THE EFFECTS OF AN INNOVATIVE DIGESTATE AND WOOD ASH MIXTURE FERTILIZER ON POTATO YIELD QUALITY

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Abstract

Field trials with the potato variety 'Rigonda' were carried out in a sod stagnogley soil. Soil agrochemical parameters were: pH_{KCl} 5.9, organic matter content – 2.3%, phosphorus (P_2O_5) content – 149 mg kg^{-1}, and potassium (K_2O) content – 200 mg kg^{-1}. Potato plots were established using different treatments of a fertilizer mixture consisting of pig and cattle manure digestate and woodchip ash in different ratios (digestate to wood ash = 4:1 and 3:1). The doses of the innovative mixed fertilizer for potato were 15 and 30 t ha^{-1}. Both norms of the digestate from pure pig and cattle manure were used as control options. The experimental design was an RCB with three replications. Crude protein content in potato dry matter varied from 8.28% to 10.94%. The application of fertilizer mixtures increased the dry matter content by 1.4–2.0%, reaching an average of 21%. Fertilizer treatments which produced higher tuber yields or higher starch contents gave also higher starch yields. In our studies, the average starch content in potato tubers dry matter was 73.3% and 15.3% in a fresh potato tuber, but the average starch yield reached 3.55 t ha^{-1}. The objective of the research was to study the influence of the rates of the digestate and wood ash mixture fertilizer on the quality of potato yield.

Keywords: *digestate, wood ash, fertilizer, potato, yield quality.*

Introduction

Potato is one of the most important agricultural crops and is rightly called "the second bread". In the world, in terms of cultivated areas, the potato crop occupies one of the first places along with rice, wheat and corn (reference). According to the literature, potato tubers contain on average 76-78% water, 13–36% dry matter, 12-15% starch, 1-3% protein, and approximately 1% minerals (reference). Potato protein has a very high biological value, because it contains an essential amino acid complex which is not synthesized in humans and animals and should be obtained from food or feed. As a result of the operation of biogas and biomass cogeneration plants, the production by-products digestate and ash are obtained. They are a good source of plant nutrients as they contain many trace elements and macroelements important for plant growth; therefore, digestate and ash can be used as an effective fertilizer for crops (Koszel and Lorencowicz, 2015; Risberg, *et al*., 2017). The physical and chemical properties of ash can vary significantly depending on plant species, plant growth conditions, parts of the plant used for combustion, parameters of the combustion process, and storage conditions (Demeyer, Nkana, Verloo, 2001). Ash contains a variety of minerals that make it a valuable source of plant nutrients. Also, 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 (Patterson *et al*., 2004; Fuzesi *et al*., 2015).

Studies have shown the positive effect of ash on soil properties, soil structure, and water regime in the soil (Demeyer *et al*., 2001). Ash fertilizer has increased the amounts of phosphorus, potassium, calcium and magnesium used in plants in the soil (Fuzesi, *et al*.2015). A decrease in nitrogen concentration in the upper soil layers and an increase in soil pH after ash application have been observed. Ash can be used to improve soil fertility and crop yield and 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 and ash in certain proportions and use the obtained mixture for the fertilization of different crops. The aim of the study was to determine the effect of the digestate and wood ash fertilizer norms on potato productivity and quality.

Materials and Methods

Field trials with the potato variety 'Rigonda' were set up in a 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}. Potato experimental plots were established using different variants of fertilizer mixtures consisting of pig (from LLC "Latvi Dan Agro") and cattle (from JSC "Ziedi JP") manure digestate and wood ash (from LLC "Gren Jelgava") in different ratios (digestate to wood ash = 4:1 and 3:1). The doses of the innovative mixed fertilizer from the pure pig and cattle manure digestate were 15 and 30 t ha^{-1} for potato and were used as control options. The amounts of nutrients supplied to potatoes applying both fertilizer doses are presented in Table 1. It is seen how the addition of ash to fertilizer mix changes the nutrient input: the amount of nitrogen supplied to potatoes decreases and the amount of potassium and phosphorus increases.

Table 1. Amount of nutrients incorporated into the soil

Type of fertilizer	Fertilizer rate, t ha^{-1}	The ratio of digestate and wood ash in the mixture	Amount of nutrient 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

The field was cultivated just before planting. Potatoes were winterized before planting, planted at the beginning of May. Planting of potatoes and the application of fertilizer mixtures were carried out by hand, in previously prepared furrows. The potato planting rate was 45000 tubers per ha. The variants of plots in the trial were randomized, in triplicate. The plot size was 5.6 m^2. A week after planting, and also after germination, the potatoes were hoed, but later during the vegetation period they were raked and hoed several times. The potato variety 'Rigonda' is suitable for early harvest in Latvian conditions, ensuring a sufficient proportion of large tubers as well as good taste characteristics. The dynamics of potato development and the number of potato stems were assessed during the vegetation period. For each experimental plot in all replicates at the end of the cultivation period, the total yield was recorded and also tuber size, and the quality of the tubers was determined: dry matter content, starch content (in fresh weight and in dry matter), and the contents of crude protein, fat, ash, phosphorus and potassium. For chemical composition analysis of tuber yield, the average samples of 1.0-1.2 kg were removed from each treatment. Qualitative indicators were determined in the Biotechnology Scientific Laboratory (BSL) of the Latvia University of Life Sciences and Technologies. The contents of dry matter, fat and ash were determined by gravimetric analysis, crude protein content – by Kjeldahl method, phosphorus content of the samples – by quinoline phosphomolybdate analysis, potassium content – by flame emission spectrometry, and starch content – by natural polarimetry. Data processing was performed using a three-way analysis of variance (ANOVA) "Microsoft Excel" computer program.

Results and Discussion

The development of a quality potato crop is a complex process of plant interaction with plant growing systems and environmental conditions which affect the rate of photosynthesis, and plant metabolism and growth. In the study, the two types of fertilizer had different effects on potato tuber yield. Using the mixture of pig manure digestate and wood ash in different ratios, the average yield reached 24.93 t ha^{-1}, but the use of the mixture of cattle manure digestate and wood ash gave a 22.78 t ha^{-1} average yield (Table 2). The applied fertilizer norm (F-factor> F-criterion) demonstrated a significant positive effect on the yield, but the type of fertilizer and the ash and digestate ratio did not show any significant effect on potato yield.

Table 2. Influence of the digestate and wood ash mixtures on the yield of potato variety 'Rigonda'

Type of fertilizer (F_A)	Fertilizer rate, t ha^{-1} (F_B)	The ratio of digestate and wood ash in the mixture (F_C)	Average tuber yield, t ha^{-1}		
			(F_C) LSD $_{.05}$=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	15	1:0	25.20	**22.71**	
		3:1	20.73		

digestate		4:1	22.19		**22.78**
	30	1:0	25.11	**22.85**	
		3:1	22.64		
		4:1	20.81		

The highest starch yields were obtained in fertilizer variants with higher tuber yields or higher starch contents. The average starch content in potato dry matter was 73.3% and 15.3% in a natural product, but the average starch yield reached 3.55 t ha-1 (Table 3).

Table 3. Influence of the digestate and wood ash mixtures on starch production for potato variety 'Rigonda'

Type of fertilizer (F_A)	Fertilizer rate, t ha^{-1} (F_B)	The ratio of digestate and wood ash in the mixture (F_C)	Average starch 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		
	30	1:0	3.57	**3.32**	
		3:1	3.21		
		4:1	3.17		

Many years of research and practical experience have confirmed the fact that tubers with a low (<20%) dry matter content disintegrate faster during cooking, while tubers with a higher dry matter content have a denser texture, are less prone to mechanical damage, and are easier to use for processing. The application of fertilizer mixtures increased the dry matter content by 1.4–2.0%, reaching an average of 21% (Table 3). An increase in dry matter content was observed at lower fertilizer rates.

The nutritional value of potato depends on the content of crude protein in tubers. In the studied variants, its content in potato dry matter varied from 8.28% to 10.94%.

Table 4. Influence of the digestate and wood ash mixtures on the chemical composition of potato cultivar 'Rigonda' tubers

Type of fertilizer (F_A)	Fertilizer rate, t ha^{-1} (F_B)	The ratio of digestate and wood ash in the mixture (F_C)	Average content in a natural product, %		Content in dry matter, %		
			starch	dry matter	crude protein	potassium	phosphorus
Pig manure digestate	15	1:0	16.54	22.22	8.65	2.17	0.34
		3:1	16.73	22.11	8.28	2.20	0.33
		4:1	14.41	20.34	10.83	2.44	0.36
	On average (F_B)		**15.89**	**20.56**	**9.25**	**2.27**	**0.34**
	30	1:0	14.90	20.25	10.94	2.29	0.36
		3:1	14.57	20.29	10.83	2.52	0.39
		4:1	15.17	21.06	10.24	2.34	0.38
	On average (F_B)		**14.88**	**20.53**	**10.67**	**2.38**	**0.38**
On average (F_A)			**15.38**	**21.05**	**9. 96**	**2.23**	**0.36**
Cattle manure digestate	15	1:0	16.45	21.81	8.47	2.14	0.33
		3:1	15.49	20.91	9.53	2.20	0.36
		4:1	16.08	21.83	10.38	2.07	0.32
	On average (F_B)		**16.01**	**21.52**	**9.46**	**2.14**	**0.34**
	30	1:0	14.67	20.19	10.76	2.30	0.36
		3:1	15.40	20.39	9.12	2.30	0.36
		4:1	14.02	19.3	10.61	2.64	0.39
	On average (F_B)		**14.70**	**19.96**	**10.16**	**2.41**	**0.37**
On average (F_A)			**15.35**	**20.74**	**9.81**	**2.28**	**0.35**

Potassium plays a vital role in human health as 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 practically had no effect on it (Table 4).

Phosphorus is involved in maintaining the acid-base balance, fat metabolism and blood circulation, it helps to restore muscles, liver and kidneys, and stabilizes the condition of teeth, hair and nails (Mitch, and Ikizler, 2012). Our research showed that 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 the mixtures of wood ash and digestate for potato fertilization and soil fertility improvement can be an efficient way to process both products and an environmentally friendly alternative to mineral fertilizers.

Conclusions

The mixtures of wood ash and biogas digestate are an innovative means of improving soil fertility. It has a positive effect on the yield of potatoes and the quality of the tuber crop.

The use of wood ash and biogas digestate mixtures for crop fertilization can be an effective way of recycling both products, and it can also be an environmentally friendly alternative to mineral fertilizers in acidic soils.

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