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INFLUENCE OF SEEDING RATE AND NITROGEN TOPDRESSING UPON THE AGRONOMIC TRAITS OF SPELT (*TRITICUM SPELTA* L.)

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ABSTRACT

Spelt (*Triticum spelta* L.) cultivation has been resumed in the Republic of Croatia for the production of flour and for animal feed. Investigations were carried out at the experimental facility of the Faculty of Agriculture in Zagreb during 2010/2011 and 2011/2012 with the aim to determine the influence of seeding rate and nitrogen topdressing upon the agronomic traits of spelt. The trial included two spelt cultivars: Nirvana and Ostro, three seeding rates (200, 300 and 400 germinated seeds m^{-2}), and nitrogen topdressing (0 and 50 kg ha^{-1} N). In both trial years, cultivar Nirvana produced a significantly higher yield of unhusked grain (5923 kg ha^{-1}) compared to cultivar Ostro (5389 kg ha^{-1}). Cultivar Ostro gave a significantly higher 1000-grain mass (50.4 g) and higher grain protein content (140.6 g kg^{-1}). Seeding rate had no effect on the studied parameters, except on the number of spikes m^{-2}. Nitrogen topdressing had a good effect on the yield of unhusked grain, number of spikes per m^2 and 1000-grain mass. Nitrogen topdressing did not affect the proportion of husked grain in total mass, nor the grain protein content.

Key words: cultivar, yield, 1000 grain weight, dehulled grain content, protein content.

INTRODUCTION

Spelt (*Triticum spelta* L.) is a very old cereal, which lost much of its importance by introduction of new high-yielding common wheat cultivars. However, spelt is again increasingly grown in south-eastern Europe, especially in organic production. New high-yielding cultivars are being developed and spelt has become a promising crop. Spelt grain remains covered with glumes after harvest and requires husking before further use. Despite this disadvantage compared to common wheat, this is also an advantage because hulled grain retains its nutrient value and is more resistant to pests and diseases. Besides, spelt genetic characteristics allow it to be grown at higher elevations and under harsh climatic conditions (Bonafaccia and Fabjan, 2003) and enable its better utilization of soil nutrients (Moudry and Dvoracek, 1999).

Compared to common wheat, spelt grain has a higher content of proteins and minerals (Capouchova, 2001; Wiwart et al., 2004). Furthermore, spelt is a valuable source of genetic variability for these parameters, especially for zinc and iron content (Gomez-Becerra et al., 2010). Spelt has a higher content of fibres than common wheat, which makes it a valuable cereal in human nutrition as prevention of colorectal cancer and obesity (Bonafaccia and Fabjan, 2003). Protein content of spelt grain ranges from 13.0 to 16.5% (Codianni et al., 1996; Capouchova, 2001; Abdel-Aal and Hucl, 2002). Grain protein content recorded in trials conducted in Croatia ranged from 14.5 to 18.1% (Pospišil et al., 2011; Mlinar and Ikić, 2012). As spelt tillering is more intensive than that of common wheat, the seeding rate of 200 to 400 seeds m^{-2} is recommended (Codianni et al., 1993; Troccoli and Codianni, 2005; Rantaša, 2004).

The investigation goal was to determine the influence of seeding rate and nitrogen topdressing upon the agronomic traits of spelt grown under the agroecological conditions of north-western Croatia.

MATERIAL AND METHODS

Investigations were carried out at the experimental facility of the Faculty of Agriculture in Zagreb during 2010/2011 and 2011/2012. The trial involved two spelt

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cultivars: Nirvana and Ostro, three seeding rates (200, 300 and 400 germinated seeds m^{-2}) and nitrogen topdressing (0 and 50 kg ha^{-1} N). The trial was laid out according to the split-block scheme with four replications. The basic plot size at seeding was 8.4 m^2 (10 rows x 0.12 m row spacing x 7 m length). Upon emergence, plot length was shortened by 0.5 m, so that the plot size at harvest was 7.8 m^2. Flax was grown as forecrop in 2010 and grain amaranth in 2011. Basic fertilization involved 200 kg ha^{-1} NPK 10:20:30. Seeding took place on 13 October 2010 and 10 October 2011. Nitrogen topdressing with 25 kg ha^{-1} N was applied at the beginning and at the end of tillering. Weed control treatment was carried out in the tillering stage with 130 mL ha^{-1} Sekator OD (iodosulfuron). Fungicide Folicur WP 25 (active substance tebuconazole) was applied at a rate of 1 L ha^{-1} at the beginning of flowering in 2011, while no weed treatment was necessary in 2012, because of low disease incidence. The number of spikes m^{-2} was assessed prior to harvest. Yield of unhusked grains, unhusked grain moisture, proportion of husked grains in total mass and 1000 husked grain mass were recorded after harvest. Proportion of husked grains was assessed with the aid of a husker by husking a 1 kg spelt sample from each trial plot. Content of crude proteins was determined according to Kjeldahl (AOAC 2002) and expressed as proteins by multiplying total nitrogen by factor 6.25. The results obtained were processed by means of analysis of variance using the MSTAT-C program (Michigan State University, 1990).

According to analyses of soil samples, taken prior to spelt seeding, the trial field soil has slightly acid reaction (pH in KCl 6.06), poor humus supply (1.76%), good nitrogen supply (0.16%) and average supplies of P_2O_5 (14.9 mg/100 g soil) and K_2O (13.0 mg/100 g soil).

RESULTS AND DISCUSSION

In the first trial year, cultivar Nirvana gave a significantly higher grain yield than Ostro (4993 kg ha^{-1}), Table 1. This cultivar also produced a somewhat larger number of spikes per unit area compared to Ostro, but the difference was not statistically significant.

Table 1. Hulled grain yield, ear number, 1000 grain weight, dehulled grain content and protein content in spelt grain in dependence on the cultivar, seeding rate and topdressing during the growing period 2010/2011

Cultivar	Seeding density (grain m^{-2})	Topdressing	Hulled grain yield (kg ha^{-1})	Ear number per m^{-2}	1000 grain weight (g)	Dehulled grain content (%)	Protein content (g kg^{-1})
Nirvana	200	T	5591	377	48.8	79.7	131.1
	200	C	4242	282	48.1	78.9	127.0
	300	T	5984	493	49.3	79.2	121.6
	300	C	4464	365	46.7	78.7	126.7
	400	T	5774	525	48.5	81.9	126.3
	400	C	3906	373	46.3	79.1	122.8
Ostro	200	T	5707	466	51.9	77.1	133.9
	200	C	3683	267	49.3	76.7	128.3
	300	T	5301	413	52.7	78.2	133.7
	300	C	3594	365	48.8	78.5	131.6
	400	T	5431	458	51.2	80.3	138.5
	400	C	3977	369	49.7	78.0	139.0
Cultivar	Nirvana		4993 a	403	48.0 b	79.6	125.9 b
	Ostro		4616 b	390	50.6 a	78.1	134.2 a
Sowing density	200		4806	348 b	49.5	78.1	130,0
	300		4836	409 ab	49.4	78.6	128.4
	400		4772	431 a	48.9	79.8	131.7
Topdressing	T		5631 a	455 a	50.4 a	79.4	130.9
	C		3978 b	337 b	48.1 b	78.3	129.2

T – topdressing; C – control.

Values followed by the same letter within the year are not significantly different at the 5% level of probability.

In the second trial year, higher yields of spelt grain were achieved; Nirvana again produced a larger number of spikes per unit area as well as significantly higher grain yield compared to Ostro (6854 kg ha^{-1}), Table 2. Under the conditions prevailing in western Slovakia, Lacko-Bartošová et al. (2010) obtained a spelt grain yield ranging, in dependence on the cultivar, from 5.38 to 6.76 t ha^{-1}.

Table 2. Hulled grain yield, ear number, 1000 grain weight, dehulled grain content and protein content in spelt grain in dependence on the cultivar, seeding rate and topdressing during the growing period 2011/2012

Cultivar	Seeding density (grain m^{-2})	Topdressing	Hulled grain yield (kg ha^{-1})	Ear number (per m^{-2})	1000 grain weight (g)	Dehulled grain content (%)	Protein content (g kg^{-1})
Nirvana	200	T	7632	431	47.7	67.4	134.4
	200	C	6199	417	44.8	67.2	128.2
	300	T	7597	563	48.0	67.8	131.3
	300	C	6115	513	46.3	65.8	127.2
	400	T	7725	562	47.6	71.6	132.7
	400	C	5854	536	45.8	67.9	130.0
Ostro	200	T	6963	529	51.8	71.7	148.7
	200	C	6109	459	50.9	69.2	144.4
	300	T	7020	469	51.4	66.9	150.5
	300	C	5302	452	49.7	68.5	144.3
	400	T	7253	554	50.1	72.1	148.7
	400	C	5331	463	47.6	64.5	144.7
Cultivar	Nirvana		6854 a	504 a	46.7 b	67.9	130.7 b
	Ostro		6163 b	488 b	50.2 a	68.8	146.9 a
Sowing density	200		6476	459 c	48.8	68.9	138.9
	300		6509	499 b	48.8	67.2	138.3
	400		6541	529 a	47.8	69.0	139.1
Topdressing	T		7365 a	518 a	49.4 a	69.6	141.0
	C		5652 b	473 b	47.5 b	67.2	136.5

T – topdressing; C – control.
Values followed by the same letter within the year are not significantly different at the 5% level of probability

Differences in unhusked grain yields between trial years are a result of different weather conditions. Lower precipitation compared to the multiyear average was recorded in both trial years, -142.0 mm in 2010/2011 and -130.8 mm in 2011/2012 (Table 3).

Precipitation distribution was more favourable in 2011/2012, which had a good effect on the number of spikes m^{-2} and grain yield. At the same time, air temperatures were higher during the growing season in both trial years compared to the multiyear average, +5.4^{o}C in 2010/2011 and +5.3^{o}C in 2011/2012 (Table 4).

Table 3. Total month precipitation (mm) during the 2010/2011 and 2011/2012 growing seasons and long-term average (1981-2010) in Zagreb-Maksimir

Month	Growing season		Long-term average 1981-2010
	2010/2011	2011/2012	
October	35.5	72.5	80.0
November	113.4	0.3	76.0
December	61.0	83.7	62.7
January	11.7	19.4	45.5
February	11.7	26.3	39.6
March	36.0	4.5	54.1
April	42.1	51.3	59.5
May	70.0	81.8	68.6
June	67.5	127.9	97.4
July	63.9	56.3	71.4
Total	512.8	524.0	654.8

Table 4. Mean monthly air temperature (°C) during the 2010/2011 and 2011/2012 growing seasons and long-term average (1981-2010) in Zagreb-Maksimir

Month	Growing season		Long-term average 1981-2010
	2010/2011	2011/2012	
October	9.4	10.4	11.3
November	8.8	3.0	5.8
December	0.1	3.7	1.6
January	2.1	2.5	0.5
February	1.3	-1.9	2.2
March	7.3	9.4	6.8
April	13.4	12.5	11.4
May	16.9	16.7	16.5
June	21.1	22.0	19.6
July	22.2	24.2	21.5

In both trial years, cultivar Ostro achieved a higher 1000-husked grain mass and higher grain protein content compared to Nirvana (Tables 1 and 2). Average 1000-husked grain mass of Ostro was 50.4 g, and that of Nirvana 47.4 g. In previous investigations, Pospišil et al. (2011) obtained higher values of 1000-husked grain mass for both spelt cultivars. In investigations carried out by Mlinar and Ikić (2012), cultivar Ostro produced a 1000-grain mass of 43.71 g while the 1000-grain mass of 46.8 g was obtained by Lacko-Bartošová et al. (2010) for the same cultivar. Higher 1000-grain mass of Ostro could not compensate for the smaller number of spikes per unit area, so this cultivar gave lower yield. In previous investigations, Pospišil et al. (2011) found that Ostro had a smaller number of sterile spikelets per spike, while Nirvana had a larger number of spikelets and grains per spike.

Ostro had an average grain protein content of 140.6 g kg^{-1}, and Nirvana 128.3 g kg^{-1}. Protein content is lower compared to the results obtained by Pospišil et al. (2011) and Mlinar and Ikić (2012), which ranged from 145 to 181 g kg^{-1}.

Seeding rate did not have a significant influence on grain yield and other studied parameters, except on the number of spikes m^{-2}, so a significantly larger number of spikes per unit area was recorded with seeding rates of 300 and 400 seeds m^{-2} compared to lower seeding rates. In investigations performed in north-western Croatia, Pospišil et al. (2011) achieved an increase in the number of spikes at harvest by increasing the seeding rate from 200 to 400 germinated seeds m^{-2}; however, the differences were not significant. Under the conditions prevailing in northern Italy, Castagna et al. (1993, 1994) did not detect any significant effect of increasing the seeding rate from 200 to 400 grains m^{-2} on spelt grain yield m^{-2}; however, a significantly higher grain yield was achieved with the seeding rate of 400 m^{-2} in central Italy. Investigating seeding rates of 100 to 200 germinated seeds m^{-2}, Troccoli and Codianni (2005) achieved a significant increase in the number of spikes by increasing the seeding rate, so the seeding rate of 200 germinated seeds resulted in 500 spikes m^{-2}, whereas the same seeding rate in our investigations resulted in an average for both cultivars of 348 spikes m^{-2} in 2010/2011, and 459 spikes m^{-2} in 2011/12.

Spelt does not require a large amount of nitrogen for its growth and development and it efficiently utilizes nitrogen from the organic matter of soil. According to Bavec and Bavec (2006), addition of nitrogen fertilizers is unnecessary if soil contains more than 20 mg kg^{-1} NO_3-N. However, Maillard (1994, cit. Bavec and Bavec (2006) achieved an increased yield of cultivar Ostro by increasing nitrogen rates up to 100 kg ha^{-1}. Also other researchers (Rüegger et al., 1993; Koutroubas et al., 2012) reported beneficial effects of nitrogen fertilization on increasing the total dry matter of above-ground mass and grain yield of spelt.

In both trial years, nitrogen topdressing had a significant effect on spelt grain yield, so in 2010/2011 the difference between the control (without topdressing) and the topdressing treatment amounted to 1653 kg ha^{-1} and 1733 kg ha^{-1} in 2011/2012. Nitrogen topdressing at the beginning and at the end of tillering had a good effect on the number of spikes m^{-2} and on 1000-grain mass. However, no significant effect of nitrogen topdressing on grain protein content was detected at this growth and development stage of spelt.

Average proportion of husked grains in total mass was 78.9% in 2010/2011 and, 68.4% in the second trial year, while none of the studied factors affected this trait. Similar results were obtained by Lacko-Bartošová et al. (2010).

CONCLUSION

In both trial years, cultivar Nirvana gave a significantly higher grain yield, while Ostro had a significantly higher 1000-grain mass and higher content of crude proteins in grain.

No significant influence of the seeding rate of 200 to 400 germinated seeds m^{-2} on grain yield and other investigated parameters was recorded, except on the number of spikes m^2.

Nitrogen topdressing at the beginning and at the end of tillering (25 + 25 kg ha^{-1} N) had a good effect on the number of spikes m^{-2}, 1000-grain mass and ultimately on spelt grain yield.

As very few data on spelt cultivation under the conditions prevailing in south-eastern Europe are available, investigation results can serve as useful information for reintroduction of this cereal into production.

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