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INFLUENCE OF DIFFERENT NUTRITION SYSTEMS ON YIELD AND OTHER PARAMETERS OF PRODUCTIVITY OF POTATO

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Abstract: In this paper results of studies of the effects of different combinations of mineral fertilizers and rotted farmyard manure on yield and other parameters of the productivity of potato are presented. The experiments were conducted in 2008 and 2009 in mountainous regions of Montenegro (Kolašin), on the alluvial-diluvial soil, at an altitude of about 900 m.

The results obtained suggested that the application of manure had significant impact on increasing the productivity of the studied parameters of potato. The influence of mineral nutrition was also very distinct. The highest values of the studied parameters of potato productivity were obtained by applying fertilizers with humic acids (NPK 15:15:15 400 kg.ha^{-1} + MCB 300 kg.ha^{-1} and MCB 800 kg.ha^{-1} + KMg 100 kg.ha^{-1}), which were, compared to the other treatments, statistically justified. The highest number, average weight and tuber yield in two years studied was obtained in the variant treated individually with MCB 800 kg.ha^{-1} + KMg 100 kg.ha^{-1} or the same variant combined with the manure. In all variants application of combination of organic and mineral fertilizers resulted in higher number and average weight of tubers, as well as the higher yield per hectare compared to the non-fertilized variant.

Keywords: potato, fertilizers, rotted farmyard manure, productivity, yield

INTRODUCTION

In Montenegro, potatoes are grown on approximately 10,000 hectares and according to the planted area, potato is a leading agricultural crop. In the total structure of production on arable land potato is grown on more than 20%. Potato yields in Montenegro are still low (about 15 t.ha^{-1}) and unstable and very susceptible to weather conditions (Monstat, Statistical Yearbook for 2011). Low yields are caused by many factors, among which, as the most important can be distinguished: production technology at a low level, growing potatoes in long monoculture, the small size plots, limited use of mechanization, production without irrigation, adverse effects of agro-ecological factors (high summer temperatures and the deficit of precipitation), epiphytotic periodic attacks of late blight and other (JOVOVIĆ et al. 2011a; MILOŠEVIĆ et al. 2004).). In such circumstances, potato production is becoming a high-risk activity, which is often, especially in dry years, resulting in large losses in yield. To achieve high and stable potato yields, in addition to favourable agro-ecological conditions, it is necessary to carry out a range of agricultural practices, including the use of fertilizer which has a very important role in the production (STEVANOVIĆ et al. 2000).

Due to the long-time crops growing, natural soil fertility gradually declines. Loss of fertility may occur as a result of nutrient leaching into the deeper soil layers and their transition to the unavailable forms for plants. High yields of potatoes are associated with high demands in the nutrition elements. Maturity group and length of the growing period are the two most important factors in

determination of the potato nutrient requirements. Early-maturing varieties generally have a high and intense need for nutrition elements in the phase of intensive growth and tuberisation until late cultivar have longer utilization of nutrients. Therefore, if fertilization does not conform to the potato variety and length of growing season high yields cannot be achieved. Insufficient or excessive fertilization of potato crops has negative affect the yield and quality of tubers (MIKKELSEN, 2006).

To ensure high yield it is necessary to plant potatoes provide many nutrients (SEEFELDT, 2012). Thus, fertilization is one of the most important agro-cultural operations in contemporary agricultural production (MANDIĆ et al. 2011). Proper nutrition of potatoes has a significant impact on the yield, quality and storage properties of potato. In addition, fertilization affects increased resistance of crops to low temperatures, pests and diseases which leads to higher yields and better quality of potato tubers.

Regular application of manure as ameliorative measure has a positive impact on the physical and chemical properties. The use of manure increases the accumulation and mineralization of nitrogen, which improves soil quality and greater availability of nitrogen to the cultivated plants (GALVÃO et al. 1999). In addition to improvement of the content of macro-and micro-elements in the soil, it improves soil structure, humus content, water retention capacity, faster heating of the soil, etc. (SANTOS et al. 2006). In such conditions, the complementary application of fertilizers provides better bioavailability of nutrients and their better utilization by the potato plants which undoubtedly cause a higher quality and yield of potatoes. The highest yields are obtained with combined application of organic and mineral fertilizers (MĂRGHITAŞ et al. 2011).

Proper organo-mineral nutrition on a significant part of acidic soils in northern Montenegro can provide cost-effective and environmentally friendly production of potatoes and preserve or increase soil fertility (JOVOVIĆ et al. 2011b). This would reduce the loss of nutrients from the soil and avoid negative impacts on the environment (HONISCH et al. 2002; MUNOZ et al. 2005)

Bearing in mind that the potato yield is very complex category and the result of joint action of several factors aim of this study was to investigate the influence of different nutrition systems on potato yield and other parameters of productivity.

MATERIALS AND METHODS

This research was done in order to examine effect of application of different combination of mineral fertilizers and manure on yield and other parameters of potato productivity. Research was conducted during 2008 and 2009 in mountainous region of Montenegro (Kolašin), at an altitude of 900 m. Ploughing of natural grassland (preceding crop of potato in both experimental years) and manure application was conducted in autumn while mineral fertilizers were applied in the time of planting. Planting of potatoes (Kennebec variety) was done manually with 70 cm between row distance and 30 cm within row plant distance respectively, achieving the density of 47600 plants per hectare. Standard agricultural practice for the potato crop was applied. Trials were conducted in dryland conditions.

The experiment was set up as two-factorial in a randomized block design in four replications. Area of elementary plot was 21 m^2. Factor A (mineral fertilizer) involved six treatments: a_1) NPK 15:15:15 800 $kg.ha^{-1}$ + KAN 240 $kg.ha^{-1}$; a_2) NPK 15:15:15 400 $kg.ha^{-1}$ + MCB 300 $kg.ha^{-1}$ (Multi Comp Base 13:11:20 + 2MgO + microelements + humic acid) + KAN 125 $kg.ha^{-1}$; a_3) MCB 400 $kg.ha^{-1}$; a_4) MCB 400 $kg.ha^{-1}$ + KMg 100 $kg.ha^{-1}$ (Multi KMg 13:0:43 + 2MgO); a_5) MCB 600 $kg.ha^{-1}$ + KMg 100 $kg.ha^{-1}$

and a_6) MCB 800 kg.ha^{-1} + KMg 100 kg.ha^{-1}. Factor B (rotted farmyard manure) was examined in two types of application: b_1) 40 t.ha^{-1} and b_2) non-fertilized variant.

The alluvial-diluvial soil in the experimental field is poorly and under-supplied in plant nutrient elements (Table 1). Content of soluble P_2O_5 and K_2O is very low: 1.9, i.e., 5.5 mg per 100 grams of the soil and insufficient to achieve high yields, and it should be compensated with fertilization. Soil in the experimental field has acidic reaction (pH in water is 5.67, and in nKCl 4.79) and weakly carbonous ($CaCO_3$ 1.68%). The humus content is high (5.07%), which means that it is well provided with organic matter. Based on meteorological data presented in Table 2 it is evident that the potato plants in both years studied had favourable thermic conditions. Slightly higher amount and better distribution of rainfall in the 2009 had a positive influence on potato yields and other parameters of productivity.

Potato harvesting was done after full maturation of canopy. The potato yield in the experiment was determined by measuring the tubers at each elementary plot, and then the yield per hectare was calculated. Statistical analysis was done using factorial analysis of variance (ANOVA), and significant differences among the means were evaluated according to least significant difference (lsd) test (MALETIĆ, 2005). Relationships between yield and yield components on the other were determined by the correlation analysis method and the obtained coefficients were tested by the t-test for significance levels of 5% and 1%.

Table 1: Chemical properties of aluvial-deluvial soil in the experiment field

Depth (cm)	pH		$CaCO_3$	Humus	Soluble mg/100 g	
	H_2O	nKCl	%	%	P_2O_5	K_2O
40	5.67	4.79	1.68	5.07	1.9	5.5

Table 2: Meteorological conditions in the course of experiment

Year	Month					Average
	May	June	July	August	September	
	Air temperature (°C)					
2008	12.5	16.4	17.2	17.6	11.8	15.1
2009	13	15.1	18.1	17.6	13.8	15.5
	Amount of rainfall (mm)					Total
2008	37.4	103.5	113.5	20.2	114.4	389
2009	85.5	166.9	43.7	70.7	63.7	430.5

RESULTS AND DISCUSSION

Results of the two years studies show that all fertilization systems applied had a positive impact on the number and weight of tubers and potato yield per unit area (Table 3 and 4). Nevertheless, the best performances were achieved in treatments with the combined application of organic and complex mineral fertilizers (NPK water soluble fertilizer, and standard NPK).

Table 3: Results of the investigation in 2008

Factor B (rotted farmyard manure)	Factor A (mineral fertilizer)						Average
	Average tuber number						
	a_1	a_2	a_3	a_4	a_5	a_6	
b_1	6.0	6.3	5.7	6.0	6.3	6.5	6.13^{a}
b_2	5.8	5.9	5.8	5.7	5.9	5.7	5.80^{b}
Average	5.90^{ab}	6.10^{a}	5.75^{b}	5.85^{ab}	6.10^{a}	6.10^{a}	5.97
	Average tuber weight (g)						
b_1	88	92	84	86	89	92	88.50^{a}
b_2	76	78	74	83	76	88	79.17^{b}
Average	82.0^{bc}	85.0^{b}	79.0^{c}	84.5^{b}	82.5^{bc}	90.0^{a}	83.99
	Tuber yield ($t.ha^{-1}$)						
b_1	25.3	27.7	22.8	24.2	26.5	28.5	25.83^{a}
b_2	20.9	21.9	20.4	22.7	21.6	24.0	21.92^{b}
Average	23.10^{cd}	24.80^{ab}	21.60^{de}	23.45^{bcd}	24.05^{bcd}	26.25^{a}	23.88

	A		B		A*B	
	LSD 0.05	LSD 0.01	LSD 0.05	LSD 0.01	LSD 0.05	LSD 0.01
Average tuber number	0.223596	0.306646	0.129093	0.177042	0.316212	0.433662
Average tuber weight (g)	3.123149	4.283176	1.803151	2.472893	4.4168	6.057326
Tuber yield ($t.ha^{-1}$)	1.139484	1.56272	0.657881	0.902237	1.611473	2.210021

The results of measurements (Table 3) show that in 2008 the highest number of tubers was found in variants a_2, a_6 and a_5 – 6.1, and the lowest in a_3 – 5.75. The differences between these systems of fertilization were statistically significant. Variety a_6 had significantly bigger tubers as compared to other methods of fertilization (90 g), while in the variant a_3 the smallest tubers were measured (79 g). In the variant a_6 highest tuber yield was measured – 26.25 $t.ha^{-1}$. The difference in yields between this variant and all others, except the a_2 variant, were statistically significant. The lowest yields were measured in treatment MCB 400 $kg.ha^{-1}$ (21.6 $t.ha^{-1}$). In application of humic acid, in combination with KMg (a_5 and a_6) or NPK fertilizers (a_2) the highest values in all the parameters of potato productivity were obtained. Achieved differences compared with the other treatments were statistically significant. The results of these studies have shown that under conditions of low phosphorus and potassium content in the soil, potato plants responds well to the application of fertilizers which is consistent with the results reported by FILGUEIRA (2000).

Application of manure positively affected all the studied parameters of productivity. In all variants where rotted farmyard manure was applied, significantly higher tuber yields were achieved compared to those obtained in unfertilized plots. Statistical analysis of the impact of the studied system of fertilization and their interaction showed a significant variation in the number, weight and tuber yield per unit area. Combined application of organic and mineral fertilizers produced significantly higher average values of the parameters, especially higher yields per hectare. Variant a_6, with or without manure application had the highest statistical significance, especially in terms of weight of tubers per plant (92 and 88 g) and tuber yield per unit area (28.5 and 24 t. ha^{-1}). Studies of other authors (MĂRGHITAŞ et al. 2010; HEITKAMP et al. 2011) demonstrated the positive impact of organo-mineral nutrition on potato in mountain climate conditions. According to RAM

(2000) integrated use of organic fertilizers with optimum levels of NPK fertilizers will not only improve the nutritional status of the soil, but it will lead to stabilization of yields over a long period of time.

Table 4: Results of the investigation in 2009

Factor B (rotted farmyard manure)	Factor A (mineral fertilizer)						Average
	Average tuber number						
	a_1	a_2	a_3	a_4	a_5	a_6	
b_1	7.3	7.4	6.5	6.8	6.9	7.5	7.07 [a]
b_2	6.5	6.8	6.5	6.6	6.5	6.6	6.58 [b]
Average	6.90[ab]	7.10[a]	6.50[b]	6.70[ab]	6.70[ab]	7.05[a]	6.83
	Average tuber weight (g)						
b_1	96	95	81	86	91	105	92.33 [a]
b_2	85	83	72	81	77	92	81.67 [b]
Average	90.5[b]	89.0[bc]	76.5[d]	83.5[c]	84.0[bc]	98.5[a]	87.00
	Tuber yield ($t.ha^{-1}$)						
b_1	33.0	33.5	25.1	27.5	29.7	37.4	31.03 [a]
b_2	26.5	26.8	22.2	25.2	23.5	29.0	25.53 [b]
Average	29.75[b]	30.15[b]	23.65[d]	26.35[c]	26.60[c]	33.20[a]	28.28

	A		B		A*B	
	LSD 0.05	LSD 0.01	LSD 0.05	LSD 0.01	LSD 0.05	LSD 0.01
Average tuber number	0.387379	0.531262	0.223653	0.306725	0.547836	0.751319
Average tuber weight (g)	3.714373	5.093997	2.144494	2.94102	5.252916	7.203999
Tuber yield ($t.ha^{-1}$)	1.433478	1.965913	0.827619	1.135021	2.027245	2.780221

Table 5: Correlations between investigation parameters in 2008 and 2009

Parameter	2008		2009	
	Tuber number	Tuber weight	Tuber number	Tuber weight
Tuber yield	0.78**	0.91***	0.80**	0.92***
Tuber number	-	0.45*	-	0.50*
Tuber weight	-	-	-	-

*, **, *** significantly different at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$.

The significant interactions of the examined factors suggest that the factors mutually synergized their effects ($p<0.05$). Yield was positively statistically very significant correlated with tuber number (0.78**) and statistically highly significant with the tuber weight (0.91***), meaning that the effect of tuber weight on yield expression was 83% (coefficient of determination). (Table 5). Tuber weight was positively significantly correlated with tuber number (0.45*).

Favourable thermic conditions and more precipitation during the vegetation season in 2009 have led to slightly higher yields. It also caused slightly different results of statistical analysis compared to 2008 (Table 4). The effect of interaction of the studied methods of fertilization was statistically significant only in the total yield of tubers.

Applied mineral and organic fertilizers exhibited a significant effect on all the parameters of productivity. The highest number of tubers in this year was measured in variants a_2 and a_6 (7.10 i 7.05) and was significantly higher compared with the treatment a_3 – 6.5 tubers. All other differences in the number of tubers were without statistical significance. As in previous year biggest tubers were measured in treatment a_6 – 98.5 g and the smallest in plots where MCB was applied in the amount of 400 kg.ha^{-1} (76.5 g).

Application of manure caused that all investigated parameters have significantly higher levels compared to unfertilized plots. This increase is particularly pronounced in the total yield of tubers. Increasing yields on plots fertilized with rotted farmyard manure was stated by OLIVEIRA et al. (2010), as a result of its chemical composition and the impact on improving the physical and biological properties of the soil, and therefore a better mineral nutrition of plants.

The best results were obtained in treatments with the combined application of organic and complex mineral fertilizers. In these terms, particularly the variant a_6, applied alone or in combination with manure resulted in a significant increase in the yield of potatoes per hectare. Combined application of these variants and manure yielded 37.4 t.ha^{-1}, which was also the highest yield in two-year studies. Under the influence of these interactions differences in tuber yields were highly statistically significant compared with other ways of fertilization. The higher yields of potato and size of tubers in variants with the application of water soluble fertilizers was reported by HUTCHINSON et al. (2003) and PACK et al. (2006). JOVOVIĆ et al. (2011b) also reported significantly higher yields of potatoes in variants fertilized with water-soluble fertilizers as compared to treatments where manure and microbial fertilizer is applied, as well as compared to the unfertilized control. The significant increase in plant height of potato, tuber number and their weight and total tuber yield as a result of potato nutrition due to the usage of fertilizer containing humic acids, was indicated by TISDALE et al. (1997).

Lowest yield in trials was achieved in potato crop fertilized with MCB in the amount of 400 kg.ha^{-1} – 25.1 t.ha^{-1}. Individual application (without manure) gave yield of 22.2 t.ha^{-1}. This treatment in combination with or without manure had the weakest effect on other parameters as well (number and weight of tubers).

Correlation between examined parameters was more expressed in 2009. There was a highly significant positive correlation between yield and investigation parameters of productivity (Table 5), especially the tuber weight.

CONCLUSIONS

Based on the two-year study of the effects of different nutrition system on the productivity of potato crops can be concluded:

1. All studied fertilization systems showed a significant influence on the potato yields. Nevertheless, the best results were obtained in variants with the combined application of organic and water soluble fertilizers.
2. Application of manure caused significantly higher levels of all investigated parameters compared to unfertilized plots. This increase is particularly pronounced in the total yield.
3. The highest values of the studied parameters were obtained by applying fertilizers with humic acids (NPK 15:15:15 400 kg.ha^{-1} + MCB 300 kg.ha^{-1} and MCB 800 kg.ha^{-1} + KMg 100 kg.ha^{-1}) comparing to the other treatments and were statistically significant.

4. In the two-year period, the biggest number, average weight and tuber yield was achieved in variant a_6 (MCB 800 kg.ha^{-1} + KMg 100 kg.ha^{-1}), and lowest in variant a_3 (MCB 400 kg.ha^{-1}).
5. Correlation analysis indicates that the effect of applied fertilizers on potato yield was mainly expressed through increased weight of tubers that trough the increased number of tubers.

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