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AGRO-ECOLOGICAL CONDITIONS AND MORPHO-PRODUCTIVE PROPERTIES OF BUCKWHEAT

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Abstract: The effect of different agro-ecological conditions on morpho-productive properties of buckwheat cultivar *Novosadska* was investigated during 2011-2012 at three different localities. The types of soil on which the experiments were conducted were as follows: the eutric cambisol - in Valjevo, the chernozem - in Nova Pazova and the grey forest soil in Nova Varoš. Agro-ecological conditions affected the growth and productivity of the buckwheat crops at all three localities. The highest yields per unit area were obtained on the chernozem-type soil (1.65 t ha^{-1}), while the average yields on the less fertile soils in the hilly and mountainous regions of Serbia were 1.31 t ha^{-1} on the grey forest soil and 0.80 t ha^{-1} on the eutric cambisol. The results showed that buckwheat can be successfully grown on different soil types, since the experiments on all locations were carried out without fertilization, i.e. using the natural fertility of the soil.

Key words: buckwheat, agro-ecological conditions, productive properties

Introduction

Buckwheat (*Fagopyrum esculentum* Moench.) is an annual plant in the family Polygonaceae, the genus Fagopyrum, which belongs to alternative cereals for its method of cultivation and use. Buckwheat is used in human and animal nutrition, as well as in pharmaceutical and other industries *(Rakić et al., 2005)*. It is very popular in developed countries, where the importance is given to healthy, organically produced food *(Popović et al., 2013)*. Its morphological properties, primarily height and stem branching, depend to certain extent on a method of cultivation and weather/soil conditions, since buckwheat is characterized by constant growth during the vegetation period. Its main product – seed – is similar to a grain of bread cereals for its nutritive value. The seed contains about 70% of carbohydrates, 10% total proteins, 3.7% cellulose, 1.73% oil, 1.72% mineral salts

(K, Ca, P, Fe, and Mg) and vitamins B and E, yet it does not contain gluten and it is suitable for people allergic to this protein. The hard pericarp should be removed from the seed prior to use *(Glamočlija et al., 2011)*. Buckwheat is also a honey plant that has a long and redundant bloom *(Zečević, 2008)*. Since buckwheat by-products are smaller seeds, not suitable for dehulling, they are therefore used for animal feed because of high protein content. Post-harvest residues have high protein content, but less digestible carbohydrates than straw from small grains. Residues from dehulling buckwheat fruits can also be used for medium quality animal feed, suitable for poultry *(Glamočlija et al., 2011)*. In some parts of a buckwheat plant there are compounds identified as having positive effects on human health *(Lačnjevac et al., 2012)*. Ground biomass can be used fresh, silage or dried as feed for domestic animals *(Glamočlija et al., 2011)*. The rise in living standards and fabrication improvement have enabled small grains and millets to dominate, decreasing the interest in buckwheat and thus minimizing its production. An increase in the quantity of produced buckwheat was recorded in the last decade, mainly due to an increase in demand for buckwheat seed products *(Zečević, 2008; Sedej, 2011)*. This species is not given attention it deserves for its adaptability and processing possibilities *(Abdel-Aal et al., 1995; Dražić et al., 2010)*. *Glamočlija et al. (2011)* point out that buckwheat can be planted in hilly areas as a post-crop after harvesting winter forages. Thus can be used for bee foraging, and, if buckwheat seeds do not reach their full maturity by early autumn frosts, buckwheat can be used for silage.

The goal of this research was to investigate possibilities of growing buckwheat in different conditions and on different types of soil.

Materials and Methods

During the two-year research (2011-2012) on effects of agro-ecological conditions on plant height and yield, seeds of buckwheat cultivar *Novosadska* (selected at the Institute of Field and Vegetable Crops from Novi Sad) were used. The experiments for this research were set up at three localities in Serbia: Valjevo (western Serbia); Nova Varoš (south-western Serbia) and Nova Pazova (Srem). The experiments were set up on different soil types - on the eutric cambisol in Valjevo, the grey forest soil in Nova Varoš and the chernozem in Nova Pazova. Wheat was used as a pre-crop at all localities. Planting was done manually. At all localities, when determining the planting date, the optimal conditions for germination, sprouting, and further growth of buckwheat were estimated. In Valjevo and Nova Pazova, planting was done at the end of the first decade of April, and in Nova Varoš in mid-May. Stem height was measured at the time of full bloom. Harvest was done manually. Yield was calculated after harvesting fruits in the stage of wax maturity from the middle of a stem. Seeds were collected from the

fruits and dried down to moisture content of 10%. Based on the dried seed mass, yield per hectare was calculated. The sample for measuring plant height and calculating yield comprised ten plants from twelve randomly chosen checkpoints from each locality (a total of 120 plants per locality). For assessing the significance of the effect of agro-ecological conditions (locality and year) on the plant height and yield of buckwheat, the analysis of variance for two-factorial experiments was used (ANOVA). Experimental data were analysed using the statistics software package STATISTICA 10 for Windows. All evaluations of significance were made on the basis of the LSD test at 0.05% and 0.01% significance levels.

Meteorological conditions. During the research, the following meteorological conditions were monitored and analysed – temperatures and amounts and distribution of precipitation in buckwheat vegetation period. Data on monthly precipitation and air temperatures in 2011/2012 were retrieved from the Republic Hydrometerological Service of Serbia. The annual heat distribution varied with the localities, months and years. In 2011, the average air temperatures recorded at all three localities were lower than in 2012 (Figure 1). As for the monthly distribution of precipitation, it varied with all localities, with pronounced maximum temperature recorded in June. In 2011, the total annual amounts of precipitation recorded at all three localities were smaller than in 2012 (Figure 2).

Soils. The experiments were conducted on three soil types that differed significantly in regard to their chemical properties (Table 1). The chernozem soil was moderately alkaline, (pH in KCl = 8.2), low humus, 2.8%, well supplied with nitrogen, 0.23%, medium available phosphorus (12.3 mg 100 g^{-1} soil) and well supplied with potassium (23.88 mg 100 g^{-1} soil).

Table 1 Agrochemiocal properties of soil

Soil values	pH		$CaCO_3$	Humus	Nitrogen	P_2O_5	K_2O
	nKCl	H_2O	%	%	%	mg 100 g^{-1}	mg 100 g^{-1}
Chernozem	8.20	7.30	8.60	2.80	0.23	12.30	23.20
Grey forest soil	5.20	4.70	1.80	2.10	0.10	1.15	6.88
Eutric cambisol	6.20	5.60	1.60	2.40	0.10	1.18	8.94

Grey forest soil was of moderately acidic reaction (pH in KCl = 5.2), low in humus, 2.10%, of medium nitrogen content, 0.10%, with a very low content of available phosphorus (1.15 mg 100 g^{-1} soil) and low potassium (6.88 mg 100 g^{-1} soil). Land of brown forest soil (eutric cambisol) was of slightly acid reaction (pH in KCl = 6.2), low in humus, 2.40%, of medium nitrogen content, 0.1%, with very low levels of available phosphorus (1.18 mg 100 g^{-1} soil) and low potassium level (8.94 mg 100 g^{-1} soil). The most fertile soil was chernozem, while the grey forest soil type and brown forest soil (eutric cambisol) had poor content of P and K.

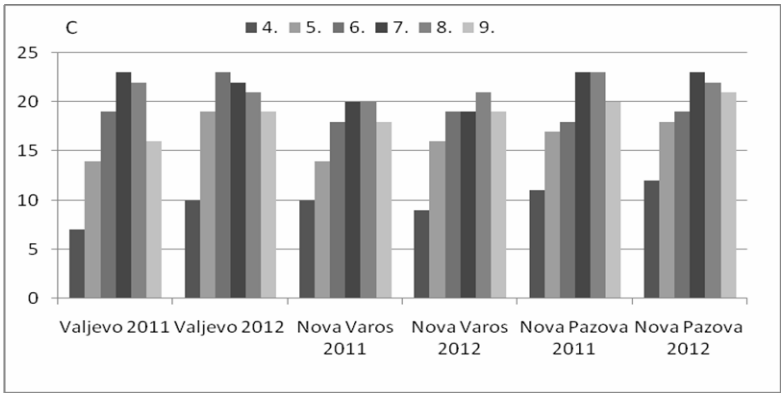

Figure 1. Temperature, °C, in Valjevo, Nova Varos, Nova Pazova, Serbia (2011-2012)

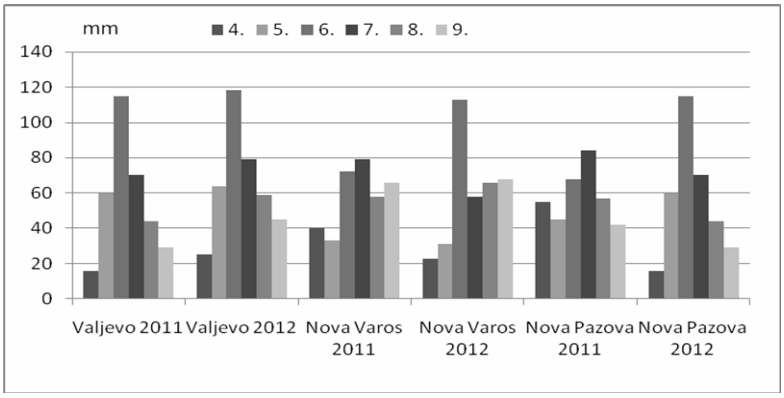

Figure 2. Precipitation, mm, in Valjevo, Nova Varos, Nova Pazova, Serbia (2011-2012)

Results and Discussion

Based on the results of the research, it was determined that the plant height and yield were considerably affected by the agro-ecological conditions (Table 2). It was also assessed that the localities considerably affected the plant height, while it was the interaction between the agro-ecological conditions (interaction locality/year, AB; Table 3) that affected the yield.

The average plant height in full bloom was considerably affected by the weather conditions and the localities. In full bloom, in the first year of the research, the plant height at all localities was considerably lower, due to smaller amount of precipitation and its adverse distribution in 2011. Considerably higher average

height had the plants cultivated on the chernozem (Nova Pazova; 116.20 cm). Comparing plant height of the plants cultivated at the other localities, there was a significant difference determined. The lowest average height had the plants cultivated on the grey forest soil (NovaVaroš; 91.30 cm).

Table 2. The effect of agro-ecological conditions on buckwheat height (cm) and yield (t ha^{-1})

Parameter	Locality, A	Year, B	Results	Average, A	LSD_{AB}	
					0.05	0.01
Plant height, cm	Valjevo	2011	103.60^{b}	102.70^{b}	2.66	3.63
		2012	101.80^{b}			
	Nova Varoš	2011	90.40^{c}	91.30^{c}		
		2012	92.20^{c}			
	Nova Pazova	2011	114.40^{a}	116.20^{a}		
		2012	118.00^{a}			
	Average, B	2011	102.80	103.4	2.17	2.97
		2012	104.00			
	$LSD_{AB\ 0.05}$		3.77			
	$LSD_{AB\ 0.01}$		5.14			
Yield, t ha^{-1}	Valjevo	2011	0.89^{d}	0.80^{c}	0.04	0.05
		2012	0.71^{e}			
	Nova Varoš	2011	1.31^{c}	1.31^{b}		
		2012	1.30^{c}			
	Nova Pazova	2011	1.57^{b}	1.65^{a}		
		2012	1.73^{a}			
	Average, B	2011	1.26	1.25	0.03	0.04
		2012	1.25			
	$LSD_{AB\ 0.05}$		0.05			
	$LSD_{AB\ 0.01}$		0.07			

a,b,c – significant at $p<0.01$

The average yield in Nova Pazova on the chernozem (1.65 t ha^{-1}) was considerably higher than the yields at the other localities. The lowest average yield (0.80 t ha^{-1}) was obtained on the eutric cambisol in Valjevo. Similar results had *Glamočlija et al. (2011)*, who pointed out that all abrupt changes in agro-ecological conditions can have adverse effect on buckwheat. However, buckwheat can recover well after the period of adverse weather conditions. With better weather conditions, buckwheat can bloom again and form new fruits, but it can also elongate the period of vegetation, with pronounced successive maturity. The results obtained on the less fertile soils in the hilly and mountainous regions of Serbia and in changed agro-ecological conditions show these plants can be also successfully cultivated in less favourable conditions for field crops production *(Popović et al., 2013)*. The evidence of a big effect that soil fertility has on buckwheat yield was given with the results of the effect of side-dressing, given by *Filipović et al. (2005)*, while *Choi et al. (1990)* point out a significant effect of the applied production

technology (time and method of planting). A growing demand for buckwheat that the food and pharmaceutical industry have shown that buckwheat production should be organized on bigger areas, mainly for meeting one's own needs, but also for export *(Dražić et al, 2010; Sedej, 2011)*.

Table 3. Analysis of variance for morphological and productive properties of buckwheat

Parameter	Source of variation	df	MS	Test			
				F		LSD	
						0.05	0.01
Plant height	Locality, A	2	1553.700	190.638	**	2.66	3.63
	Year, B	1	10.800	1.325	ns	2.17	2.97
	AB interaction	2	18.900	2.319	ns	3.77	5.14
	Error	20	8.150				
Yield	Locality, A	2	1.822	1108.961	**	0.04	0.05
	Year, B	1	0.002	0.982	ns	0.03	0.04
	AB interaction	2	0.071	43.471	**	0.05	0.07
	Error	20	0.002				

^{NS} not significant; * significant at $p<0.05$; **significant at $p< 0.01$

Buckwheat nowadays tends to get new economic importance, and a new agro-technological and agro-commercial value *(Glamočlija et al., 2010)*. Not taking into account the value of buckwheat by-products, honey and positive impact this plant has on overall conditions of soil, with the average yield of 1.200 kg ha^{-1} one can achieve a positive financial result. The same author points out that, if buckwheat is used for bee foraging and green biomass, it can be planted approximately five times in succession to elongate the period of its use as long as possible.

There was no difference in the average yields in the related period. Analysing the yields from the different localities, the interaction between the localities and the year of the experiment was determined.

Conclusion

The agro-ecological conditions at all three localities affected the growth and productivity of buckwheat. The plants cultivated on the chernozem had higher values of the investigated properties than the ones cultivated on the eutric cambisol and the grey forest soil. The highest yields per unit area were obtained on the chernozem-type soil (1.65 t ha^{-1}), while the average yield on the less fertile soils in the hilly and mountainous region of Serbia was 1.31 t ha^{-1} on the grey forest soil and 0.80 t ha^{-1} on the eutric cambisol. The obtained results showed buckwheat had great cropping potential, since the experiments were conducted on the soil fund of natural fertility at all localities, so that buckwheat can be also grown successfully in changed agro-ecological and soil conditions.

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AGROEKOLOŠKI USLOVI GAJENJA I MORFOLOŠKO-PRODUKTIVNA SVOJSTVA HELJDE

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Ispitivan je uticaj različitih agroekoloških uslova na morfološko-produktivne osobine heljde sorte *Novosadska* u periodu od 2011-2012. na tri različita lokaliteta. Tipovi zemljišta na kome su postavljeni ogledi su: gajnjača - lokalitet Valjevo, černozem - lokalitet Nova Pazova i sivo šumsko zemljište na lokalitetu u Novoj Varoši. Agroekološki uslovi na sva tri posmatrana lokaliteta uticali su na rast i produktivnost heljde. Najveći prinosi zrna heljde po jedinici površine dobijeni su na zemljištu tipa černozem (1,65 t ha^{-1}), dok na zemljištima manje prirodne plodnosti brdsko-planinskog područja Srbije, prosečan prinos bio je 1,31 t ha^{-1} na sivom šumskom zemljištu, a na gajnjači 0,80 t ha^{-1}. Dobijeni rezultati su pokazali da se heljda može uspešno gajiti na našim zemljištima, budući da su ogledi na svim ispitivanim lokalitetima izvedeni bez prihrane tj. na prirodnoj plodnosti zemljišta.

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