EFFECTS OF LIMING AND NUTRIENT MANAGEMENT ON YIELD AND OTHER PARAMETERS OF POTATO PRODUCTIVITY ON ACID SOILS IN MONTENEGRO

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Introduction

Potato is of great importance for the Montenegrin economy and, according to the planted areas, represent the leading agricultural crop. It accounts for about 25% of the production on arable land. The main regions intended for potato production for storage and consumption during the autumn and winter are located in the central and mountainous regions of the country. Potato yields in Montenegro are very low (about 15 tha^{-1}) and highly dependent on weather conditions. In addition to the direct effects of climate change (high temperatures, droughts and excessive rainfall during the growing season), there are number of other factors that are affecting such productivity state, of which, in importance, stand out: relatively small use of certified planting material, limited use of irrigation, potato cultivation in long-term monoculture, diseases and pests and poor agronomic practices, especially poor nutrient management. In order to improve the situation in this production, besides favourable agro-ecological conditions, more intensive application of agro-technical measures will be necessary, especially irrigation and fertilization.

Material and methods

The trial was set up as three-factorial in a randomized block design in four replications during 2015 and 2016, in the mountainous area of Montenegro (Municipality of Kolašin), at an altitude of 900 m, on acid-brown soil. The preceding crop in both years was a natural meadow. Plowing was done in the fall, along with the application of rotted farmyard manure and calcification. The manual planting of potatoes (Kennebec variety) was carried out at a distance of 70x30 cm, with density of 43300 plants per hectare. The size of the elementary plot was 21 m^2. During the growing season, standard agrotechnical measures for potatoes were applied.

Factor A (mineral fertilizer) consisted of six treatments: a_1) NPK 15:15:15 800 kgha^{-1} + KAN 240 kgha^{-1}; a_2) NPK 15:15:15 400 kgha^{-1} + MCB (water-soluble mineral fertilizer NPK 13:11:20 + 2MgO + microelements + humic acid) 300 kgha^{-1} + KAN 125 kgha^{-1}; a_3) MCB 400 kgha^{-1}; a_4) MCB 400 kgha^{-1} + KMg (water-soluble mineral fertilizer NPK 13:0:43 + 2MgO) 100 kgha^{-1}; a_5) MCB 600 kgha^{-1} + KMg 100 kgha^{-1} and a_6) MCB 800 kgha^{-1} + KMg 100 kgha^{-1}. Factor B (rotted farmyard manure) involved two types of application: b_1) non-fertilized variant and b_2) 40 tha^{-1}. Factor C (liming) was examined in two variants: c_1) without calcification and c_2) 1000 kgha^{-1}.

RESULTS AND DISCUSSION

Results shown in table 1 show that in 2015 the largest number of tubers was determined in the variants a_5, a_6 and a_2 – 6.18, 6.18 and 6.10, and lowest in treatment a_3 – 5.8. The number of tubers in variants a_5 and a_6 was statistically significantly higher compared to all mineral fertilizer treatments, except for the combination applied in variant a_2. In 2016, the highest number of tubers per potato plant was found in treatments a_6, a_2 and a_1 - 7.20, 7.12 and 7.0, respectively. The increase in the average number of tubers in the plots fertilized with these fertilizers compared to all other variants, except variant a_1 - 7.00 was statistically justified.

Table 2. Results of the investigation)

Year	Factor A (min. fertil.)	Factor C (liming) c_1 b_1 ABC	c_1 b_2 ABC	c_1 Average AC	c_2 b_1 ABC	c_2 b_2 ABC	c_2 Average AC	Average AB Factor B (manure) b_1	Average AB Factor B (manure) b_2	Aver. A
Average tuber number										
2015	a_1	5.8^{a}	6^{b}	5.9^{b}	5.9^{bc}	6.3^{a}	6.1^{a}	5.85^{b}	6.15^{bc}	6.0^{b}
	a_2	5.9^{a}	6.3^{a}	6.1^{a}	5.7^{c}	6.5^{a}	6.1^{a}	5.8^{b}	6.4^{ab}	6.1^{ab}
	a_3	5.8^{a}	5.7^{c}	5.75^{b}	5.8^{bc}	5.9^{b}	5.85^{b}	5.8^{b}	5.8^{d}	5.8^{bc}
	a_4	5.7^{a}	6.0^{b}	5.85^{b}	5.8^{bc}	6.0^{b}	5.9^{b}	5.75^{b}	6.0^{c}	5.88^{b}
	a_5	5.9^{a}	6.3^{a}	6.1^{a}	6.2^{a}	6.3^{a}	6.25^{a}	6.05^{a}	6.3^{b}	6.18^{a}
	a_6	5.7^{a}	6.5^{a}	6.1^{a}	6.0^{ab}	6.5^{a}	6.25^{a}	5.85^{b}	6.5^{a}	6.18^{a}
Average		**5.8^{c}**	**6.1^{b}**	**5.95^{b}**	**5.9^{c}**	**6.3^{a}**	**6.1^{a}**	**5.85^{b}**	**6.2^{a}**	**6.03**
2016	a_1	6.5^{a}	7.3^{ab}	6.90^{ab}	6.8^{a}	7.4^{ab}	7.10^{ab}	6.65^{a}	7.35^{a}	7.00^{ab}
	a_2	6.8^{a}	7.4^{a}	7.10^{a}	6.7^{a}	7.6^{a}	7.15^{a}	6.75^{a}	7.50^{a}	7.12^{a}
	a_3	6.5^{a}	6.5^{c}	6.50^{c}	6.8^{a}	6.5^{d}	6.65^{c}	6.65^{a}	6.50^{c}	6.58^{bc}
	a_4	6.6^{a}	6.8^{c}	6.70^{bc}	6.8^{a}	6.8^{cd}	6.80^{bc}	6.70^{a}	6.80^{bc}	6.75^{b}
	a_5	6.5^{a}	6.9^{bc}	6.70^{bc}	6.6^{a}	7.0^{bc}	6.80^{bc}	6.55^{a}	6.95^{b}	6.75^{b}
	a_6	6.6^{a}	7.5^{a}	7.05^{a}	6.9^{a}	7.8^{a}	7.35^{a}	6.75^{a}	7.65^{a}	7.20^{a}
Average		**6.60^{b}**	**7.10^{a}**	**6.85^{a}**	**6.77^{b}**	**7.18^{a}**	**6.98^{a}**	**6.68^{b}**	**7.14^{a}**	**6.92**
Average tuber weight (g)										
2015	a_1	76^{d}	88^{ab}	82.0^{c}	78^{cd}	93^{b}	85.5^{c}	79^{c}	85^{bc}	82^{d}
	a_2	78^{cd}	92^{a}	85.0^{b}	84^{b}	94^{b}	89.0^{b}	81.5^{bc}	88.5^{ab}	85^{b}
	a_3	74^{d}	84^{c}	79.0^{d}	76^{d}	86^{d}	81.0^{d}	76.5^{c}	81.5^{d}	79^{e}
	a_4	83^{b}	86^{bc}	84.5^{bc}	81^{bc}	88^{cd}	84.5^{c}	83.7^{b}	85.3^{bc}	84.5^{bc}
	a_5	76^{d}	89^{ab}	82.5^{c}	81^{bc}	92^{bc}	86.5^{bc}	79.3^{c}	85.8^{b}	82.5^{cd}
	a_6	88^{a}	92^{a}	90.0^{a}	92^{a}	102^{a}	97.0^{a}	89^{a}	91^{a}	90^{a}
Average		**79.2^{d}**	**88.5^{b}**	**83.8^{b}**	**82.0^{c}**	**92.5^{a}**	**87.2^{a}**	**81.5^{b}**	**86.2^{a}**	**83.8**
2016	a_1	85^{b}	96^{b}	90.5^{b}	87^{b}	99^{b}	93.0^{b}	86^{b}	97^{bc}	91.8^{b}
	a_2	83^{b}	95^{bc}	87.0^{c}	89^{b}	101^{ab}	95.0^{b}	86^{b}	98^{b}	91.0^{b}
	a_3	72^{d}	81^{e}	77.5^{e}	76^{cd}	88^{d}	82.0^{d}	74^{d}	84^{e}	79.7^{d}
	a_4	81^{bc}	86^{d}	83.5^{d}	79^{c}	94^{c}	86.5^{c}	80^{c}	90^{d}	85.0^{c}
	a_5	77^{c}	91^{c}	84.0^{cd}	74^{d}	98^{bc}	86.0^{c}	75^{d}	94^{c}	85.0^{c}
	a_6	92^{a}	105^{a}	98.5^{a}	102^{a}	105^{a}	103.5^{a}	97^{a}	105^{a}	101.0^{a}
Average		**81.7^{d}**	**92.3^{b}**	**87.0^{b}**	**84.5^{c}**	**97.5^{a}**	**91.0^{a}**	**83.1^{b}**	**94.9^{a}**	**88.9**
Tuber yield										
2015	a_1	20.9^{c}	25.3^{c}	23.1^{c}	21.9^{cd}	27.6^{c}	24.8^{c}	21.4^{c}	26.4^{c}	24.0^{c}
	a_2	21.9^{bc}	27.7^{ab}	24.8^{b}	22.9^{bc}	29.2^{b}	26.1^{b}	22.4^{bc}	28.5^{b}	25.5^{b}
	a_3	20.4^{c}	22.8^{d}	21.6^{d}	21.0^{cd}	24.2^{d}	22.6^{e}	20.7^{c}	23.5^{e}	22.0^{d}
	a_4	22.7^{ab}	24.2^{cd}	23.4^{c}	22.3^{bcd}	25.1^{d}	23.7^{d}	22.5^{b}	24.6^{d}	23.5^{c}
	a_5	21.6^{bc}	26.5^{bc}	24.1^{bc}	23.8^{b}	27.7^{bc}	25.8^{bc}	22.7^{b}	27.1^{c}	25.0^{b}
	a_6	24.0^{a}	28.5^{a}	26.3^{a}	26.0^{a}	31.5^{a}	28.8^{a}	25.0^{a}	30.0^{a}	27.6^{a}
Average		**21.9^{d}**	**25.8^{b}**	**23.8^{b}**	**23.0^{c}**	**27.6^{a}**	**25.3^{a}**	**22.5^{b}**	**26.7^{a}**	**24.6**
2016	a_1	26.5^{b}	33.0^{b}	29.8^{b}	27.9^{b}	34.7^{bc}	31.3^{b}	27.2^{b}	33.9^{b}	30.6^{b}
	a_2	26.8^{b}	33.5^{b}	30.2^{b}	28.6^{b}	36.6^{b}	32.6^{b}	27.7^{b}	35.0^{b}	31.4^{b}
	a_3	22.2^{c}	25.1^{e}	23.7^{d}	24.5^{cd}	27.1^{e}	25.8^{d}	23.4^{d}	26.1^{e}	24.8^{d}
	a_4	25.2^{bc}	27.5^{d}	26.4^{c}	25.5^{c}	30.3^{d}	27.9^{c}	25.3^{c}	28.9^{d}	27.2^{c}
	a_5	23.5^{c}	29.7^{c}	26.6^{c}	23.4^{d}	32.8^{c}	28.1^{c}	23.4^{d}	31.2^{c}	27.4^{c}
	a_6	29.0^{a}	37.4^{a}	33.2^{a}	33.5^{a}	39.1^{a}	36.3^{a}	31.2^{a}	38.2^{a}	34.8^{a}
Average		**25.5^{d}**	**31.0^{b}**	**28.3^{b}**	**27.2^{c}**	**33.4^{a}**	**30.3^{a}**	**26.3^{b}**	**32.2^{a}**	**29.3**

The largest tubers in 2015 were measured in the variant a_6-90 g, while the tubers with the lowest average weight had plants grown in the variant a_3-79 g. The increase in the average weight of tubers in the a_6 treatment in comparison with all other methods of fertilization was marked as statistically significant. In 2016, as in the previous year, the highest average weight of tubers was measured in the treatment a_6 - 101.0 g, while the smallest tubers had plants grown in the variant a_3 - 79.7 g. In both research years, the a_6 variant (27.6 tha^{-1} in 2015 and 34.8 tha^{-1} in 2016) yielded significantly higher tuber yields compared to all other mineral fertilizer variants. At the same time, the lowest yields were in potato plants grown on treatment a_3 (22.0 tha^{-1} in 2015 and 24.8 tha^{-1} in 2016).

Variant a_6 (beginning of the flowering phase)

Variant a_3 (beginning of the flowering phase)

Fertilization with rotted farmyard manure had a very positive effect on the potato crop. In both studied years, significantly higher values were achieved for all studied parameters of potato productivity in variants fertilized with organic fertilizer (average number of tubers 6.2 in 2015 and 7.14 in 2016, average tuber weight 86.2 in 2015 and 94.9 g in 2016 and tuber yield 26.7 in 2015 and 32.2 tha^{-1} in 2016) compared to plots without its application (average number of tubers 5.85 in 2015 and 6.68 in 2016, average tuber weight 81.5 in 2015 and 83.1 g in 2016 and tuber yield 22.5 in 2015 and 26.3 tha^{-1} in 2016).

The application of liming significantly increased the average tuber weight and yield in both studied years. The average weight of tubers in limed plots was 82 g in 2015 and 84.5 in 2016, and in non-limed variants 79.2 and 81.7, respectively. This caused the yield of tubers in lime plots (23.0 tha^{-1} in 2015 and 27.2 tha^{-1} in 2016) to be significantly higher compared to plots where this agricultural measure was not applied (21.9 tha^{-1} in 2015 and 25.5 tha^{-1} in 2016). Differences in the average number of tubers per plant between limed (5.9 in 2015 and 6.77 in 2016) and non-limed plots (5.8 in 2015 and 6.6 in 2016) were without statistical significance.

Conclusion: The results of these studies confirm that the liming in combination with organic and mineral fertilizers, through soil pH optimization and neutralization of soil acidity, as well as better availability of nutrients, has a positive impact on potato yield and other parameters of potato productivity. The combined application of mineral fertilizers, rotted farmyard manure and liming significantly affected the increase in average tuber number, average tuber weight and total tuber yield.