

The Efficiency of Using Alternative Fertilizers in Potato Plantations

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Abstract. Field trials with the two potato variety were carried out in sod stagnogley soil. Soil agrochemical parameters: pH_{KCl} 6.7 organic matter (OV) content in soil 2.3%, phosphorus (P_2O_5) content - 149 mg kg^{-1} and potassium (K_2O) content - 200 mg kg^{-1} in soil. Potato plantations were created using different variants of fertilizer mix with pig (from SIA "Latvi Dan Agro") and cattle (from SIA "Ziedi JP") manure digestate and wood ash (from SIA "Gren Jelgava") in different ratio (digestate :wood ash ratio used: 4:1and 3:1). The rates of innovative mixed fertilizer for pig and cattle manure digestates for potatoes were 15 and 30 t ha^{-1} . Both norms for digestate manure from pure pigs and cattle were used as control options. The potato production norm was 3.0 t ha^{-1} . The placement of the variants in the trial was randomized, in triplicate. In the study, the two types of fertilizer had different effects on potato tuber yield. Using mixtures of pig manure digestate and wood ash in different ratios, the average yield was 34.2 t ha^{-1} , but using mixtures of cattle manure digestate and wood ash, the average yield was 27.8 t ha^{-1} . In the studied variants, its content in potato dry matter varied in the range of 9.15-11.42%. The amount of dry matter affects the culinary properties of the tubers. The application of fertilizer mixtures increased the dry matter content by an average of 1.7–2.7%. Fertilizer variants with higher tuber yield or higher starch content provided the highest starch yield. In general, the use of mixtures of wood ash and biogas digestate to fertilize crops and improve soil fertility can be an efficient way to process both products and can be an environmentally friendly alternative to fertilizers. The objective of the research was to study the influence of digestate and wood ash mixtures fertilizer rates on potato productivity and quality.

Keywords: digestate, fertilizer mix, potatoes, wood ash.

I. INTRODUCTION

Potatoes are one of the most important agricultural crops and are rightly called the second bread. In the world,

in terms of cultivated areas, they occupy one of the first places along with rice, wheat and corn.

According to the literature, potato tubers contain on average 76-78% water and 13 to 36% dry matter, with 12-15% starch, 1-3% protein and about 1% minerals. Potato protein has a very high biological value because it contains an essential amino acid complex that is not synthesized in humans and animals and must be obtained from food or feed.

As a result of the operation of biogas and biomass cogeneration plants, production by-products are obtained - digestate and ash. It is a good source of plant nutrients because it contains many trace elements and macroelements important for plant growth, so digestate can be used as an effective fertilizer for crops [1], [2]. The physical and chemical properties of ash can vary significantly depending on the plant species, plant growth conditions, parts of the plant used for combustion, parameters of the combustion process and storage conditions [3]. Ash contains a variety of minerals that make it a valuable source of plant nutrients. They contain various macronutrients and microelements important for plant growth and development, with the exception of nitrogen, which is released into the atmosphere by flue gases during combustion [4], [5].

Studies have shown a positive effect of ash on soil properties, structure and water regime in the soil [3]. Ash fertilizer increased the amount of phosphorus, potassium, calcium and magnesium used in plants in the soil [5]. A decrease in nitrogen concentration in the upper soil layers and an increase in soil pH after ash application have been observed. They can be used to improve soil fertility, crop yields and crop quality. However, the use of both products separately can cause certain environmental problems. To prevent this, at least in part, the idea arose to mix digestate

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and ash in certain proportions and use them to fertilize different crops.

The aim of the study: to determine the effect of digestate and wood ash fertilizer norms on potato productivity and crop quality.

II. MATERIALS AND METHODS

Field trials with the potato variety 'Rigonda' were set up (2020 and 2021) in sod stagnogley soil. Soil agrochemical parameters: pH_{KCl} 5.9, organic matter content in soil - 2.3%, phosphorus (P_2O_5) content - 149 mg kg^{-1} and potassium (K_2O) content - 200 mg kg^{-1} in soil. Potato plantations were created using different variants of fertilizer mixtures with pig (from LLC "Latvi Dan Agro") and cattle (from JSC "Ziedi JP") manure digestate and wood ash (from LLC "Gren Jelgava") in different ratios (used digestate: wood ash ratio – 4: 1 and 3: 1). The rates of innovative mixed fertilizer for pig and cattle manure digestate for potatoes were 15 and 30 t ha^{-1} . The amount of nutrients delivered to potatoes with this fertilizer rate can be seen in Table 1.

Both rates of digestion of pure pig and cattle manure were used as control options.

TABLE 1 AMOUNT OF NUTRIENTS INCORPORATED INTO THE SOIL (2020-2021)

Type of fertilizer	Fertilizer rate, t ha^{-1}	Digestate and wood ash ratio in the mixture	Amount of elements incorporated into the soil, kg ha^{-1}		
			N	P_2O_5	K_2O
Pig manure digestate	15	1:0	98	93	35
		3:1	75	131	139
		4:1	80	128	125
	30	1:0	196	186	70
		3:1	150	262	278
		4:1	160	256	250
Cattle manure digestate	15	1:0	81	54	86
		3:1	61	101	177
		4:1	66	85	150
	30	1:0	162	108	172
		3:1	122	202	354
		4:1	132	170	300

Table 1 shows how the addition of ash to fertilizer changes the nutrient input: the amount of nitrogen supplied to potatoes decreases and the amount of potassium and phosphorus increases. It is also possible to

see a rather logical regularity that doubling the dose of fertilizer doubles the amount of nutrients supplied. The potato planting rate was 3.0 t ha^{-1} . Trials variants were conducted randomized in three replications. The harvest recording area in each replicate was 2 m^2 , for each variant of trials - 6 m^2 .

Potato variety 'Rigonda' is suitable for early harvest in Latvian conditions, ensuring a sufficient proportion of large tubers in the harvest, as well as good taste characteristics. In experiments performed in Latvia, in the organic farming system, where only manure was previously applied to the soil, the yields ranged from 23.3–30.0 t ha^{-1} .

For potatoes during the vegetation period, the dynamics of potato development and the number of stems were hoped for. At the end of the vegetation, for each experiment, the total yield was counted and distributed by tuber size in all replicates, and the yield quality was determined: dry matter content, starch content (naturally moist and dry matter), and crude protein, fat, ash, phosphorus and potassium. To determine the quality of the harvest, an average sample was prepared for each variant, consisting of two medium-sized potatoes selected in each replicate.

Qualitative indicators are defined in the Biotechnology Scientific Laboratory (BSL) of the Latvia University of Life Sciences and Technologies. The dry matter, fat and ash content were determined by gravimetric analysis, the crude protein content was determined by the Kjeldahl method, the phosphorus content of the samples was determined by quinoline phosphomolybdate analysis, the potassium content by flame emission spectrometry and the starch by natural polarimetry.

Data processing was performed using three-way analysis of variance (ANOVA) "Microsoft Excel" computer program.

III. RESULTS AND DISCUSSION

The development of a quality potato crop is a complex process of plant interaction with growing systems and environmental conditions that affect the rate, metabolism and growth of photosynthesis. In the study, the two types of fertilizer had different effects on potato tuber yield. Using a mixture of pig manure digestate and wood ash in different ratios, the average yield was 24.93 t ha^{-1} , but using a mixture of bovine manure digestate and wood ash, the average yield was 22.78 t ha^{-1} (Table 2). There was a significant positive effect on yield on the fertilizer norm ($F\text{-factor} > F\text{-criterion}$), but no significant effect on yield was observed for the type of fertilizer, ash and digestate ratio. Potatoes are one of the most important foods for needed by humans in potato tubers determines its value as a food product.

TABLE 2 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON YIELD OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F _A)	Fertilizer rate, t ha ⁻¹ (F _B)	Digestate and wood ash ratio in the mixture (F _C)	Average tuber yield, t ha ⁻¹		
			(F _C) LSD 0.05= 2.62	(F _B) LSD 0.05= 2.70	(F _A) LSD 0.05= 2.38
Pig manure digestate	15	1:0	25.43	24.66	24.93
		3:1	25.63		
		4:1	22.92		
	30	1:0	26.76	25.19	
		3:1	25.54		
		4:1	23.28		
Cattle manure digestate	15	1:0	25.20	22.71	22.78
		3:1	20.73		
		4:1	22.19		
	30	1:0	25.11	22.85	
		3:1	22.64		
		4:1	20.81		

Starch is the main ingredient in potatoes. The highest starch yield was provided by fertilizer variants with higher tuber yield or higher starch content. In our studies, the average starch content in the dry matter was 73.3% and 15.3% in the natural product, but the average starch yield was 3.55 t ha⁻¹ (Table 3).

TABLE 3 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON STARCH PRODUCTION OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F _A)	Fertilizer rate, t ha ⁻¹ (F _B)	Digestate and wood ash ratio in the mixture (F _C)	Average tuber yield, t ha ⁻¹		
			(F _C) LSD 0.05= 0.45	(F _B) LSD 0.05= =0.63	(F _A) LSD 0.05= 0.71
Pig manure digestate	15	1:0	4.21	4.16	3.90
		3:1	3.99		
		4:1	4.27		
	30	1:0	3.30	3.63	
		3:1	3.72		
		4:1	3.87		
Cattle manure digestate	15	1:0	4.15	3.68	3.50
		3:1	3.68		
		4:1	3.21		

Type of fertilizer (F _A)	Fertilizer rate, t ha ⁻¹ (F _B)	Digestate and wood ash ratio in the mixture (F _C)	Average tuber yield, t ha ⁻¹		
			(F _C) LSD 0.05= 0.45	(F _B) LSD 0.05= =0.63	(F _A) LSD 0.05= 0.71
30		1:0	3.57	3.32	
		3:1	3.21		
		4:1	3.17		

Tubers with a low (<20%) dry matter content dissolve faster during cooking, while tubers with a higher dry matter content are denser, less prone to mechanical damage and easier to use for recycling. The application of fertilizer mixtures increased the dry matter content by an average of 1.4–2.0%, reaching an average of 21% (Table 4, Table 5). The tendency to increase the dry matter content is observed at lower fertilizer rates. The crude protein content of tubers determines the nutritional value of potatoes. In the studied variants, its content in potato dry matter varied in the range of 8.28–10.94%.

TABLE 4 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON THE CHEMICAL COMPOSITION OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F _A)	Fertilizer rate, t ha ⁻¹ (F _B)	Digestate and wood ash ratio in the mixture (F _C)	Content in dry matter, %		
			crude protein	potassium (K)	phosphorus (P)
Pig manure digestate	15	1:0	8.65	2.17	0.34
		3:1	8.28	2.20	0.33
		4:1	10.83	2.44	0.36
	On average (F _B)		9.25	2.27	0.34
	30	1:0	10.94	2.29	0.36
		3:1	10.83	2.52	0.39
		4:1	10.24	2.34	0.38
	On average (F _B)		10.67	2.38	0.38
	On average (F _A)			9.96	2.23
Cattle manure digestate	15	1:0	8.47	2.14	0.33
		3:1	9.53	2.20	0.36
		4:1	10.38	2.07	0.32
	On average (F _B)		9.46	2.14	0.34

Type of fertilizer (F _A)	Fertilizer rate, t ha ⁻¹ (F _B)	Digestate and wood ash ratio in the mixture (F _C)	Content in dry matter, %		
			crude protein	potassium (K)	phosphorus (P)
	30	1:0	10.76	2.30	0.36
		3:1	9.12	2.30	0.36
		4:1	10.61	2.64	0.39
	On average (F _B)	10.16	2.41	0.37	
On average (F _A)		9.81	2.28	0.35	

TABLE 5 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON THE CHEMICAL COMPOSITION OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F _A)	Fertilizer rate, t ha ⁻¹ (F _B)	Digestate and wood ash ratio in the mixture (F _C)	Average content in natural product, %	
			starch	dry matter
Pig manure digestate	15	1:0	16.54	22.22
		3:1	16.73	22.11
		4:1	14.41	20.34
	On average (F _B)	15.89	20.56	
	30	1:0	14.90	20.25
		3:1	14.57	20.29
		4:1	15.17	21.06
	On average (F _B)	14.88	20.53	
	On average (F _A)		15.38	21.05
	Cattle manure digestate	15	1:0	16.45
3:1			15.49	20.91
4:1			16.08	21.83
On average (F _B)		16.01	21.52	
30		1:0	14.67	20.19
		3:1	15.40	20.39
		4:1	14.02	19.30
On average (F _B)		14.7	19.96	
On average (F _A)			15.35	20.74

Potassium plays an important role in human health because it is involved in regulating muscle activity and affecting the resistance of nerve cells to stress. Its content in the dry matter of potato tubers averaged 2.28% and the types and norms of mixed fertilizers had practically no effect on its changes (Table 4, Table 5).

Phosphorus is involved in maintaining the acid-base balance. Participates in fat metabolism and blood circulation, helps to restore muscles, liver, kidneys. It stabilizes the condition of teeth, hair and ails [6]. The content of phosphorus in the dry matter of potato tubers averaged 0.35% and the studied factors did not change its amount.

In general, the use of mixtures of wood ash and biogas digestate to fertilize potatoes and improve soil fertility can be an efficient way to process both products and can be an environmentally friendly alternative to fertilizers.

IV. CONCLUSIONS

Using mixtures of pig manure digestate and wood ash in different ratios, the average yield of tubers was 24.92 t ha⁻¹, but using mixtures of bovine manure digestate and wood ash, the average yield was 22.78 t ha⁻¹.

The highest starch yield of 4.27 t ha⁻¹ was provided by the pig manure digestate fertilizer variant, where the fertilizer rate was 15 t ha⁻¹ and the digestate to ash ratio was 4: 1. Using mixtures of pig manure digestate and wood ash in different ratios, the average starch yield was 3.90 t ha⁻¹, but using mixtures of bovine manure digestate and wood ash, the average starch yield was 3.50 t ha⁻¹.

Differences in the chemical composition of potato tubers have also been observed, but they do not have a single specific trend, each fertilizer variant has changed its chemical composition differently.

Higher crude protein content in potato tubers was observed in variants where pig manure digestate with the norm of 30 t ha⁻¹ was used for fertilization, which was 10.67%, while higher potassium and phosphorus content was applied with bovine manure digestate with the norm of 30 t ha⁻¹.

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