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Onion Yield and Yield Contributing Characters as Affected by Organic Fertilizers

Milka Brdar-Jokanović • Milan Ugrinović • Dejan Cvikić • Nenad Pavlović • Jasmina Zdravković • Slađan Adžić • Milan Zdravković

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Summary: Two-year field study was performed with the aim to investigate the effect of organic fertilizers (fully decomposed farmyard manure and bacterial fertilizer) on yield, bulb weight and number of bulbs per plot in five onion cultivars. The applied bacterial fertilizer included *Bacillus megaterium, Bacillus licheniformis, Bacillus suptilis, Azotobacter chrocoocum, Azotobacter vinelandi* and *Derxia* sp. NPK fertilized and unfertilized plots were included in the trial as controls. Yields from unfertilized, plots treated with manure and bacterial fertilizer were 24.3%, 25.3% and 48.8% of yield measured for NPK control (100.0%), respectively. Since farmyard manure did not provide significant increase in yield, bulb weight and number of bulbs per plot in comparison to unfertilized control, its application is not recommended for onion. Bacterial fertilizer may be used for organically grown onion. However, significant differences in yield and bulb weight that have been found among the cultivars imply the importance of genotypes screening. Cultivar Zlatno gnezdo responded well to bacterial amendment and it could be recommended to organic producers and exploited in breeding programs.
Key words: onion, organic fertilizers, yield

Introduction

Onion (*Allium cepa* L.) accounts for around 10% of world's vegetable production, making it the second most important vegetable crop, following only tomato. It is a valuable part of everyday diet, due to its compounds that have perceived benefits to human health (Griffiths et al. 2002, Wu et al. 2006, Kumar et al. 2007). In Serbia, onion crops occupy approximately 19,000 ha, with low average yields of 6.9 t ha^{-1}. Mainly owing to irrigation and production from seed, yields are higher in Vojvodina province than in central Serbia (10.9 t ha^{-1} and 5.4 t ha^{-1}, respectively). However, it is still far below world's average of 40 t ha^{-1} (Republički zavod za statistiku 2010). Since cultivars predominantly grown in Serbia still posses good yielding capacity, low yields may be attributed to inadequate agricultural practice. Recently conducted research that has been mostly performed to determine optimal sowing/planting dates and watering regime may contribute to higher onion bulb and seed productivity (Ilić et al. 2006, Milenković et al. 2008, Pejić et al. 2008, Šunić et al. 2008).

Unlike for conventional agricultural production relaying on intensive use of synthetic fertilizers and pesticides, high yields are not always in foreground in organic agriculture. Although it appears that organically grown food has gained an increasing interest among consumers in Serbia and preconditions for the production are good, areas occupied by the crops are still limited to 2,876.5 ha (registered and certified producers in 2009, according to Serbian Chamber of Commerce). The fact is not surprising, since organic farming is a new agricultural discipline requiring education of farmers, application of appropriate bio-fertilizers and pesticides in optimal doses, at least two years for transition from conventional to organic production and use of organic or conventionally produced untreated seed, if possible. Moreover, there is an open question related to choice and breeding of cultivars suitable for organic farming; the available cultivars are selected in conventional farming

M. Brdar-Jokanović (✉) • M. Ugrinović • D. Cvikić • N. Pavlović • J. Zdravković • S. Adžić • M. Zdravković
Institute for Vegetable Crops, Karađorđeva 71, 11420 Smederevska Palanka, Serbia
e-mail: milkabrdar@yahoo.com

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systems and therefore not necessary adapted to organic conditions. Currently, there is no organic cultivar of any agricultural plant in Serbia, and until the release of the first such cultivar those that are grown conventionally should be evaluated for yield response to low input conditions. The cultivars with the best performance in organic conditions should be recommended to the producers (Lazić & Malešević 2004, Čuvardić 2006, Berenji 2009, Milovanović et al. 2009, Čabilovski et al. 2010, Vlahović et al. 2010).

This preliminary study was undertaken to evaluate the effect of mineral and two widely available organic fertilizers on five commercially grown onion cultivars. The cultivars with good response to organic amendments will be recommended to organic producers and used for breeding organic onion.

Materials and Methods

Five commercially grown onion cultivars (Jasenički crveni, Jasenički žuti, Majski srebrnjak, Holandski žuti and Zlatno gnezdo) were included in a complete randomized block designed field trial with three replications. The trial was conducted during two onion growing seasons (2009 and 2010) at the experimental field of Institute for Vegetable Crops in Smederevska Palanka, Serbia (44° 22' N, 20° 57' E, elevation 121 m). The soil type is vertisol. The mean plot consisted of 3 rows, 5 m long, with 10 cm spacing inside row and 20 cm spacing between rows. Sowing was performed on 23rd and 25th March for growing seasons of 2009 and 2010, respectively, and harvesting when 50% of plants fall over of the canopy (15th July and 8th August). Weather data covering the two seasons were collected from the nearby meteorological station. The seasons were characterized by higher temperatures but also higher precipitation sum when compared to long-term average (Tab. 1).

In order to define yield increase obtained by mineral fertilization, the trial included two controls (NPK fertilizer and without fertilization). Treatments were bacterial fertilizer 'Slavol', produced by Agrounik d.o.o., Belgrade (*Bacillus megaterium, Bacillus licheniformis, Bacillus suptilis, Azotobacter chrocoocum, Azotobacter vinelandi, Derxia* sp.) and fully decomposed farmyard manure. NPK fertilizer (15 % N, 15 % P_2O_5 and 15 % K_2O) and farmyard manure were applied prior to sowing, at the rate of 500 kg ha^{-1} and 45 t ha^{-1}, respectively; which is a common agricultural practice in the region. Foliar application of bacterial fertilizer was performed twice during each growing season, at the three-leaf stage of onion development.

NPK fertilized plots were kept from diseases and weeds by applying pesticides that are commonly used in conventional agricultural practice. No such preparation was applied to unfertilized plots and plots treated with farmyard manure and bacterial fertilizer, which were maintained free from weeds by hand-weeding. All plots were irrigated several times during the growing seasons.

Bulb weight (g), number of bulbs per plot and yield (kg per plot) were determined after harvest. The samples included 30 randomly selected plants per plot.

The data were processed by ANOVA, using LSD test for comparison of means.

Results and Discussion

The results of factorial analysis of variance demonstrated significant differences among the onion cultivars, growing seasons and fertilizer treatments for yield, bulb weight and number of bulbs per plot. The interactions among the cultivars, seasons and treatments were also significant in all cases, with the exception of cultivar/season/

Table 1. Weather parameters for onion growing seasons of 2009 and 2010 (Smederevska Palanka, March 20th-July 20th)
Tabela 1. Meteorološki podaci za vegetacioni period crnog luka u 2009. i 2010. (Smederevska Palanka, 20. mart-20. jul)

Parameter / Parametar	Year / Godina 2009	2010	Long-term average Višegodišnji prosek (1981-1990)
Sum of temperatures Suma temperatura (°C)	2128.0	2170.8	1946.0
Average daily temperature Srednja dnevna temperatura (°C)	17.4	17.8	15.9
Sum of precipitation Suma padavina (mm)	305.0	304.7	258.0

Table 2. Mean squares (MS) from ANOVA for the analyzed onion traits
Tabela 2. Sredine kvadrata (MS) iz ANOVA-e za ispitivana svojstva crnog luka

Effect / Efekat	*df*	Trait / Svojstvo Yield Prinos	Bulb weight Masa lukovice	No of bulbs per plot Broj lukovica po parceli
Cultivar (C) / Sorta	4	12.69**	432.48**	515.01**
Season (S) / Sezona	1	0.70**	2829.49**	168.03**
Treatment (T) / Tretman	3	156.28**	16010.58**	1444.28**
C / S	4	1.02**	119.02**	30.14*
C / T	12	4.30**	162.89**	95.09**
S / T	3	0.41**	194.52**	219.79**
C / S / T	12	1.05**	67.93**	19.62
Error / Pogreška	80	0.03	9.93	11.62

df – degrees of freedom
*, ** – significant at the 0.05 and 0.01 levels of probability, respectively
df – stepeni slobode
*, ** – značajno na 0,05 i 0,01 nivoima verovatnoće

treatment interaction for number of bulbs per plot (Tab. 2).

On average for all cultivars, the highest onion yield was obtained when applying NPK fertilizer. However, the differences among the cultivars were significant (Tab. 3). Among the cultivars, the highest yield was noted for Majski srebrnjak, and the lowest for Jasenički žuti. The yields were in the range previously reported for the location and the cultivars, when grown in optimal conditions (Pavlović et al. 2003).

As expected, and in accordance to the results reported by other authors investigating the possibilities for growing organic onion (Shaheen et al. 2007, Vidigal et al. 2010), plants grown on unfertilized plots yielded lowest (24.3% of NPK control). The obtained results imply that the cultivars used in the study are highly adapted to conventional growing systems.

Concerning the applied organic fertilizers, onion plants treated with bacterial fertilizer yielded significantly higher than those treated with manure (48.8% and 25.3% of yield obtained on NPK fertilized plots, respectively). Since farmyard manure obviously could not provide significant yield increase in comparison to the unfertilized control, one may conclude that its application is not justified for onion. Similar results have been obtained by Mirzaei et al. (2007) for garlic.

However, the differences regarding onion yield measured on bacterial fertilizer treatment that have been observed among the cultivars were highly significant, implying the importance of screening genotypes for adaptability to organic growing conditions and the possibility of breeding organic onion. The highest yield improvements that have been achieved by application of bacterial fertilizer were for cultivars Jasenički žuti and Zlatno gnezdo (64.0% and 59.3% of NPK control, respectively). Since Jasenički žuti was the lowest yielding cultivar in the experiment, the yield response to bacterial fertilizer is not sufficient to recommend the cultivar for growing in organic conditions. However, it could be further analyzed and used in breeding programs aimed to create onions suitable for organic agriculture. Unlike Jasenički žuti, Zlatno gnezdo is a high yielding cultivar and responded well to bacterial amendment. Therefore, it could be recommended to organic producers as well as exploited in breeding programs.

Similarly to yield, the highest onion bulb weight and number of bulbs per plot were recorded on plots treated with mineral fertilizer (Tab. 3). Concerning bulb weight, the lowest values were noted on unfertilized and plots treated with manure (39.2% and 40.5% of NPK control, respectively), whereas bacterial fertilizer improved bulb weight up to 55.1% of NPK control. The lowest number of bulbs per plot was counted on manure treatment (83.2% of NPK control) and there was no significant difference between plots treated with mineral and bacterial fertilizer. Therefore, when bacterial fertilizer was applied, differences among the studied cultivars regarding bulb weight correspond to the differences regarding yield.

However, it is important to note that onion yield improvements obtained by the bacterial fertilizer application were moderate, even in the best responding cultivars when compared to those reported by Lee (2010), for example, who used

Table 3. The effect of mineral and organic fertilizers on yield (kg per plot), bulb weight (g) and number of bulbs per plot in five onion cultivars (two-year average)
Tabela 3. Efekat mineralnog i organskih đubriva na prinos (kg po parceli), masu lukovice (g) i broj lukovica po parceli kod pet sorti crnog luka (dvogodišnji prosek)

Cultivar Sorta	NPK fertilizer NPK đubrivo	Without fertilization* Bez đubrenja	Bacterial fertilizer* Mikrobiološko đubrivo	Manure* Stajnjak
	Yield / Prinos			
Jasenički crveni	5.70 *a*	17.1 *a*	42.9 *a*	18.0 *a*
Jasenički žuti	4.58 *b*	36.7 *b*	64.0 *b*	36.7 *b*
Majski srebrnjak	9.47 *c*	19.8 *a*	40.6 *a*	21.8 *c*
Holandski žuti	5.65 *a*	23.0 *c*	37.1 *a*	24.4 *cd*
Zlatno gnezdo	6.31 *a*	24.8 *c*	59.3 *b*	25.4 *d*
Average / Sredina	6.34	24.3	48.8	25.3
	Bulb weight / Masa lukovice			
Jasenički crveni	78.4 *a*	35.8 *a*	49.4 *a*	36.8 *a*
Jasenički žuti	69.7 *a*	48.1 *b*	60.2 *b*	51.6 *b*
Majski srebrnjak	97.0 *b*	36.7 *a*	51.9 *a*	33.9 *a*
Holandski žuti	76.3 *a*	38.0 *a*	52.5 *a*	42.7 *c*
Zlatno gnezdo	81.5 *a*	37.3 *a*	61.4 *b*	37.6 *a*
Average / Sredina	80.6	39.2	55.1	40.5
	Number of bulbs per plot / Broj lukovica po parceli			
Jasenički crveni	123.8 *ab*	80.8 *a*	91.9 *a*	78.8 *a*
Jasenički žuti	118.0 *a*	104.5 *b*	108.9 *b*	89.6 *b*
Majski srebrnjak	144.0 *c*	83.2 *a*	92.4 *a*	78.0 *a*
Holandski žuti	126.5 *b*	87.2 *a*	93.4 *a*	87.7 *ab*
Zlatno gnezdo	136.0 *d*	82.7 *a*	97.6 *a*	81.7 *ab*
Average / Sredina	129.7	87.7	96.9	83.2

Values within the same column followed by the same letter do not differ significantly at the 0.05 level of probability, according to LSD test
*% of NPK treatment (100%)
Vrednosti u okviru iste kolone pored kojih se nalazi isto slovo ne razlikuju se značajno na 0,05 nivou verovatnoće, prema NZR testu
*% u odnosu na vrednost izmerenu na NPK tretmanu (100%)

a complex organic amendment, developed the method of its application and examined its impact on soil. The research performed by Lee (2010) was primarily focused on improvement of organic environment. On the other hand, Lammerts van Bueren et al. (2005) and Osman et al. (2008) stress the necessity of screening onion genotypes and broadening its genetic base in order to develop cultivars adapted to organic farming systems, proposing marker assisted selection as a useful tool in breeding organic cultivars (Lammerts van Bueren et al. 2010). Therefore, a comprehensive research that would take place in our environmental conditions and include soil analyses, agricultural procedures and genotype screening is required to maintain satisfactory yield in organically grown onion.

To our knowledge, the results of this experiment are the first report on the effect of organic fertilizers on different field-grown onion cultivars in our country. Since only two treatments and five widely grown onion cultivars were included in this study, it should be referred as a preliminary one and moderate yield improvements obtained by using bacterial fertilizer should not be considered as disappointing. The obtained results pointed out: 1) the effect of conventional agricultural practice on onion, concerned with the range between the yield obtained from unfertilized plots and the yield obtained when applying mineral fertilizer; 2) the importance of choosing the appropriate organic amendment for field-grown onion and 3) the necessity of screening onion genotypes in organic environments.

Conclusions

Fertilizing field-grown onion with farmyard manure does not provide significant yield increase when compared to unfertilized control, whereas applying bacterial fertilizer could improve the yield. Among five analyzed onion cultivars widely grown, Zlatno gnezdo appears to be the most suitable for growing in field organic conditions.

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Uticaj organskih đubriva na prinos i svojstva koja su u vezi sa prinosom crnog luka

Milka Brdar-Jokanović • Milan Ugrinović • Dejan Cvikić • Nenad Pavlović • Jasmina Zdravković • Slađan Adžić • Milan Zdravković

Institut za povrtarstvo, Karađorđeva 71, 11420 Smederevska Palanka, Srbija

Izvod: Dvogodišnji poljski ogled je postavljen sa ciljem ispitivanja uticaja organskih đubriva (zgoreli stajnjak i mikrobiološko đubrivo) na prinos, masu lukovice i broj lukovica po parceli kod pet sorti crnog luka. Primenjeno mikrobiološko đubrivo sadrži *Bacillus megaterium, Bacillus licheniformis, Bacillus suptilis, Azotobacter chrocoocum, Azotobacter vinelandi* i *Derxia* sp. Parcele tretirane NPK đubrivom i neđubrene parcele su uključene u ogled kao kontrole. Prinosi izmereni na neđubrenim parcelama, parcelama đubenim stajnjakom i mikrobiološkim đubrivom iznosili su 24,3%, 25,3% i 48,8% prinosa utvrđenog kod NPK kontrole (100,0%) po redosledu. Pošto kod tretmana stajnjakom nisu utvrđeni značajno veći prinos, masa lukovica i broj lukovica po parceli u odnosu na neđubrenu kontrolu, primena ovog organskog đubriva se ne preporučuje kod crnog luka. Mikrobiološko đubrivo bi se moglo koristiti u organskoj proizvodnji crnog luka, međutim, značajne razlike u prinosu i masi lukovica koje su utvrđene među sortama ukazuju na značaj skrininga genotipova. Sorta Zlatno gnezdo bi se mogla preporučiti za organsku proizvodnju i iskoristiti u oplemenjivačkim programima.

Ključne reči: luk, organska đubriva, prinos