Influence of crop management upon the agronomic traits of spelt (*Triticum spelta* L.)

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ABSTRACT

Investigations were carried out at the experimental field of the Faculty of Agriculture in Zagreb in the growing seasons 2008/2009 and 2009/2010 with the aim to determine the influence of seeding rate and fungicide treatment upon the yield and yield components of spelt (*Triticum spelta* L.). The trial included two spelt cultivars: Nirvana and Ostro, three seeding rates: 200, 300, and 400 germinated seeds/m^2, and a fungicide treatment (tebuconazole). Cultivar Nirvana produced a significantly higher grain yield in both trial years, higher number of spikelets per spike, higher grain number and mass per spike. Cultivar Ostro had a significantly higher grain crude proteins content, higher 1000 grain weight, and also a higher number of sterile spikelets per spike. No significant effect of seeding rate on grain yield was determined while the fungicide treatment had a significant effect on grain yield only in the warmer year 2008/2009.

Keywords: seeding rate; fungicide treatment; yield; yield components

Spelt (*Triticum spelta* L.) is a cereal rarely grown in Croatia and elsewhere in Europe. However, since increasing attention is being paid to diverse and good quality nutrition, forgotten and rare cereals are gaining on importance. Special attention is directed to the possible production of alternative cereals in organic production. Owing to its hulled grain and genetic polymorphism of its population, spelt is resistant to pests and diseases and hence suitable for organic production. Besides, spelt can be also grown at higher elevations and under harsh climatic conditions (Bonafaccia and Fabjan 2003). Glumes that remain on spelt grain even after harvest protect the grain against attacks of diseases and enhance the germination ability of spelt even under adverse conditions (Riesen et al. 1986). In case of infection with *Fusarium culmorum*, spelt shows higher resistance than common wheat (Wiwart et al. 2004). High germination under adverse conditions combined with its high ability of productive tillering and formation of large grains enable spelt to produce stable grain yields (Rüegger et al. 1990). Spelt production is recommendable for extensive production systems (low-input systems) because of better nutrient utilization and higher mineral content of grain (Moudrý and Dvořáček 1999). One of the reasons for reintroducing spelt into production is its grain quality. Compared to common wheat, spelt has a higher content of proteins and minerals (Capouchova 2001, Wiwart et al. 2004). Protein content of spelt grain ranges from 13.0 to 16.5% (Capouchova 2001, Abdel-Aal and Hucl 2002). Owing to its higher tillering ability, the seeding rate for spelt is lower than that for common wheat. Seeding rates of 200 to 400 seeds/m^2 are generally recommended (Rantaša 2004, Troccoli and Codianni 2005).

MATERIAL AND METHODS

Investigations were carried out at the experimental field of the Faculty of Agriculture in Zagreb (45°49'26''N, 16°02'07''E), over the growing seasons 2008/2009 and 2009/2010. The trial involved two spelt cultivars: Nirvana and Ostro, three seeding rates: 200, 300, and 400 germinated seeds/m^2, and a fungicide treatment (tebuconazole). Cultivar

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Nirvana is the property of the Institute of Field and Vegetable Crops, Novi Sad, and cultivar Ostro of the company Delley Samen und Pflanzen AG. The trial was laid out according to the randomized block design with four replications. Plot size at seeding was 9.6 m^2 (10 rows × 0.12 m row spacing × 8 m length). Upon emergence, plot length was shortened by 0.5 m, so that the plot size at harvest was 9.0 m^2. Flax was grown as forecrop in 2008 and grain amaranth in 2009. Spelt seeding was performed on 16. 10. 2008 and on 13. 10. 2009. Seeding rate was determined using the germination test and weight of hulled kernel. Fertilization with 200 kg/ha NPK 10:20:30 was done within basic tillage. No weed treatment was necessary in 2009, while in the spring of 2010 weeds were treated with clopyralid at the tillering stage (90 mL a.i./ha). Fungicide Folicur EW 250, based on the active substance tebuconazole, was applied at a rate of 250 g a.i./ha at the end of flowering. Upon germination, the number of emerged plants was determined, and the number of spikes per/m^2 was determined prior to harvest. Hulled grain yield, grain moisture and 1000 dehulled grain weight were recorded after harvest. Hulled grain yield was expressed at 13% moisture level. The following yield components were determined on a sample of 40 spikes: number of spikelets per spike, number of sterile spikelets per spike, number of grains per spike, dehulled grain mass per spike and content of dehulled grains in the ear entire mass. Crude proteins content was determined according to Kjeldahl (AOAC 2002) and expressed as proteins by multiplication with factor 6.25. The results obtained were processed by means of analysis of variance using the MSTAT-C program (Michigan State University, 1990).

RESULTS AND DISCUSSION

In both trial years, cv. Nirvana produced significantly higher grain yields compared to Ostro (Tables 1 and 2). Nirvana achieved hulled grain

Table 1. Yield and yield components of spelt in dependence on the cultivar, seeding rate and fungicide treatment during the growing period of 2008/2009

Cultivar	Seeding density (grain/m^2)	Fungicide	Hulled grain yield (t/ha)	Spikelet number per ear	Sterile spikelet number per ear	Grain number per ear	Dehulled grain weight per ear (g)	Dehulled grain content per ear (%)	1000 grain weight (g)
Nirvana	200	T	7.281	22.7	3.10	36.3	1.74	72.4	47.2
	200	N	6.538	22.0	2.73	36.8	1.95	73.3	50.4
	300	T	7.679	22.4	2.76	38.8	2.09	72.4	50.1
	300	N	7.204	22.9	2.98	37.7	2.20	75.8	54.7
	400	T	7.039	22.8	2.65	40.0	2.17	76.9	53.9
	400	N	5.800	22.5	2.68	38.7	2.03	74.4	52.5
Ostro	200	T	6.908	22.4	4.08	33.9	2.02	68.3	59.4
	200	N	5.966	21.9	3.90	33.0	1.85	71.5	55.8
	300	T	6.857	21.5	4.10	31.5	1.86	69.2	58.6
	300	N	5.914	22.0	3.98	32.0	1.86	65.8	58.0
	400	T	7.054	21.4	4.45	29.9	1.78	70.1	59.0
	400	N	6.261	21.5	4.28	30.8	1.74	70.5	55.5
Mean	Nirvana		6.923*	22.5*	2.82	38.0*	2.03*	74.2*	51.5
Cultivar	Ostro		6.493	21.8	4.13*	31.9	1.85	69.2	57.7*
Mean	200		6.673	22.3	3.45	35.0	1.89	71.4	53.2
Sowing	300		6.914	22.2	3.46	35.0	2.00	70.8	55.3
Density	400		6.538	22.0	3.51	34.9	1.93	73.0	55.3
Mean	T		7.136*	22.2	3.53	35.1	1.94	71.6	54.7
Fungicide	N		6.281	22.1	3.42	34.8	1.94	71.9	54.5

T – treatment with fungicide; N – without fungicide; *significant difference between means at $P = 0.05$

Table 2. Yield and yield components of spelt in dependence on cultivar, seeding rate and fungicide treatment during the growing period of 2009/2010

Cultivar	Sowing density (grain/m^2)	Fungicide	Hulled grain yield (t/ha)	Spikelet number per ear	Sterile spikelet number per ear	Grain number per ear	Dehulled grain weight per ear (g)	Dehulled grain content per ear (%)	1000 grain weight (g)
Nirvana	200	T	4.843	23.3	4.35	32.9	1.69	73.7	51.3
	200	N	4.960	25.7	4.08	34.6	1.71	73.5	49.3
	300	T	4.689	23.3	4.33	32.5	1.59	74.3	48.8
	300	N	5.036	23.4	4.43	32.9	1.63	74.1	49.3
	400	T	4950	23.9	4.48	34.3	1.73	72.6	50.6
	400	N	5038	23.4	4.05	33.6	1.64	73.5	48.7
Ostro	200	T	4.100	23.0	6.03	28.2	1.45	66.5	51.3
	200	N	4.192	23.1	6.45	27.7	1.50	66.0	54.0
	300	T	4.318	23.3	5.85	30.2	1.60	66.2	53.1
	300	N	4.580	21.4	5.63	27.3	1.43	67.8	52.3
	400	T	4.313	22.6	6.28	28.2	1.52	68.8	53.7
	400	N	4.273	22.1	6.30	26.8	1.46	68.0	54.3
Mean	Nirvana		4.919*	23.8*	4.28	33.5**	1.66**	73.6**	49.7
Cultivar	Ostro		4.296	22.6	6.09**	28.1	1.49	67.2	53.1**
Mean	200		4.524	23.8	5.23	30.9	1.59	69.9	51.5
Sowing	300		4.656	22.9	5.06	30.7	1.56	70.6	50.9
Density	400		4.643	23.0	5.28	30.7	1.59	70.7	51.8
Mean	T		4.535	23.2	5.22	31.1	1.59	70.3	51.5
Fungicide	N		4.680	23.2	5.15	30.5	1.56	70.5	51.3

T – treatment with fungicide; N – without fungicide; significant difference between means at *P = 0.05; ** P = 0.01

yield of 6.92 t/ha in 2008/2009 and of 4.92 t/ha in the following year. In the investigations done by Lacko-Bartošová et al. (2010) in western Slovakia, yields of spelt grain ranged, in dependence on the cultivar, from 5.38 to 6.76 t/ha. Higher grain yield in 2008/2009 was a result of significantly higher productive tillering compared to 2009/2010. Lower tillering in 2009/2010 was due to much lower mean daily temperatures in the second and third decades of October and the first decade of November compared to 2008/2009. The greatest difference in temperatures was recorded for the first decade of November when the average temperature was 13.2°C in 2008/2009 and only 5.5°C, with snow, in 2009/2010. Cultivar Nirvana produced 701 spikes/m^2 in 2008/2009 and 411 spikes/m^2 in the following year (Table 3). At the same time, cv. Ostro produced 594 and 406 spikes/m^2, respectively. Considerably more precipitation (748 mm) fell in the growing period of 2009/2010 than in the

Table 3. Spike number in harvest per m^2 in dependence on cultivar and seeding rate

Cultivar	Sowing density (grain/m^2)	Spike number per m^2	
		2008/2009	2009/2010
Nirvana	200	676	416
	300	670	374
	400	759	443
Ostro	200	555	349
	300	610	431
	400	616	437
Mean	Nirvana	701*	411
Cultivar	Ostro	594	406
Mean	200	615	382
Sowing	300	640	403
Density	400	687	440

*significant difference between means at P = 0.05

Table 4. Total monthly precipitation (mm) and divergence from the long-term average (mm) (1961–1990) during the 2008/2009 and 2009/2010 growing season

Month	2008/2009		2009/2010	
	precipitation	divergence from average	precipitation	divergence from average
October	78.1	+8.9	66.8	–2.4
November	66.1	–15.1	88.0	+6.8
December	95.4	+37.4	79.2	+21.2
January	82.4	+36.0	84.1	+37.7
February	43.6	+1.6	67.3	+25.3
March	42.7	–13.1	45.7	–10.1
April	52.0	–11.6	63.3	–0.3
May	48.8	–29.9	97.5	+18.8
June	67.5	–32.6	103.8	+3.7
July	96.2	+12.8	52.5	–30.9
Total	672.8	–5.6	748.2	+69.8

growing period of 2008/2009 (Table 4). The amount of precipitation corresponding to the long-term average in the growing period 2008/2009, along with mean monthly air temperatures above the long-term average (Table 5), had a beneficial effect on spelt growth and development, resulting in higher yield. In both trial years, cv. Nirvana produced a significantly higher number of spikelets per spike, grain number and mass per spike whereas cv. Ostro had a significantly higher number of sterile spikelets (4.13, and 6.09, respectively). Consequently, Nirvana gave a significantly higher grain yield. The obtained results concur with the results of Zečević et al. (2009), who determined a significant influence of genetic factors and the year on the number of sterile spikelets in common wheat (*Triticum aestivum* L.).

Cultivar Nirvana also produced a significantly higher content of dehulled grains per spike in both trial years (74.2 and 73.6%, respectively). This content of dehulled grains is very high and concurs with the results of Lacko-Bartošová et al. 2010, who, in dependence on the cultivar, obtained 65.3–71.3% of dehulled grains in the overall yield.

Table 5. Mean monthly air temperature (°C) and divergence from long-term average (°C) (1961–1990) during the 2008/2009 and 2009/2010 growing season

Month	2008/2009		2009/2010	
	air temp.	divergence from average	air temp.	divergence from average
October	12.6	+2.1	11.7	+1.2
November	7.6	+2.3	8.0	+2.7
December	3.4	+2.5	2.8	+1.9
January	–1.1	+0.3	–0.4	+0.4
February	2.9	+1.1	2.3	+0.5
March	7.6	+1.7	6.8	+0.9
April	14.5	+3.9	12.0	+1.4
May	18.4	+3.1	16.6	+1.3
June	19.8	+1.3	20.4	+1.9
July	22.3	+2.2	23.2	+3.1
Average	10.8		10.3	

Table 6. Protein content in spelt grain in dependence on cultivar, seeding rate and fungicide treatment

Cultivar	Sowing density (grain/m^2)	Fungicide	Protein content (g/kg)	
			2008/09	2009/10
Nirvana	200	T	145.7	161.0
	200	N	156.7	159.4
	300	T	142.3	150.9
	300	N	138.0	165.0
	400	T	149.0	165.5
	400	N	140.0	167.5
Ostro	200	T	164.0	163.9
	200	N	173.0	184.7
	300	T	159.0	188.7
	300	N	172.3	182.8
	400	T	156.3	172.8
	400	N	180.3	184.4
Mean	Nirvana		145.3	161.6
Cultivar	Ostro		167.5*	179.5
Mean	200		159.8	167.3
Sowing	300		152.9	171.8
Density	400		156.4	172.6
Mean	T		152.7	167.1
Fungicide	N		160.1	174.0

T – treatment with fungicide; N – without fungicide; *significant difference between means at $P = 0.05$

Cultivar Ostro gave a significantly higher 1000 grain weight compared to Nirvana. The 1000 grain weight of Ostro varied, in dependence on the trial year, from 53.1 to 57.7 g while Lacko-Bartošová et al. 2010, recorded 46.8 g. In their investigations, the 1000 grain weight of the studied spelt cultivars ranged from 38.3 to 50.1 g.

Seeding rate did not have a significant influence on yield and yield components in either trial year (Tables 1 and 2). In both years, higher grain yields were obtained with the seeding rate of 300 germinated seeds per m^2 (6.91 and 4.66 t/ha, respectively); however, differences from the other two seeding rates were very small. Under the conditions prevailing in northern Italy, Castagna et al. (1993, 1994) did not detect any significant effect of seeding rate increasing from 200 to 400 grains/m^2 on spelt grain yield; however, a significantly higher grain yield was achieved with the plant density of 400/m^2 in central Italy.

The number of spikes/m^2 increased with increasing seeding rate, but the differences in the number of spikes per m^2 at harvest were not significant (Table 3). Investigating lower seeding rates (100 to 200 germinated seeds/m^2), Troccoli and Codianni (2005) achieved a significant increase in the number of spikes with increasing seeding rate, so the seeding rate of 200 germinated seeds resulted in 500 spikes/m^2. At the same seeding rate, the average for both cultivars was 615 spikes/m^2 in the first year of our trial, and 382 spikes/m^2 in the climatically less favourable 2009/2010.

Fungicide application had a significant effect on spelt grain yield only in 2008/2009 due to strong attacks of powdery mildew (*Blumeria graminis*) and leaf rust (*Puccinia recondita*). Fungicide treated spelt had a higher number of grains per spike compared to untreated crop, but the difference was not significant.

Cultivar Ostro had a significantly higher grain protein content than Nirvana in both trial years (Table 6). The two-year average for crude protein content of Nirvana was 153.5 g/kg, and that of Ostro 173.5 g/kg.

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