Breeding Institute. Thirteen varieties (Estonian Variety List of 2005) of each spring cereal crop, wheat, barley and oat, were tested in organic and conventional conditions. The trials were established on 5 m<sup>2</sup> plots in 4 replications by randomized complete block design on soddy-podzolic soil. The organic trial was organised in accordance of the principles

of organic farming in Estonia. In the organic trial the contents of P and K in soil were fluctuating but no decrease was evaluated. The content of P remained on good and K on average level. The soil pH decreased from 6.4 to 6.2 in the trial period. Precrop in organic trial was red clover in 2005 and 2006 followed by buckwheat in 2007 and 2008. Mechanical weed control by repeated harrowing was carried out after germination and at the 3–4 leaves stage. Precrops in conventional trials were potato (2005, 2006) and rapeseed (2007, 2008). Fertilizer level  $N_{70}P_{16}K_{29}$  was used for oat and  $N_{90}P_{20}K_{38}$  for barley and wheat in the conventional trial. Chemical control of weeds (mixture of Lintur 120 g/ha and MCPA 500 ml/ha) and insects (Proteus 0,6 l/ha) was carried out every year. Seeding rate of 500 (barley) and 600 (wheat, oat) germinating seeds per m<sup>2</sup> was used. Yield, 1000 kernel weight, volume weight, protein content (Kjeldahl method), falling number (ICC/No. 107/1) for wheat and husk content for oat was measured after harvest. Significance of differences between the means was estimated using ANOVA of the statistical package Agrobase.

Weather conditions were the most favourable for spring cereals in 2005, when the first part of the vegetation period was cool and there was enough moisture in the soil for good root development and plant growth. Drought in July somewhat hindered plant development, but in spite of that weather conditions favoured high yield formation. In 2006 and 2007 all the cereals suffered because of drought. In 2008 very dry soil conditions in May and first half of June turned to continuous rains up to harvesting. This improved the yield potential but decreased the quality. Harvesting was carried out in extremely unfavourable conditions.

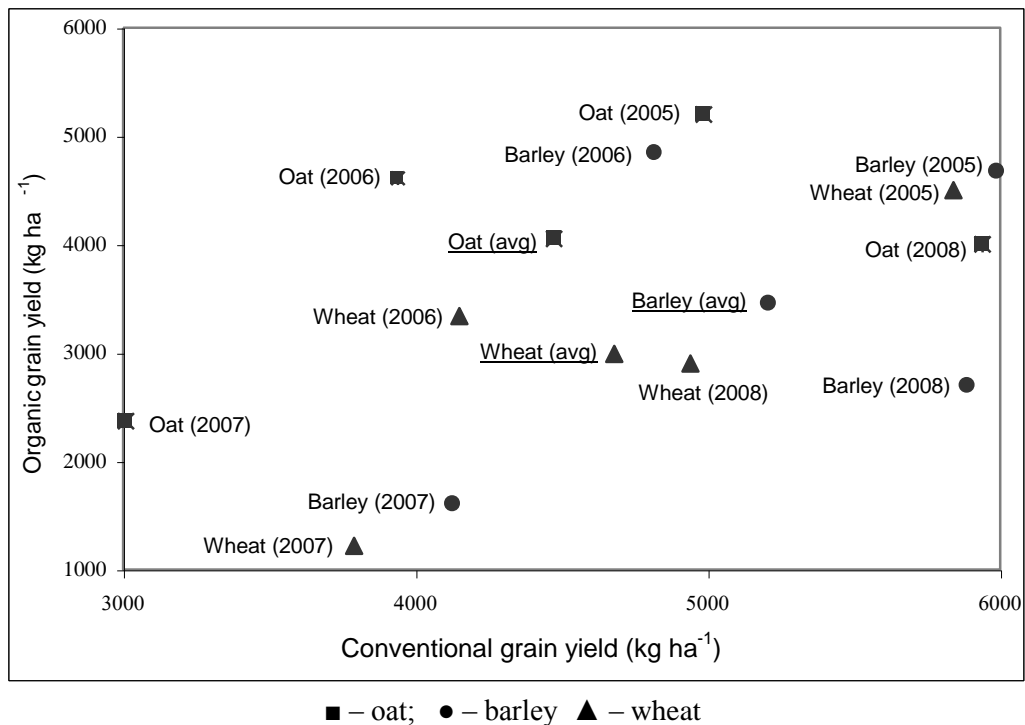
## RESULTS AND DISCUSSION

**Grain yield.** Oat was the highest yielding (4050 kg ha<sup>-1</sup>) in the organic conditions considering the four years average (Fig. 1). The yields of wheat and barley were significantly lower, 3450 and 2990 kg ha<sup>-1</sup> respectively. It has also been common experience in Norway that oat generally performs better than wheat with lower nutrients availability (Loes et al., 2007). Oat is less demanding on soil nutrient content and able to produce comparatively high yields also in moderate soil fertility conditions (Forsberg & Reeves, 1995). The grain yield of oat turned up to be 35% higher compared to that of wheat in organic trial. Nutritional needs of wheat are the highest among the tested spring cereals. In conventional conditions barley was the highest yielding followed by wheat and oat. Oat was the less influenced by the two management systems and produced quite similar yields in both conditions. Organic oat gave a 10% lower yield than conventional oat. In organic conditions grain yield of barley constituted 66 and that of wheat 64% of the conventional yield. Yielding level of spring cereals in organic conditions was largely influenced by the precrop and weather conditions. In the first trial year after the favourable precrop (red clover) and favourable weather conditions all the cereals produced yields higher than 4500 kg ha<sup>-1</sup>. Oat varieties average was even 5200 kg ha<sup>-1</sup>. In 2006 oat and barley grain yields after red clover were high, 4600 and 4840 kg ha<sup>-1</sup> respectively. The same year spring wheat suffered mostly from drought and average yield was 3340 kg ha<sup>-1</sup>. In the last two years after buckwheat the yields of all the cereals were lower than after red clover. The lowest average yields were produced in 2007, caused by heavy soil crust during germination and early drought before heading. Spring wheat and barley yields were

very low – 1220 and 1600 kg ha<sup>-1</sup>. In the last year of the trial cycle (2008) after an unsuitable precrop (buckwheat) the yields were higher than in 2007 but lower than after the red clover (oat 4000, wheat 2900 and barley 2670 kg ha<sup>-1</sup>). The varietal differences were characterised in our earlier publication (Ingver et al., 2008). Considerable differences in grain yield between the varieties were found and the majority of them ranked similarly in both growing conditions. The correlation coefficients between grain yields in organic and conventional trials were 0.71\*\* for oat, 0.63\* for barley and 0.71\*\* for wheat (Table 1). In favourable conditions all the spring cereals were able to produce comparatively high yields also in organic cultivation. In unfavourable weather conditions and unsuitable precrop yield differences between the two cultivation regimes were higher.

**Grain quality.** *Spring wheat* quality characteristics are important for cultivation for food purposes. Weather conditions had the biggest influence on the grain quality.

The average 1000 kernel weight in the organic trial was even bigger (35.8 g) compared to the conventional one (34.2 g) (Table 2). Volume weight was somewhat lower in organic cultivation. The number of grains per head in organic conditions was smaller but grains grew bigger. In the organic trial significantly lower was the protein content, respectively 12.6% and 15.0%. The same tendency occurred in all the trial years. Previous studies have shown that yield and protein content of wheat produced under organic conditions are often 20–40% lower than those achieved in conventional conditions (Mäder et al., 2002; Taylor & Cormack, 2002).



**Fig. 1.** Grain yields of spring cereals in organic and conventional conditions in 2005–2008 (LSD<sub>0.05</sub> for 2005=212, 2006=186, 2007=159, 2008=128, average =132 kg ha<sup>-1</sup>).

**Table 1.** Correlation coefficients (R) of grain yield and quality characteristics of spring cereals between conventional and organic trial.

Characteristic	Oat	Barley	Wheat
Grain yield	0.71**	0.63*	0.71**
1000 kernel weight	0.93**	0.95***	0.93***
Volume weight	0.78**	0.74**	0.78**
Protein content	0.85**	0.64*	0.85***

\* – significant for  $P < 0.05$ ; \*\* – significant for  $P < 0.01$ ; \*\*\* – significant for  $P < 0.001$

**Table 2.** Grain quality characteristics of spring cereals in conventional and organic conditions.

	Conventional conditions			Organic conditions			LSD <sub>0.05</sub>
	Oat	Barley	Wheat	Oat	Barley	Wheat	
1000 kernel weight, g	35.0	45.3	34.2	36.0	44.8	35.8	1.0
Volume weight, g l <sup>-1</sup>	498	674	783	472	675	767	23
Protein content, %	12.2	12.0	15.0	11.3	11.3	12.6	0.3

The gluten content of wheat in the organic trial was also lower (27.1 and 34.4% resp.) but its quality was better. Falling numbers were similar (285 and 268 sec) and more depending on weather conditions of the year than on the cultivation regime.

*Barley* grain quality characteristics during the years were more similar. 1000 kernel weight was 44.8 g in the organic and 45.3 g in the conventional trial. The same tendency was estimated in volume weight (675 and 674 g/l). Only the protein content in the organic trial was lower (11.3%) compared to the conventional one (12.0%).

*Oat* 1000 kernel weight was higher in the organic (36.0) compared to the conventional trial (35.0 g). Husk content was also comparable (25.8 and 25.5% respectively). Average volume weight was estimated lower in the organic management (472 g l<sup>-1</sup>) compared to the conventional (498 g l<sup>-1</sup>). Bigger differences occurred only in year 2007 (early drought), 420 in organic and 512 g l<sup>-1</sup> in the conventional trial respectively. Lower protein contents were found in organic conditions (11.3 and 12.2%).

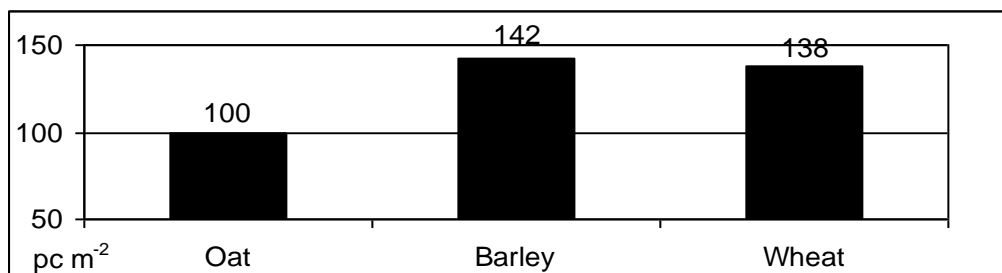
Grain quality of the same varieties was higher in both management conditions. There were high positive correlations between grain quality traits in organic and conventional conditions of all the crops.

**Plant diseases.** The most common diseases of the barley varieties were net blotch, spot blotch and to a small extent also scald. Average infection level was not exceeded during the tested years and differences between the two managements were not remarkable. Low infection by crown rust and leaf blotch of oat varieties was found in both trials. Spring wheat varieties were more infected by powdery mildew, septoria, brown rust, DTR and spot blotch. More favourable conditions for septoria, mildew and DTR appeared in 2007 and 2008 when above average level of infection was recorded. The infection level of most of the diseases in the two compared cultivation managements was quite similar. Some diseases decrease in importance in organic management systems since disease pressure is generally lower compared to the conventional management (Vogt-Kaute, 2001). The same situation of wheat powdery mildew occurred in some years in our trial (in 2005 and 2008). Diseases that are common in conventional farming due to high crop densities

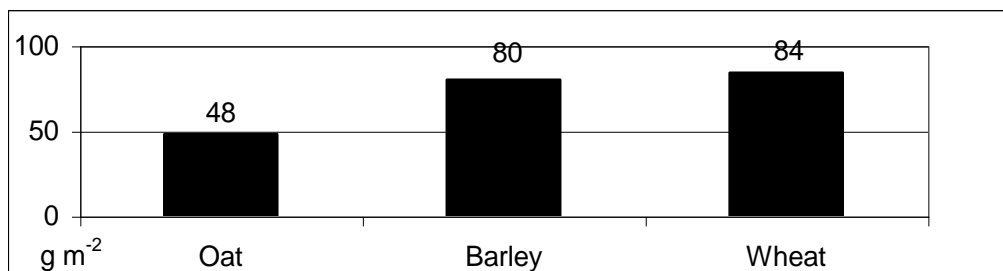
and frequent nitrogen applications, such as mildew in cereals, are rarely a problem in organic farming (Lammerts van Bueren et al., 1998).

**Weeds** may be one of the primary problems in organic cultivation. Therefore cereals weed suppression ability is important. For estimations all the weeds from a 0.5 m<sup>2</sup> test area were counted and weighed in each plot. Totally 32 species of weeds were found during the trial years in the organic trial. The weed species distribution between the cereal crops was equal. The number of weed species was higher in the years of higher precipitation. The most dominating were common lamb's quarters (*Chenopodium album*), field pancy (*Viola arvensis*), black bindweed (*Fallopia convolvulus*) and sun spurge (*Euphorbia helioscopia*) covering 2/3 of the total number of weeds. In spite of two harrowings the number of weeds per m<sup>2</sup> was quite high although their biomass under the cereals suppression was not high. A tendency for less weeds (100 plants per m<sup>2</sup>) was found in the oat plots (Fig. 2). The number in barley and wheat plots was higher, 142 and 138 respectively. The number of weeds in the organic trial field had no increase during the four years. The highest number of weeds was in 2005 when there was enough moisture in the soil in the first half of the vegetation period. The less weeds were in 2008 when there was shortage of moisture in soil at the beginning of the vegetation period (May and first half of June). The smallest average weeds biomass (48 g) was in the oat plots (Fig. 3). The weeds biomass in barley and wheat plots was higher, 80 and 84 g respectively. The biggest weeds biomass was in 2008 when a droughty beginning of the vegetation period was followed by continuous rains up to harvesting. The smallest biomass was in 2006 when droughty conditions extended for the whole growing season.

Oat suppressed weeds more successfully than wheat and barley. There was no significant difference in weed suppression ability of wheat and barley.



**Fig. 2.** Average number of weeds in the organic trial in 2005–2008 (LSD<sub>0.05</sub>=8).



**Fig. 3.** Average biomass of weeds in the organic trial in 2005–2008 (LSD<sub>0.05</sub>=6).

## CONCLUSIONS

The results of the trials indicated that on fertile soil and after a suitable precrop (red clover) all the spring cereals produced comparatively high yields with good quality in organic conditions. Yielding potential decreased while cultivating the spring cereals after an unfavourable precrop (buckwheat). In organic conditions oat was the highest yielding among the spring cereals. Oat also had the best weeds suppression ability. Concerning the quality characteristics, protein content was the most influenced by the cultivation regime. It was lower in organic trial of all the cereals. The biggest decrease in protein content was found in the wheat trials. The other quality characteristics were less influenced by the management regime. Kernel weight of oat and wheat even increased under organic conditions. In cultivating spring wheat high soil fertility should be guaranteed to produce high yield with good quality. A yield gap between organic and conventional production depended on crop, precrop and growing conditions. Combining information from both organic and conventional cultivation is beneficial for low-input farmers.

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