10.7251/AGSY1303364G

MORPHOLOGICAL AND PRODUCTION CHARACTERISTICS OF SPELT WHEAT ON THE CHERNOZEM AND DEGRADED SOIL

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Abstract

The effect of agro-ecological conditions on morphological and production characteristics of the first domestic spelt wheat cultivar - *Nirvana* was studied. *Nirvana* was selected by the Institute of Field and Vegetable Crops from Novi Sad. It is a winter cultivar, very tolerant to frost. In the period 2011-2013, field micro experiments were set up on two locations - on an experimental field of the "Tamis" Institute on a carbonated (micellar) chernozem soil formed on the loess terrace, and on a field in the vicinity of the Thermal Power Plants "Nikola Tesla" on a degraded soil, formed on a coal-mine dumping ground and uncultivated for more than 15 years. The agro-ecological conditions on these two locations affected the growth and productivity of the spelt wheat. Although average weather conditions on both locations were relatively favourable, growth and development were more intensive in the second year of research. The effect of soil conditions on morphological characteristics was highly statistically significant. The plants grown on the chernozem had 45% higher stems, 46% longer spikes and about 6.4% more spikelets per spike. The quality of soil also had significant effect on yield indicators, so the plants grown on the chernozem had 16.23% more grains per spike and 19.8% larger grain weight per spike. The two-year average yield of dehulled grains obtained on the chernozem was 3010 kg ha^{-1}, 35% higher than the yield obtained on the degraded soil. Despite all the indicators of the plants grown on the degraded soil were significantly lower, yet it can be concluded this type of wheat achieved satisfying grain yield.
Key words: spelt wheat, morphological and production characteristics, yield data, soil type.

Introduction

Spelt wheat is a species that belongs to the one of the most ancient genus of cereals, *Triticum*. Spelt wheat was known and cultivated in ancient Egypt 6000 years ago. Ancient Romans used spelt wheat grain in their diet, expending its production across the Roman Empire – today's Europe and northern Africa. The production of spelt wheat retained in the mountainous regions of south-eastern Europe until the 20th century (*Glamoclija et al.*, 2012a, 2012b).

The growing of spelt wheat has recently become very popular, especially after studying the relationship among the plants and agro-ecological and soil conditions, and finding the most appropriate production technology (*Stallknecht et al.*, 1996). After studying the chemical characteristics of spelt wheat grain and flour, *Zielinski et al.* (2008) point out that this cereal is great for making bread of a higher nutritional value. Special bread and pastry products are very well accepted, especially in countries in which growing number of population increasingly use organic products (*Abdel-Aal et al.,* 1995). Growing this cereal is also becoming more interesting in Serbia. Areas under spelt wheat are increasing in hilly-mountainous but also in lowland regions.

The objective of this research is to study basic production characteristics of the first domestic spelt wheat cultivar *Nirvana*, grown on the most fertile soil in Serbia and on degraded soil that is being used for field crop production after 15 years.

Material and Methods

In the period 2011-2013 field micro experiments were set up on two locations, on an experimental field of the "Tamis" Institute in Pancevo and on a field in the vicinity of "TENT 2" - Thermal Power Plants "Nikola Tesla" in Obrenovac (Usce). The experimental field in Pancevo was on a carbonated (micellar) chernozem soil formed on the loess terrace. Because of its natural fertility, a favourable soil solution reaction and physical characteristics, this soil type has a huge potential for wheat production (*Glamoclija et al.*, 2012a, 2012b). Another experimental field was on a degraded soil, formed on a coal-mine dumping ground and uncultivated for more than 15 years. The subject matter of this research was the first domestic spelt wheat cultivar *Nirvana*, selected by the Institute of Field and Vegetable Crops from Novi Sad. This cultivar is a winter crop and it is very frost-tolerant. According to the results of previous research (*Mladenovic & Dencic*, 2010), *Nirvana* spelt wheat cultivar can be successfully grown on less fertile soils and it is more resistant to draught than common wheat. Its requirements for nitrogen are lower, so the best results this cultivar achieves on moderately fertile soils, while under conditions of much fertile soils and in intensive nitrogen fertilization it is prone to lodging due to its high stem. Cropping potential of *Nirvana* is over 4000 kg ha^{-1}. On the top of the stem (average height 107 cm) is a spike with average length of 10-15 cm, with about 20 two-blossom spikelets. During threshing, the grain remains tightly wrapped in glumes, lemmas and paleas. Dehulled grain volume weight is 75-78 kg and 1000-grain weight is about 41 g. Grains contain up to 17.5% of total proteins. Due to a specific ratio of gliadine and glutenin, spelt wheat flour can be used for making special pastry products of a high nutritional value, rich in vitamins B and mineral salts. When compared to common wheat, spelt wheat grains contain 7 to 8 times more calcium, magnesium, phosphorus and selenium. Mineral salts in grains are bound to organic carbon and easily absorbed by the organism. Due to its biological characteristic, *Nirvana* is suitable for organic production.

On the experimental field of the "Tamis" Institute, standard cropping practices for common wheat (*Triticum vulgare* L.) are applied. A pre-crop was sunflower. The basic post-harvest tillage was conducted, when 250 kg ha^{-1} of NPK fertilizer 15:15:15 was applied. Considering spelt wheat small requirements for nitrogen and its susceptibility to lodging, no top-dressing nitrogen was applied on the crops. At the same time, pre-sowing preparation was performed at the depth of 6-8 cm. Sowing was done with an experimental sowing machine in late October. During the growing season, no crop tending or plant protection measures were applied. Prior to harvest, conducted with an experimental combine in early July, samples for testing the following parameters were taken: stem height, spike length, number of spikelets, number of grains, grain weight and chaff weight.

At the experimental field in the vicinity of "TENT 2" - Thermal Power Plants "Nikola Tesla" in Obrenovac after amelioration (cleaning the plot of different waste and removing weeds), in summer the soil was ploughed down to 20 cm of depth, and in autumn it was prepared for sowing. In pre-sowing fertilization, 600 kg ha^{-1} of NPK mineral fertilizers 15:15:15 were used. Sowing was done manually in late October. During the growing season no crop tending or plant protection measures were applied. Harvest was done manually in early July and samples for testing the following parameters were taken: stem height, spike length, number of spikelets, and number of grains, grain weight and lemma/palea weight.

All data were then processed using the analysis of variance and LSD test.

Growing conditions

During the research, the basic meteorological data for both experimental fields were monitored. Data on monthly rainfall and air temperatures in 2011/12 and 2012/13 were taken from the Republic Hydro-Meteorological Service of Serbia.

Rainfall. Total rainfall sums during spelt wheat growing season at both experimental fields were smaller in the first year of the research (Table 1).

Table 1. Rainfall sums during spelt wheat growing season, mm

Month	Pancevo			Obrenovac		
	2011/12	2012/13	Average	2011/12	2012/13	Average
X	39	38	50	45	49	50
XI	51	71	51	57	45	55
XII	55	30	59	54	61	59
I	45	73	40	45	82	45
II	40	46	35	41	62	35
III	42	1	37	48	3	44
IV	57	80	55	56	77	55
V	52	100	47	53	128	56
VI	85	10	80	88	19	82
VII	16	67	65	25	24	63
∑	**437**	**516**	**517**	**512**	**550**	**537**

In 2011/12 in Pancevo there was 18% and in Obrenovac about 5% less rainfall compared to the multiannual average. Despite smaller total sums, rainfall distribution was favourable. In months of the highest water consumption (April, May, first half of June), the water regime at both locations was favourable. In the second year, Pancevo rainfall sums for spelt wheat growing season was in line with the multiannual average, while rainfall sums in Obrenovac were 2.5% higher than the average. Monthly water regime was very favourable, with the highest values in the second half of April and in May, that is, in the period of the highest water consumption.

Temperature conditions. In the first year, the average air temperatures for spelt wheat growing period were 0.7-0.8^{0}C higher on both locations (Table 2).

Table 2. Air temperature during growing period of spelt wheat, ^{0}C

Month	Pancevo			Obrenovac		
	2011/12	2012/13	Average	2011/12	2012/13	Average
X	13	11	13	12	10	11
XI	5	6	7	5	6	7
XII	6	2	2	4	3	4
I	3	-0.3	1	3	0	2
II	-3	2	3	-2	2	3
III	10	6	7	11	7	8
IV	14	13	13	14	14	15
V	18	18	18	17	18	18
VI	25	21	21	24	22	20
VII	26	23	24	29	23	22
Average	**11.7**	**10.2**	**10.9**	**11.7**	**10.5**	**11.0**

In the second year, the average air temperatures on both locations were 0.5-0.7^{0}C lower than the average for this region.

The analysis on the monthly heat distribution in the first year showed that the winter was extremely cold with a long period of frosts. Since the crops were covered by snow, those frosts did not affect the spelt wheat. On the other hand, summer months were very hot. In the winter of second year there were no long periods of frosts, and the summer was characterized by more favourable air temperatures for the generative development of the crops, which had a positive effect on grain filling and synthesising of grain nutrients.

Results and Discussion

Stem height. The average stem height at the time of harvest was 96.8 cm on both experimental fields. The crops grown on the chernozem had considerably higher stems (114.6 cm) than the crops grown on the degraded soil (79.0 cm), in the two-year average and by years of variation (Table 2). Between-year variations in stem height were also statistically significant. In 2013, higher stems were formed on both locations. Although this species is less susceptible to adverse soil conditions than common wheat, crops need optimum agro-ecological and soil conditions for their growth, as *Stallknecht and Gilbertson* (1995) pointed out.

Spike length. Spike length was 10.99 cm in the two-year average. Variations were significant by the locations and years. The longest spikes were formed in the second year by the crops grown on the chernozem soil in Pancevo, while the shortest spikes (8.63 cm) were formed in the first year by the crops grown the degraded soil of the thermal power plant. Some previous research on the effects of agro-ecological conditions on morphological and production characteristics of spelt wheat have shown that spike formation strongly depends on weather and soil conditions (*Ugrenovic et al.* 2012).

Number of spikelets per spike. The average number of spikelets per spike varied from 18.87 (degraded soil, the thermal power plant, 2012) to 21.28 (chernozem, Pancevo, 2013). Total variation in number of spikelets per spike was significant both by the locations and years.

Number of grains per spike. In the total average, the number of grains per spike was 28.05. Comparing this value with the number of spikelets per spike, it can be concluded that the spikelets on average had 1.4 grain. The number of grains per spike was significantly affected by soil conditions. The crops grown on the degraded soil formed spikes with 25.94 grains, while the crops on the chernozem had 30.15 grains. This difference, together with the differences between the years, was statistically significant to very significant.

Grain weight per spike. The crops grown on the chernozem formed longer spikes with more spikelets and grains of 1.27 g of weight in the two-year average. This value is about 20% higher, compared with the one in the crops grown on the degraded soil. Group and individual variations of grain weight per spike were statistically significant. The crops grown on the chernozem formed higher stems and longer spikes with more spikelets per spike, more grain per spike and larger grain weight per spike.

Dehulled grain yield. This value shows a spelt wheat yield after dehulling the grains using specialized hullers. The average two-year grain yield for the whole experiment was 2620 kg ha^{-1}. The yield on the chernozem varied from 2850 kg ha^{-1} (2012) to 3170 kg ha^{-1} (2013). The average grain yield on the degraded soil in the first and second year was 35% and 42% lower than the one on the chernozem. This variation together with the variations between the years was statistically significant.

However, although the difference in yields was statistically significant, it should be pointed out that the degraded soil gave higher grain yield, which implies that this species can be grown in adverse edaphic conditions (*Glamoclija et al.*, 2010).

Table 3 Indicators of morphological and production characteristics

Characteristics, Location, Year	Stem height	Spike length	Number of spikelets per spike	Number of grains per spike	Grain weight per spike,g	Grain yield, kg ha^{-1}
PPS, 2012	107.4	12.55	19.58	29.12	1.06	2850
PPS, 2013	121.7	13.53	21.28	31.17	1.48	3170
Average	114.6	13.04	20.43	30.15	1.27	3010
TENT, 2012	77.7	8.63	18.87	24.33	1.03	2107
TENT, 2013	80.3	9.23	19.55	27.55	1.09	2350
Average	79.0	8.93	19.21	25.94	1.06	2229
Total average	**96.8**	**10.99**	**19.82**	**28.05**	**1.17**	**2620**
LSD 2011/12	$_{0,05}$ 8.14; $_{0,01}$ 12.33	$_{0,05}$ 0.981; $_{0,01}$ 1.484	$_{0,05}$ 0.411; $_{0,01}$ 0.621	$_{0,05}$ 1.211; $_{0,01}$ 1.821	$_{0,05}$ 0.53; $_{0,01}$ 0.806	$_{0,05}$ 925.1; $_{0,01}$ 1397.8
LSD 2012/13	$_{0,05}$ 18.7; $_{0,01}$ 27.2	$_{0,05}$ 2.081; $_{0,01}$ 2.965	$_{0,05}$ 1.741; $_{0,01}$ 2.542	$_{0,05}$ 2.421; $_{0,01}$ 3.632	$_{0,05}$ 0.352; $_{0,01}$ 0.510	$_{0,05}$ 629.9; $_{0,01}$ 907.8

PPS - "Tamis" Institute, Pancevo; TENT - TPP "Nikola Tesla", Obrenovac

Conclusions

Considering the results of the research on the effect of soil conditions on morphological and productive characteristics of spelt wheat, the following can be concluded:

Despite of the relatively favourable average weather conditions on both locations, spelt wheat growth and development were more intensive in the second year of the research;

The effect of soil conditions on morphological indicators was statistically very significant. The crops grown on the chernozem formed 45% higher stems, 46% longer spikes and about 6.4% more spikelets per spike;

The quality of soil significantly affected yield indicators. The crops grown on the chernozem formed 16.23% more grains per spike and had 19.8% larger grain weight per spike;

The two-year average yield of dehulled grains grown on the chernozem was 3010 kg ha^{-1}, 35% higher than the yield on the degraded soil;

Despite all the indicators of morphological and production characteristics of the spelt wheat grown on the degraded soil of the Thermal Power Plants "Nikola Tesla" in Obrenovac were significantly lower than the one of the crops grown on the chernozem, it can be concluded that this species achieved satisfactory grain yield.

Acknowledgement

This research was funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia, program on Technological Development, project no. TR-31006 "The Possibilities of Using Contaminated Water for Growing Alternative Grains".

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