GENOTYPE AND ENVIRONMENT INTERACTION ON YIELD AND QUALITY PARAMETERS OF ORGANICALLY GROWN WINTER WHEAT – *Triticum aestivum* L. GENOTYPES

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Abstract

The interaction of genotype and environment upon yield and quality parameters of eight winter wheat (*Triticum aestivum* L.) genotypes was studied under organic conditions in Austria over two growing periods, 2001/2002 and 2002/2003, respectively. Two sites that have significantly different climatic conditions, Innviertel and Marchfeld, were chosen for the field experiment.

Study site weather and soil conditions are important yield-affecting factors. Although the yield of Marchfeld-grown genotypes were lower, they had shown higher quality parameter values. Soil moisture conditions increase the grain yield but decrease its quality. To obtain seed with higher quality, a production site with favourable climate conditions should be chosen.

Introduction/Problem: Agriculture in industrial countries over the last 20 years has been going through strong structural change. Increasing operating costs and surplus production are seen in many sectors. The intensive application of synthetic plant treatment products and water-soluble nitrogen fertilizers can lead to higher yields, but also to the pollution of ground water. This in turn reduces the natural soil fertility and creates soil erosion.

Organic farming is one of the key issues in reshaping European agricultural policy, with economic and political questions of organic farming becoming increasingly important. Organic farming can be seen as an approach to agriculture where the aim is to create integrated, humane, environmentally and economically sustainable agricultural production systems.

Organic farming is more than just an environmentally friendly production method. It is also seen by consumers as producing ‘wholesome’ food. Consumers most often refer to the fact that organic crops are not treated with chemical pesticides, i.e. that they are free of chemical residues (De Waart, 1998).

The organic farming system differs fundamentally from conventional agriculture in the management of soil fertility, weeds, diseases and pests. This implies a greater need for ‘reliable’ varieties, which means varieties with a greater buffering capacity and flexibility to cope with such conditions compared to conventional farming systems (Lammerts, 2003).

Methodology: Field experiments were conducted with eight winter wheat (*Triticum aestivum* L.) genotypes. These were carried out at two different study sites, detailed in Table 1, which differ significantly with regard to climatic conditions. The growing periods were 2001/2002 and 2002/2003, hereafter termed 2002 and 2003, respectively.

Table 1. The study sites' environmental condition

Study sites	Elevation, m	Location in Austria	Soil type	Annual mean rainfall, mm	Annual mean temp., °C
Innviertel	350	Upper Austria	Eutric cambisol	834	8.5
Marchfeld	150	Lower Austria	Chernozem	500	9.2

Ear emergence data was recorded in day numbers (after May 1) when 80% of ears had emerged. Yield was recorded in dt per hectare (dt/ha) after combine harvesting. Thousand kernel weight (TKW) and hectolitre weight (HLW) were determined according to the ICC standard method. Kernels were milled to flour using an AQC 109 lab mill (Agromatic AG, Laupen, Switzerland). The milled samples were put in the dryer at 104°C for 4 hours.
Kernel and straw nitrogen content were analysed by C/N Analyser LECO (USA) equipment. The raw protein content was expressed as:

Kernel protein (%) =Nitrogen (%)*5.7
(5.7 = conversion factor for raw protein content)

Kernel gluten content was determined by NIT (Near Infrared Transmission) according to the ICC standard method. The wet gluten content is recorded in percent.
Combined analysis of variance (ANOVA) was used to determine the effects of genotype, year, study site, genotype-by-year, genotype-by-site, site-by-year, and genotype-by-year-by-site interactions for the relevant parameters.
Pearson's correlation coefficients (r) were used as measure of the phenotypic association between the parameters.

Results and discussion:

Table 2. Mean values and ranges of the EED, yield and quality parameters

Location of harvest	Innviertel 2002		Innviertel 2003		Marchfeld 2002		Marchfeld 2003	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
EED (days after 1 May)	23	21-24	26	24-28	22	17-28	25	23-26
Yield (dt/ha)	64.86	56.5-75.5	66.15	62.0-71.5	47.12	44.7-52.7	45.58	36.3-50.1
TKW (g)	41.53	38.9-42.1	40.89	39.0-41.8	38.78	32.7-42.4	36.69	35.0-38.5
HLW (g)	83.38	81.6-86.1	83.51	81.7-84.8	79.98	73.1-82.0	83.13	81.0-84.5
Protein (%)	12.18	11.0-13.1	12.53	11.5-13.5	15.82	15.2-16.8	12.99	12.0-13.0
Gluten (%)	25.82	21.8-31.8	27.00	24.0-30.5	35.71	33.7-38.4	26.70	24.7-29.3

Table 2 shows that yield and TKW were higher for the genotypes grown in Innviertel. According to Jones and Singh (2000), Olesen et al. (2000), and Wheeler et al. (2000), factors like weather and soils are important causes for crop yield variability. Kravchenko & Bullock (2005) report that soil properties explain about 30% of yield variability, with soil organic matter content influencing yield the most. Despite Marchfeld's better soil conditions (chernozem), its lower yield is connected with soil water availability.
Protein content was relatively high for the Marchfeld genotypes. Soil moisture conditions increase the grain yield of winter wheat but decrease its quality (Ozturk & Aydin, 2004).

Table 3. ANOVA results for the EED, yield and quality parameters

		EED			Yield		
Source	DF	MS	F	Pr>F	MS	F	Pr>F
GEN	7	17.13	5.73	0.0001***	41.79	0.76	0.6262
SITE	1	13.68	4.58	0.0385*	5087.73	92.12	<0.0001***
YEAR	1	143.23	47.94	<0.0001***	42.04	0.76	0.3881
GEN*YEAR	7	8.15	2.73	0.0206*	15.85	0.29	0.9553
GEN*SITE	7	6.58	2.20	0.0544	12.18	0.22	0.9783
SITE*YEAR	1	1.59	0.53	0.4604	62.04	1.12	0.2933
GEN*SITE*YEAR	7	5.40	1.81	0.1101	20.52	0.37	0.9128
		TKW			HLW		
GEN	7	10.74	14.32	<0.0001***	13.56	141.52	<0.0001***
SITE	1	206.25	275.00	<0.0001***	62.04	647.45	<0.0001***
YEAR	1	30.06	40.09	<0.0001***	49.09	512.27	<0.0001***
GEN*YEAR	7	4.74	6.32	<0.0001***	4.94	51.61	<0.0001***
GEN*SITE	7	7.37	9.82	<0.0001***	4.08	42.59	<0.0001***
SITE*YEAR	1	8.25	11.00	0.0019***	38.73	404.13	<0.0001***
GEN*SITE*YEAR	7	10.05	13.39	<0.0001***	8.45	88.20	<0.0001***

***$p \leq 0.001$; **$p \leq 0.01$; * $p \leq 0.05$.

ANOVA revealed significant site and year effects on the EED. The result is consistent with previous findings Talbert et al. (2001), reported that environment is a significant source of variation for grain fill duration and other traits. Only genotype-by-year interaction was significant on the EED.
Site effect was only significant for the yield. The result is consistent with previous findings reported by Hiltbrunner et al. (2004), who found a significant site effect on the yield of organic winter wheat in Switzerland.
The interactions of genotype, year and site affected both TKW and HLW. There was a Type III (cross-over) interaction for both TKW and HLW.

Table 4. ANOVA for quality parameters

		Kernel protein			Wet gluten		
Source	DF	MS	F	Pr>F	MS	F	Pr>F
GEN	7	1.91	2.42	0.036*	21.13	2.13	0.062
SITE	1	76.51	97.16	<0.0001***	414.82	41.76	<0.0001***
YEAR	1	31.51	40.02	<0.0001***	262.09	26.38	<0.0001***
GEN*YEAR	7	0.95	1.22	0.316	7.49	0.75	0.627
GEN*SITE	7	0.50	0.64	0.72	15.03	1.51	0.191
SITE*YEAR	1	47.88	60.8	<0.0001***	469.70	47.29	<0.0001***
GEN*SITE*YEAR	7	0.8	1.02	0.43	10.22	1.03	0.42

***$p \leq 0.001$; **$p \leq 0.01$; * $p \leq 0.05$.

ANOVA revealed a significant genotype effect only for kernel protein content. The single effect of the site, year and site-by-year interaction was significant for both kernel protein and wet gluten content.

Table 5. Correlation coefficients of the EED and yield parameters

	Innviertel 2002			Innviertel 2003		
	EED	Yield	TKW	EED	Yield	TKW
Yield	-0.33***			-0.16		
TKW	-0.13	0.46***		-0.06	0.17	
HLW	-0.43***	0.07	0.11	-0.39***	0.28**	0.21*
	Marchfeld 2002			Marchfeld 2003		
Yield	-0.52***			0.18		
TKW	-0.24	0.31*		0.24**	0.13	
HLW	-0.28*	0.05	0.41**	-0.42**	0.15	0.72**

In 2002, the EED was significantly correlated with the yield at both study sites (r=-0.33***; -0.52***). But this result is inconsistent with others (Yildirum et al., 1996) who reported a positive correlation between yield and EED in wheat. EED was significantly correlated with the HLW at both study sites in both years, respectively.

Yield was significantly correlated with the TKW (r=0.46***; 0.31*) only in 2002. This result is consistent with previous findings reported by Ozturk & Aydin (2004), who found a positive correlation between yield and TKW. However, that was not the case in 2003. There have been reports by Housley et al. (1982) and Bruckner & Frohberg (1987) of no association between grain yield and kernel weight.

TKW was significantly correlated with the HLW at both study sites in both years. Previous studies (e.g., Ozturk & Aydin, 2004), found a significant positive correlation between TKW and HLW.

Table 6. Correlation coefficients for the yield, protein and wet gluten content

	Innviertel 2002		Innviertel 2003		Marchfeld 2002		Marchfeld 2003	
	Yield	Protein	Yield	Protein	Yield	Protein	Yield	Protein
Protein	-0.48**		-0.37*		-0.39**		-0.09	
Gluten	-0.44**	0.94***	-0.39**	0.89***	-0.37**	0.96	-0.11	0.87***

Table 6 shows yield (dt/ha) was significantly correlated with both quality parameters at the Innviertel site. In agreement with our results, Simmonds (1996) and Ozturk & Aydin (2004) found a negative correlation between yield and kernel protein and kernel gluten content. Since grain yield and protein content are related, the grain protein contents also vary considerably within the paddock (Strong et al., 2003; Stewart et al., 2002).

Kernel protein content was correlated with wet gluten content (r=0.94***; 0.89***) for the genotypes grown in Innviertel. This was not the case at the Marchfeld site in 2002.

Conclusions

Study site weather and soil conditions are important yield-affecting factors. Although, the yields of the genotypes grown in Marchfeld were lower, they showed higher quality parameter values. Soil moisture conditions increase the grain yield but decrease its quality in organic condition. To obtain seed with higher quality, a production site with favourable climate conditions should be chosen.

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