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COMPARATIVE STUDY OF GROWING WINTER SMALL GRAIN CEREALS IN ORGANIC AND CONVENTIONAL PRODUCTION SYSTEMS

KOMPARATIVNA ANALIZA GAJENJA OZIMIH STRNIH ŽITA U ORGANSKOJ I KONVENCIONALNOJ PROIZVODNJI

Srđan ŠEREMEŠIĆ[*]*, Maja MANOJLOVIĆ*[*]*, Bojan VOJNOV*[*]*, Brankica BABEC*[**]*,*
Anamarija KOREN[**]*, Tamara MIRJAČIĆ*[*]*, Vladimir SIKORA*[**]
[*]*University of Novi Sad, Faculty of Agriculture, Sq Dositeja Obradovića 8, Novi Sad, Serbia*
[**]*Institute of Field and Vegetable Crops, 21000 Novi Sad, Maksima Gorkog 30, Serbia*
e-mail: srdjan.seremesic@polj.uns.ac.rs

ABSTRACT

The purpose of this study is to compare the yields and yield components of 3 winter small grain cereals (wheat ('NS 40S'), oat ('NS Jadar') and rye ('NS Savo')) grown in conventional and organic production systems. The experiment was conducted as a block design with three replicates at the Bački Petrovac experiment field of the Institute of Field and Vegetable Crops in 2016/2017. The fertilization of conventional cereals examined was based on mineral fertilization, whereas foliar fertilizers with green microalgae (Chlorella vulgaris) were applied in the organic production system. The results obtained indicate differences in the number of organic and conventional plants per m^2, particularly in the instance of winter wheat (277/m^2 in the organic production system and 545/m^2 in conventional production system). Relative to all the cereals observed, significantly higher grain yields per ha were determined in the conventional production system as a result of the mineral nitrogen addition. The research has shown that soil fertility and cultural practices play a decisive role in realizing the full yield potential of winter small grain cereals cultivated in the organic farming system.

Key words: *winter cereals, yield components, organic agriculture.*

REZIME

U ovom radu analizirana je proizvodnja 3 vrste ozimih žitarica (pšenica - NS 40S, ovas - NS Jadar i raž - NS Savo) kako bismo uporedili prinose i komponente prinosa u konvencionalnom i organskom sistemu, a u cilju unapređenja proizvodnje ovih žitarica u organskom sistemu uzgoja. Istraživanje je sprovedeno tokom 2016. i 2017. godine u Institutu za ratarstvo i povrtarstvo, Odeljenju za alternativne kulture i organsku proizvodnju u Bačkom Petrovcu (45° 56′ N 20° 12′ E). Ogled je postavljen na parcelama površine 1000 m^2, po slučajnom blok sistemu u 3 ponavljanja, sa sojom kao predusevom. Konvencionalni sistem proizvodnje baziran je na primeni mineralnih đubriva, dok su u organskoj primenjena folijarna đubriva na bazi algi (Chlorella vulgaris). Setva je izvršena 16.10.2016., a žetva 8.07.2017. Analizom ispitivanih useva utvrđene su razlike u broju biljaka po m^2, što je posebno bilo izraženo kod ozime pšenice (277 biljaka po m^2 u organskoj i 545 bijaka po m^2 u konvencionalnoj). Sve žitarice ostvarile su značajno veći prinos zrna po ha u konvencionalnom sistemu kao rezultat dodavanja azota, ali masa zrna po biljci nije se statistički razlikovala u organskoj i konvencionalnoj proizvodnji. U proseku za sve tri žitarice konvencionalni uzgoj značajano je uticao na sledeće morfološke parametre: dužinu klasa (metlice), masu slame po m^2 i visina biljke, dok masa klasa (metlice) i masa 1000 zrna nisu bili značajno različiti. Ostvareni prinosi ozimih žitarica u organskoj, iako niži, bili su približni višegodišnjim prosečnim vrednostima prinosa ozimih žitarica u našim proizvodnim uslovima.

Ključne reči: *ozima strna žita, komponente prinosa, organska poljoprivreda.*

INTRODUCTION

The developing awareness of the raw food material quality has been a topical issue exacting proper monitoring, control and management of cropping systems. It is widely accepted that the grain quality depends on the practices applied during production. Therefore, it is of great importance to use sustainable cropping systems able to meet different requirements and produce high yields. However, the introduction of sustainable agriculture could be associated with different disadvantages relative to weed and pest control, as well as the nutrient provision for crops. Consequently, yields could vary and are highly dependent on the seasonal crop performance. Organic production represents one of the most important systems of sustainable agriculture (*Šeremešić et al. 2017*). However, the introduction of a cropping design may require a decade to mature until reaching the agroecosystem integrity.

In the certified organic system, winter cereals are devoted to larger areas compared to other crops. According to the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, the areas devoted to organic cereals in Serbia have been increasing over the past years (4,252 ha in 2015, i.e. 27.8 % of the total cultivated area) *(MPŠV 2018)*. Organic production faces various agricultural and ecological challenges. The increasing demand for the safe food production has raised awareness of finding new solutions that will improve the organic system of crop and vegetable production, create complementary relationships with the neighboring ecosystems, as well as preserve the environment (*Šeremešić et al. 2018*). Therefore, there is a constant need to keep abreast of the latest advances in organic cereal production. From the perspective of scientific results, potential feasibility and market development, and in line with the recommendations of nutritionists, the production of organic cereals and their products with high nutritional value and health safety is considered extremely topical *(Radosavljević, 2010)*. Wheat, oats and rye are cereals used for human and animal nutrition, and by promoting the ecological awareness of consumers, as well as the increasing interest in organic agriculture, there is a need to increase areas devoted to organic production.

However, one of the most common impediments to the conversion from conventional to organic cereal production is the anticipation of reduced yields *(Berry et al., 2002)*, as a result of the dominant influence of weeds, the absence of chemical protection, the use of minerals nitrogen fertilizers, etc. *(Knapp et al., 2018)*. To establish organic agriculture as an important tool in sustainable food production, the factors limiting organic yields need to be better comprehended.

The purpose of this paper is to compare the organic and conventional production of three cereal types (wheat, oats and rye) on the basis of the yield and yield components.

MATERIAL AND METHOD

The research was conducted at the Bački Petrovac experiment field of the Institute of Field and Vegetable Crops, Alternative Crops and Organic Production Department (45° 56´ N 20° 12´ E) in 2016/2017. For the purpose of the experiment, the seeds were obtained from the Institute of Field and Vegetable Crops, Novi Sad, the winter wheat cultivar 'NS 40S', the winter oat cultivar 'NS Jadar' and the winter rye cultivar 'NS Savo'. Each cultivar was sown at a depth of 2 cm with an inter-row spacing of 12.5 cm on 6th November. The soybean was the preceding crop for both the organic and conventional experimental cereals. The experiment was conducted as a complete block design with three replicates. The size of the elementary plot was 1000 m^2. The conventional plot fertilization was based on mineral fertilizers, i.e. 60 kg of nitrogen used for spring topdressing. However, the organic plot fertilization entailed foliar fertilizers with green microalgae (*Chlorella vulgaris*) applied twice in the tillering and stem elongation phases. The harvest was carried out on 8th July 2017 by cutting plants to the ground surface using a standard squares method (1m^2) in 3 replicates per a single block.

The plant material obtained was analyzed at the Laboratory for the Agroecology of the Faculty of Agriculture in Novi Sad. Morphological properties were determined on a total of 10 randomly sampled plants per repetition, i.e. a total of 30 plants per single crop. The following morphological traits were observed: number of plants per m^2, height of plants, length of spikes (panicles), weight of spikes (panicles), mass of 1000 grains and yield per hectare. Weather parameters were obtained from the meteorological station located at the Alternative Crops and Organic production Department in Bački Petrovac (Figure 1).

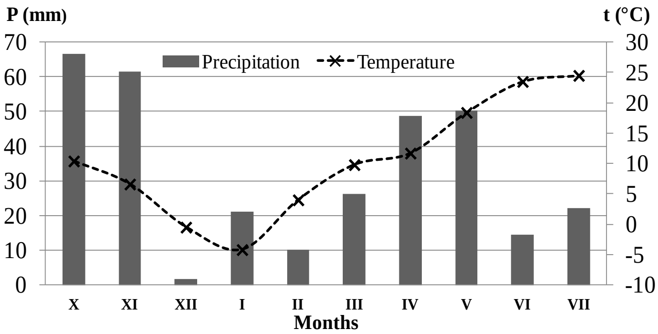

Fig. 1. Average monthly temperature and precipitation sum at the experimental site

The agrochemical properties of the experimental plots were determined (Table 1) indicating higher humus, P and K values of the conventional plots. However, soil properties were not considered a significant impediment to cereal production.

Table 1. Basic soil agrochemical properties (O-Organic agriculture; C-Conventional agriculture)

	Depth (cm)	pH KCl	pH H_2O	$CaCo_3$ (%)	Humus (%)	Total N (%)	Al-P_2O_5 (mg/100g)	Al-K_2O (mg/100g)
O	0-30	7.39	8.10	18.31	2.11	0.16	13.5	22.70
C	0-30	7.30	8.01	6.81	2.86	0.21	69.0	54.50

The data obtained were statistically analyzed using the analysis of variance (ANOVA). The Fisher LSD test was used to compare the parameter means obtained relative to the $p < 0.05$ level of significance. All the calculations were performed using the software system STATISTICA v13.3. StatSoft, Inc.

RESULTS AND DISCUSSION

The results obtained show differences in the yields and morphological properties of the cereals examined depending on the conventional and organic production system (Figure 1).

Relative to the number of harvested plants, a significantly smaller number of plants were found on organic plots. The difference in the number of plants per m^2 is due to poor soil preparation on organic plots compared to the conventional plots of poorer physical and chemical properties.

According to the results obtained, the largest influence of the production method was recorded in wheat, indicating the largest difference between the number of plants per m^2 between organic (277 plants per m^2 on average) and conventional (545 plants per m^2 on average) plants. The ensuing assumption is that untreated seeds of organic cereals were not fully incorporated in soil during sowing. Consequently, the seedlings suffer from low temperature exposure during the winter. The experiment showed that plant height values were higher in conventional than in organic winter wheat crops, primarily due to the use of nitrogen on conventional plots, but also due to better chemical properties of the soil. The height of the wheat plants cultivated was 80-85 cm on average. The average height of the conventional wheat plants was 80.97 cm, compared to a height of 61.7 cm of the organic wheat plants (organic oat 64.27 cm, conventional oat 93.1 cm; organic rye 108.6 cm, conventional rye 144.7 cm).

The average values of the length of spikes (panicles) in the organic production system were somewhat lower than the length of spikes (panicles) recorded in the conventional cultivation system relative to all the types of winter grain cereals under consideration. In rye, this difference was more pronounced than in wheat and oat. Moreover, a higher variability of the length of spikes (panicles) was observed, relative to the standard variation values, in organic oats and rye compared to their conventional counterparts (Figure 2c). By comparing organic and conventional production, a statistically significant difference in the values of this parameter was determined.

The spike mass values of wheat in organic and conventional production systems were approximately the same. The mass of spikes of organic oats was a slightly higher than that of conventional oats, but still statistically non-significant.

According to *Miloševˇ (2000)*, the 1000 grain mass is the result of a complex interaction of varietal specificities, agroecological conditions and applied cultural practices. *Milošev et al. (2006) and Jaćimović et al. (2008, 2012)* found that the absolute grain mass was significantly higher in fertilizer treatments, especially with nitrogen. The production system did not significantly affect the mass of 1000 grains and the analysis of variance did not show statistically significant differences between organic and conventionally grown winter cereals.

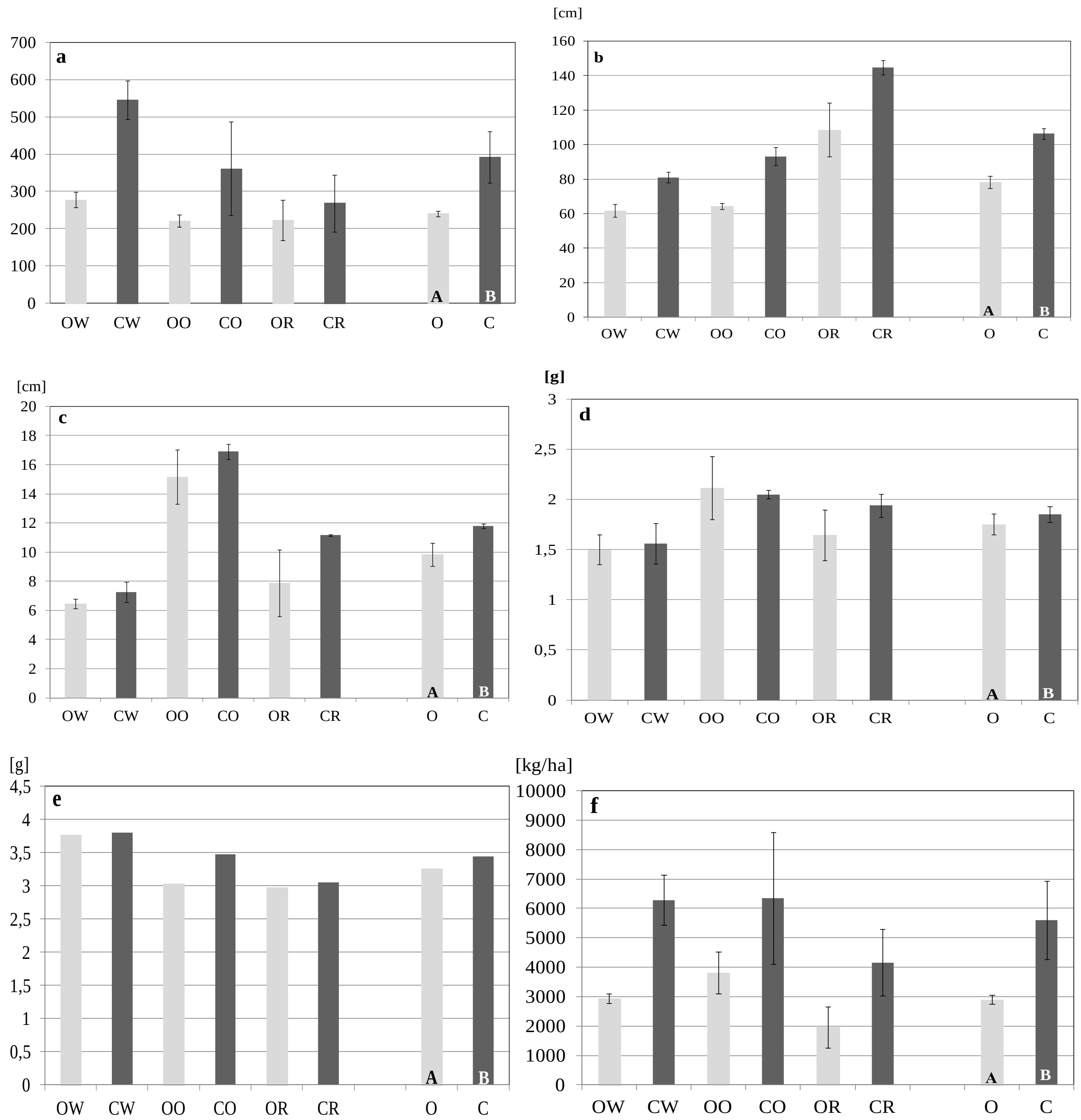

Fig. 2. a) number of plants per m^2 b) weight of plants c) length of spikes d) mass of spikes e) mass of 1000 grains f) grain yield (O- organic; C- conventional; OW-organic wheat; OO- organic oat; OR-organic rye; CW- conventional wheat; CO- conventional oat; CR- conventional rye)

According to *Jaćimovic et al. (2012)*, the 1000 grain mass of wheat ranged from 32.2 g to 35.9 g. The same authors found that the largest mass of 1000 grains was recorded when the NPK fertilizer was applied, whereas the lowest values of 1000 grain mass were achieved in non-fertilized, control plants. In our experiment, a high mass of 1000 grains was achieved, within the limits optimal for the experimental cultivar (35-40 g). The average mass of 1000 grains of the experimental organic and conventional wheat plants was 37.7 g and 38 g, respectively. Grain yield is the result of many developmental and physiological changes throughout the plant’s life cycle (*Okuyama et al., 2004*). Numerous authors point out that the yield is determined by three main components: the number of plants per unit area, the number of grains per class and the mass of 1000 grains (*Jaćimović et al., 2012*).

In our research, the grain yield per hectare obtained was significantly higher in conventional cultivation and is directly related to the number of plants per m^2. A number of previous studies on organic cereals such as *Oljača et al. (2009)* reported that barley yields were similar in both organic and conventional farming systems. A significantly smaller number of plants per m^2 on organic plots results from poorly prepared soil and poorer physical properties compared to conventional plots. Accordingly, some cereals are more tolerant to poor soil condition than others. *Galie et al. (2004)* showed that oats are very suitable for cultivation according to the principles of organic production, taking into account the high yields obtained

(4 to 5 t/ha) *(Spasova et al., 2017)*. Oats have lower requirements for nitrogen compared to other winter cereals and are considered a good competitor with weeds *(Taylor and Cormack, 2001). Seufert et al. (2012)* used a comprehensive meta-analysis to globally examine the relative yield performance and found lower yields of organic cereals by 26 % compared to conventional cereals. In our study, the yields of cereals under consideration were assessed relative to a specific year, thus the “year” effect cannot be excluded. It has been assumed that the average yield requirement in the conventional production system would take some time until the organic integrity achievement. Nitrogen availability in the critical stages of development could be of great importance to cereal production. *Bogdanović et al. (2009)* demonstrated that the mineralization without the addition of fertilization, lower than 10 kg ha^{-1}, is not sufficient for cereal growth. Balanced production inputs have to be considered for the achievement of cost-effective organic production.

CONCLUSIONS

In the present study, the obtained yields of the organic and conventional winter small grain cereals under consideration were somewhat comparable. However, lower yields per hectare were recorded in all three cereal types examined when grown in the conventional production system. Conventional cultivation methods significantly influenced the following morphological parameters of cereals: the length of spikes (panicles), the mass of straw per m^2 and the height of the plant. In contrast, the mass of spikes (panicles) and the mass of 1000 grains were not significantly different relative to the growing system. Of 3 cereals examined, winter wheat exhibited the greatest difference between the organic and conventional growing systems, indicating better adaptation of oats and rye in the organic production system. This research will contribute significantly to the selection of crops and management practices in organic cereal production.

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