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**THE INFLUENCE OF SOW DENSITY ON PRODUCTIVITY AND
MOISTURE IN BUCKWHEAT GRAIN (*Fagopyrum esculentum* Moench.)
IN CONDITION OF STUBBLE SOWING AND IRRIGATION**

SUMMARY

The important role of buckwheat in moder human diet and contemporary, sustainable agriculture derives from its chemical composition of grain and modest growing requirements. Consequently, there is an increasing trend of areas under buckwheat with a rate of 22.46% per year. Buckwheat arouses great interest as essential ingredient for functional foods because of its health benefits. Its grain is one of the best sources of high quality protein in the plant kingdom. Buckwheat is very sensitive to the lack of moisture, especially during the first development phases, in period of rooting, during flowering and yielding period. So, the aim of investigation was to estimate the optimal seed rate of buckwheat to achieve the productive, economic and other objectives, especially important for ecological agriculture, in conditions of stubble sowing and irrigation. The investigation included 12 genotypes and three sowing density (80, 120 and 160 grains m⁻²).

The highest average grain yield is obtained in density of 160 grains per m⁻², then in density of 120 grains per m⁻², but the lowest in 80 grains per m⁻² density. Difference in grain yield between 160 grains per m⁻² and 120 grains per m⁻² density variants is a slight, only 80 kg or 3.49% that means both sowing density variant could be applied successfully in buckwheat planting technology, but sowing density of 120 grains per m⁻² has priority because of production economics.

Key words: buckwheat, density, grain yield, irrigation.

INTRODUCTION

Buckwheat is plant species known for centuries and has cultivated, according to recent evidence, more than 7000 years (Ohnishi et al., 1998). It originates from the mountainous parts of central and northeast Asia, Junan and Sećuan provinces. Due to nomadic tribes, buckwheat has been spread to the

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Balkan Peninsula in the, most likely, 13th century. It is interesting that buckwheat is one of the few plant species transferred from Europe to America, during 16th century. For a long time, it has been neglected plant species, excluded from production, human and animal nutrition. Buckwheat exhibits, very often, characteristics of wild, uncultivated plant species, sensitive to mineral fertilizers (Kreft *et al.*, 2008). Such characteristics like modest demands, economy and good competitive ability recommends it for ecological farming system (Gadzo *et al.*, 2009; Dedic, 2012).

Nowadays, buckwheat is planted to an average of 2.113 million hectares worldwide. There is an increasing trend of areas under buckwheat with a rate of 22.46% per year. The highest production of buckwheat of 93.67 % in the world was in Europe and on Asian continent (1.133 ha, 846.799 ha), that is 53.61 % and 40.06 %, respectively. The most significant producers of buckwheat in the world are: China (34.25 %), Russia (32.43 %) and Ukraine (11.46 %) (Popovic *et al.*, 2014).

Buckwheat arouses great interest as essential ingredient for functional foods because of its health benefits (Li *et al.*, 2001; Zhang *et al.*, 2012). Its grain is one of the best sources of high quality protein in the plant kingdom. It contains about 52.11% starch, 11-12.55% of the total protein, 8.7% of the pulp, 2.23% oil, 11% water and 1.75% of N protein (Popovic *et al.*, 2013). The most important ingredients of this plant are flavonoids (Arsic *et al.*, 2008). Grain contains a large amount of indispensable amino acids (EAA), primarily lysine and methionine and dietary protein, vitamins B₁ and B₂, minerals like Fe, Zn and Se (Bavec and Bavec, 2006). The presence of antioxidants like rutin, tannin and fagopyrin has special importance (Kreft *et al.*, 2006). Complete grain is used as a nutritive supplement for different stews, while flour is used for preparation of porridge (polenta) or mixed with wheat or rye for preparation of bread with higher digestion value. Because of the beneficial chemical composition, and the absence of adhesive proteins, buckwheat is suitable for diabetics and children diets. Like a honey plant, buckwheat is very useful for bees throughout the entire summer and fall period in absence of other flowered plants. Buckwheat honey contains increased amounts of bioflavonoids that have antibacterial effects (Janovska *et al.*, 2008).

At the same time, buckwheat crops protect the soil from erosion, attract beneficial insects and raise the level of organic matter in the soil (Wallace, 2001). Barac *et al.* (2012) emphasized the importance of the threshing device on a harvester and quality of harvesting for the quality of the threshed grain. The properly done this phase is very important to keep and care quality of seed products.

The aim of investigation was to estimate the optimal seed rate of buckwheat to achieve the productive, economic and other objectives, especially important for ecological agriculture, in conditions of stubble sowing and irrigation.

MATERIAL AND METHODS

Climate and soil conditions during experiment conducting

Buckwheat is very sensitive to the lack of moisture, especially during the first development phases, in period of rooting, during flowering and yielding period. During the later phases, excess of moisture causes a lot of negative effects. It has very high transpiration coefficient, up to 700 (Janovska et al., 2008). Influences of temperatures are rather strong, too.

During 2010, 360.4mm precipitation were in May and July, while 125.6mm precipitation only or almost three times less were in the same period in 2011. It means that 2010. was more favorable in term of soil moisture, necessary for germination. During July and August, almost the same precipitation sums (120mm, averagely) were in the both of investigation years in generative phase (impregnation and grain filling phases) (Table 1).

Table 1. Distribution and total precipitation (mm) in growing season at Sombor locality

Year	Month				Total precipitation in growing season (mm)
	V	VI	VII	VIII	
2010	166	194.4	77	44.2	481.6
2011	67.8	57.8	66.6	50.4	242.6

This precipitation sum could be limiting factor to obtain more yield per unit area because it is critical period for buckwheat. Several irrigation doses, however, made good conditions for yielding.

Air temperatures in vegetative phase of development (intensive growth of trees and branching) were very favorable during the both of investigation years (Table 2).

Table 2. Air temperatures ($^{\circ}\text{C}$) during vegetative seasons at Sombor locality

Year	Month											
	V			VI			VII			VIII		
	min	X	max	min	X	Max	min	X	Max	min	X	max
2010	12.1	16.9	21.8	15.6	20.3	24.9	17.6	23.1	28.6	15.7	21.8	27.9
2011	10.2	16.6	23.0	15.1	21.0	26.9	15.8	21.9	28.0	15.6	22.7	29.7

Buckwheat does not tolerate high temperatures. Growth is already slowing down at 28°C , as the percentage of impregnation and grain formation (Glamoclija, 2011). The optimal temperature for grow and development is 20°C while temperatures above 30°C , during flowering phase, followed by low air moisture, cause drying and falling flowers and bad pollination (Pauseva, 1976).

There were not extreme temperatures which could limit normaly fertilization and yielding during this experiment.

The trial was set up on carbonate meadow black soil, with wheat as preceding crop, on field of APS "Sombor" in Sombor, Serbia as double cropping system, during 2010. and 2011., under irrigation. The investigation included 12 genotypes: P₂, P₄, P₅, P₆, P₉, P₁₀ and P₁₁, as domestic and foreign populations, Darja, Bamby, Oberon and Bylly, as foreign cultivars and Novosadska, as domestic cultivar. The experiment was designed as block system, in three replications, with area of elementary plot 20m². Distance between rows was 25 cm. Sowing was in accordance with planned sowing density (80, 120 and 160 grains m⁻²). The sowing was done on 15th July in 2010, but on 9th July in 2011. The plants were irrigated three times: in phase of intensive growth of trees and branching, 15 days after and in phase of intensive flowering and yielding, with 25l water per m⁻², each time. The harvest was done in moment when 2/3 of yield were riped respectively when grains of the latest genotype were dark brown. The harvest was one – phased, done on 20th August, in 2010. and on 12th August, in 2011. The grain yield was measured per each plot and appropriate sowing density. On the base of that, average yield was calculated and expressed as grain yield with 13% of moisture.

Statistical analysis

Data were analyzed statistically using two factorial model of analysis of variance according to Hadzivukovic (1973). The differences of means were tested using an LSD test at p=0.05 and p=0.01 probability levels.

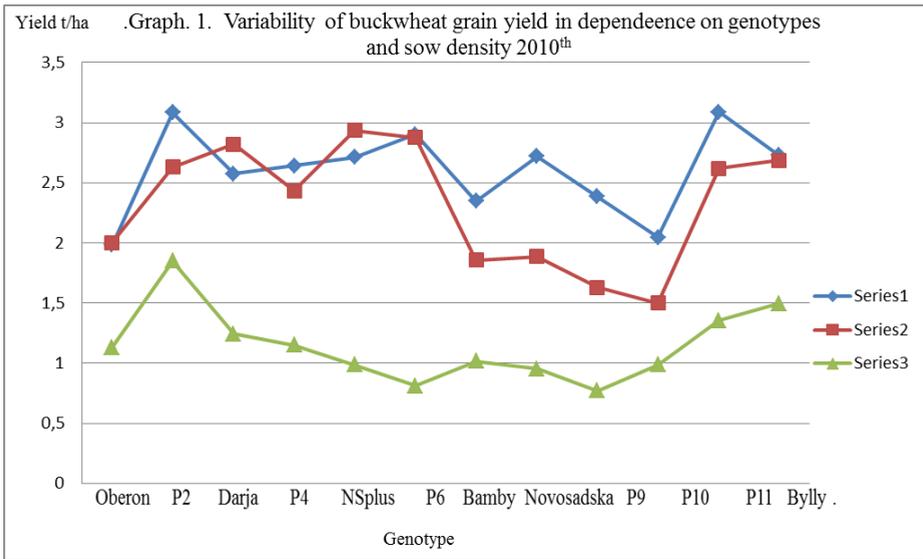
RESULTS AND DISCUSSION

Grain yield

Buckwheat is grown primarily due to grain. Grain yield is quantitative trait influenced by genotype, external factors and applied growing technology. After harvest, it is necessary to free the grain from the harvest residues and inert matter, as soon as it is possible.

Investigated genotypes obtained high and stabile grain yield in sowing density of 160 grains m⁻² in 2010. P₂ and P₁₁ gained yield above 3 t ha⁻¹. The most of genotypes (P₂, Darja, P₄, NS plus, P₆, P₁₁, Bylly) gained yield between 2.5 and 3 t ha⁻¹ in sowing density of 120 grains m⁻², while significant grain yield decline was noticed in all genotypes, in sowing density of 80 grains m⁻² (Graph.1).

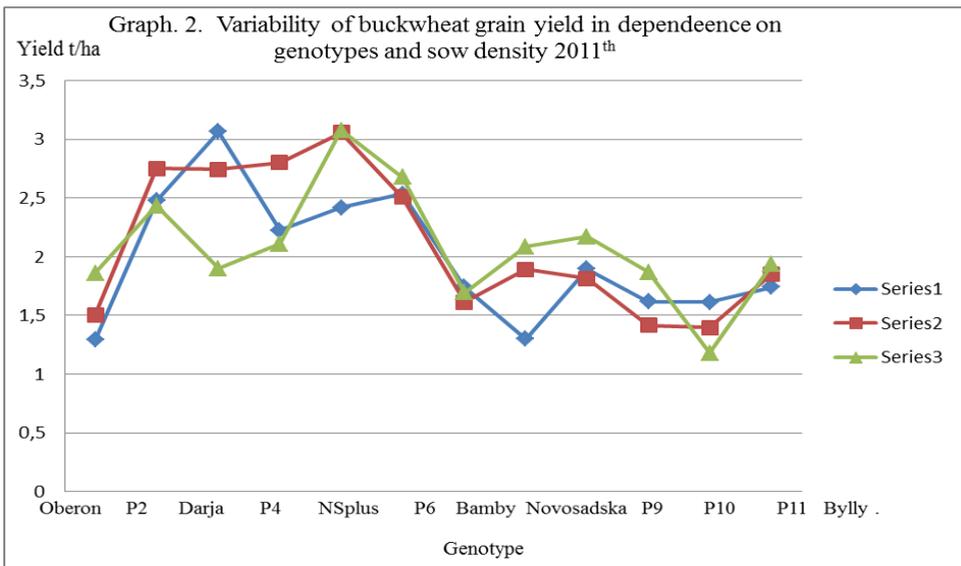
According to grain yield and its dependence on sowing density, during 2011, buckwheat genotypes were divided in two groups: with more variable and higher grain yield above 2 t ha⁻¹ (P₂, Darja, P₄, NS plus, P₆) and with less variable and medium grain yield - between 1 and 2 t ha⁻¹ (Oberon, Bamby, Novosadska, P₉, P₁₀, P₁₁, Bylly) (Graph.2).



LSD_{0.05} = 111; LSD_{0.01} = 148; CV = 5.86

Legend: series 1 - 160 grains m⁻²; series 2 - 120 grains m⁻²; series 3 - 80 grains m⁻²

Graph 1. Variability of buckwheat grain yield depending on genotype and sowing density in 2010.



LSD_{0.05} = 62; LSD_{0.01} = 82; CV = 3.18

Legend: series 1-160 grains m⁻²; series 2-120 grains m⁻²; series 3-80 grains m⁻²

Graph 2. Variability of buckwheat grain yield depending on genotype and sowing density in 2011.

These results are in accordance with previous results reported by Popovic *et al.* (2014) and Gadzo *et al.* (2007). However, cited authors planted buckwheat as main crop, without irrigation. In such conditions, influences of external factors are more expressed. Further analysis leads to observation that adequate yields can be achieved by reduction of seed quantity, with applying new growing technologies and more productive genotypes and populations. These two years results show that sowing density of 120 grains m^{-2} is economical and efficient in the given conditions.

Considering average grain yield, during each of investigated years, at all of three sow rates, it can be observed that almost a half of genotypes (Oberon, P2, Bamby, Novosadska, P10) obtained stable average yields and showed less sensitivity to environmental influence during investigation years. Population P2 stands out, with yields over 2.5 t ha⁻¹. The strongest environmental influence was registered on genotype NS plus and population P11 (Tab.3).

Table 3. Stability of grain yield of investigated buckwheat genotypes in 2010. and 2011.

Year	Genotype											
	Oberon	P2	Darja	P4	NS plus	P6	Bamby	Novo sadka	P9	P10	P11	Bylly
2010	1.56	2.56	2.57	2.38	2.85	2.57	1.68	1.76	1.96	1.64	1.40	1.84
2011	1.71	2.52	2.22	2.07	2.21	2.20	1.74	1.85	1.60	1.51	2.35	2.30

Popovic *et al.* (2014) noticed that favorable climatic conditions and adequate planting technology have important influence on yield while this investigation pointed out importance of genetic structure of genotype and population and interaction genotype x environment.

This investigation points to the possibility of buckwheat cropping in lowland areas, irrigation and double cropping system obtaining more yields than average ones in world.

Table 4. Average buckwheat grain yield in dependence on sowing density

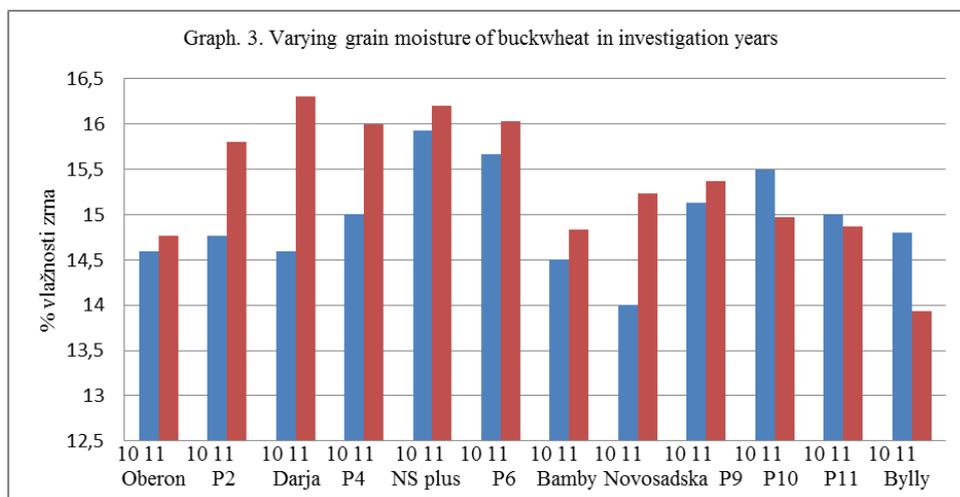
Year	Grain yield (kg)	Sowing density (grain number m^{-2})			Yield (kg)	LSD		CV
		160	120	80		0.05	0.01	
2010	Grain yield (kg)	2.601	2.323	1.145	2.023	111	148	5.86
2011		1.994	2.114	2.083	2.064	62	82	3.18
2010/2011		2.298	2.218	1.614	2.043	63	83	4.69

Different sowing density influences grain yield of some genotypes and average grain yield in different sowing density variants while average grain yield in investigation years do not vary significantly (Tab. 4). The highest average grain yield is obtained in density of 160 grains per m^{-2} , then in density of 120 grains per m^{-2} , but the lowest in 80 grains per m^{-2} density. The increases of grain yield in 160 grains per m^{-2} and 120 grains per m^{-2} density variants in relation to

variant of 80 grain per m^{-2} are 684kg (29.77%) and 604kg (27.24%), respectively. Difference in grain yield between 160 grains per m^{-2} and 120 grains per m^{-2} density variants is a slight, only 80 kg or 3.49%. It means that both sowing density variant could be applied successfully in buckwheat planting technology, but sowing density of 120 grains per m^{-2} has priority because of production economics. Less sowing density, 80 kg per ha^{-1} , is recommended for earlier sowing times, but later sowing, like double cropping system, requires a higher amount of seeds, above 100 kg per ha^{-1} (Rotim et al., 2012). Lower sowing density decreases production cost, but sowing density, however, have to provide such crop structure that will improve the effectiveness of weed control (Bavec et al., 2006). Omid Beygi et al. (2002) studied effects of different nitrogen amounts and sowing density on plants growing, grain yield and rutin content and concluded that density of 100 plants per m^{-2} and total amount of 100 kgN per ha^{-1} give the best results. Gavric et al. (2018) registered significant influence of sowing density and meteorological conditions on grain yield of buckwheat, too, but not to chemical compose of grain. Increasing sowing rate had positive effect on grain yield, but it had no effect on chemical compose of kernel. The same authors noticed that unfavorable weather conditions (drought and high temperature) resulted in low average yield, but in high grain quality i. e. high content of crude protein, starch and total phenol in grain.

Grain moisture

Harvesting buckwheat is the most important agrotechnical procedure in system of planting technology required flawless planning and proper doing. It can be as one phase, like in this trial and two phases process.



LSD_{0.05} = 1.29; LSD_{0.01} = 1.72; CV = 7.32

Legend: series 10-2010; series 11-2011.

Graph 3. Varying grain moisture of buckwheat in investigation years

One phase harvest is performed at the moment of high percent of moisture and inert matters in grains, catching up parts of biomass (leaves, branches and stems). Therefore, it is necessary to carry out the grain drying and separation, immediately after harvest. Two phases harvest means mowing and hay drying and, after that, threshing on different threshing machines. The importance of determination of grain moisture is reflected in decrease losses, drying and entire production costs as well as preserving the grain quality of buckwheat for a longer period.

Grain moisture varied from 14.0% to 15.93%, and from 13.93 to 16.3% in 2010. and 2011., respectively. Differences in grain moisture between investigation years are not significant for most of genotypes, except for Darja (1.7%) and NS buckwheat (1.23%) (Graph. 3.)

Results presented in Table 5. show that there are not differences in grain moisture in various sowing density variants in both of years.

Table 5. Average values of grain moisture of buckwheat depending on sowing density

Year	Grain moisture (%)	Sowing density (grain number m ⁻²)			Average (%)	LSD		C _v
		160	120	80		0.05	0.01	
2010		14.09	15.79	14.99	14.96	1.79	2.42	7.09
2011		16.28	15.50	14.29	15.36	1.95	2.64	7.52
2010/2011		15.19	15.65	14.64	15.16	1.29	1.72	7.32

CONCLUSIONS

Different sowing density influences grain yield of some genotypes and average grain yield in different sowing density variants while average grain yield in investigation years do not vary significantly. The highest average grain yield is obtained in density of 160 grains per m⁻², then in density of 120 grains per m⁻², but the lowest in 80 grains per m⁻² density. Difference in grain yield between 160 grains per m⁻² and 120 grains per m⁻² density variants is a slight, only 80 kg or 3.49% that means both sowing density variant could be applied successfully in buckwheat planting technology, but sowing density of 120 grains per m⁻² has priority because of production economics. Various sowing density did not influence grain moisture in both of years.

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