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THE EFFICIENCY OF USING NON-TRADITIONAL FERTILIZERS FOR WINTER OILSEED RAPE CROPS

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ABSTRACT

Biogas plants and solid fuel boilers where wood ash and digestate are produced as by-products are widely used for energy and heat production. In agriculture, both wood ash and biomass digestate are used separately as liming and fertiliser materials, Field trials were conducted at the Study and Research Farm "Peterlauki" in sod calcareous soil. Winter oilseed rape sowings were established using different variants of fertilizer mix with cattle manure digestate (D) and wood ash (P) at different ratios: B1 – D; B2 – D + P 1:1; B3 – D + P 2:1; B4 – D + P 3:1; B5 – D + P 3:1 + N16P40K60 kg ha-^{1}; B6 – D + P 3: 1 + N 68.8 kg ha^{-1}; B7 – D + P 4: 1. The norms of the innovative mixed fertilizer from cattle manure digestate and wood ash were: A1 – 5 t ha^{-1}, A2 – 10 t ha^{-1}, and A3 – 20 t ha^{-1}. Unfertilized winter oilseed rape fields and cattle manure digestate (D) fertilizer rates were used as control options. Studies have shown that using wood ash and digestate mixtures, it is possible to obtain good winter rapeseed yields without the use of mineral fertilizers. The highest winter rapeseed yield in the particular experimental year was obtained from variants where fertilizer rates of 10 t ha^{-1} were used for fertilization.

Key words: *digestate, wood ash, mixtures, winter oilseed rape.*

INTRODUCTION

Winter oilseed rape (*Brassica napus* L.) is widely cultivated in Latvia, with increasing yields (from 2.5 t ha^{-1} in 2010 to 3.3 t ha^{-1} in 2020) and total size of the growing area (from 67.6 thous. ha in 2010 to 141.1 thous. ha in 2023). To grow winter oilseed rape, a particular attention should be paid to the agronomic and economically sound use of fertilizers, thus reducing the costs and potential risks of environmental pollution (Litke, Gaile, Ruža, 2019).

Currently in Latvia, biogas cogeneration plants and various solid fuel boilers are widely used for heat and energy production, with digestate and wood ash as by-products. So far, these materials have been used in agriculture only as liming materials and fertilizers (Patterson et al., 2004; Koszel et al., 2020); however, the mixtures of wood ash and digestate can provide a high quality fertilizer that can be used to fertilize a wide range of agricultural crops (such as winter oilseed rape),

providing increase in the productivity and quality of crops (Hejcman, Ondracek, Smrz, 2011; Koszel et al., 2020).

The aim of the research was to study the effects of the mixtures of digestate and wood ash on the yield and quality of winter oilseed rape.

MATERIAL AND METHODS

The field trials were established at the Study and Research Farm "Peterlauki" (56°53' N, 23°71' E) of the Latvia University of Life Sciences and Technologies in the autumn of 2020-2023. Soil characteristics: sod calcareous soil Luvisols (according to FAO classification); granulometric composition – heavy dusty sand clay. Soil agrochemical parameters: soil reaction pH_{KCl} 6.7; plant-available phosphorus (P_2O_5) content – 60 mg kg^{-1}; potassium (K_2O) content – 144 mg kg^{-1}; organic matter (OM) content – 2.6%.

Winter oilseed rape was sown using fertilizer mixtures from cattle manure digestate (D) (obtained from joint stock company "Ziedi JP") and wood ash (P) (obtained from company with limited liability "Gren Jelgava") at different ratios: B1 –D; B2 –D +P 1:1; B 3 –D +P 2:1; B 4 –D +P 3:1; B 5 –D +P 3:1 + N16P40K60 kg ha^{-1}; B 6 –D +P 3:1 + N 68.8 kg ha^{-1}; B 7 –D +P 4:1. Innovative results from the digestate and wood ash mixture application were observed at the rates of A1 – 5 t ha^{-1}, A2 – 10 t ha^{-1}, and A3 – 20 t ha^{-1}.

The chemical composition of the digestate and wood ash mixtures is presented in Table 1 by which it is possible to calculate the amount of nutrients applied with each fertilizer mixture and rate.

Table 1. Nutrient content of the digestate and wood ash mixtures

Nutrients	Content in dry matter, %				
	D	D+P 1:1	D+P 2:1	D+P 3:1	D+P 4:1
Nitrogen in a natural sample (N)	0.29	0.27	0.30	0.51	0.34
Ammonium nitrogen (N/NH4), g kg^{-1}	1.20	0.43	0.40	0.76	0.37
Phosphorus (P)	0.74	0.90	0.89	0.83	0.83
Potassium (K)	1.70	2.90	2.92	2.73	2.64
Calcium (Ca)	2.41	13.44	13.55	10.48	10.86
pH	9.27	12.19	11.84	11.22	10.91

D – cattle manure digestate; P – wood ash

Unfertilized rapeseed plots and different cattle manure digestate norms were used as control variants. The variants in two-factorial trials were randomly allocated in three repetitions. In total, 66 plots were established, where the area of each plot was 30 m^2.

Figure 1. Fild trials with winter oilseed rape crops

The pre-crop to winter oilseed rape was winter wheat (*Triticum aestivum* L.). To prepare the experimental plots, ploughing was carried out to a depth of 22 cm and the pre-prepared mixtures of wood ash, cattle manure digestate and B 5 –D + P 3:1 + N16P40K60 kg ha^{-1} were spread onto the plots, incorporating the mixture into the soil with the "ZIRKON 8" compactor. For sowing eding the winter oilseed rape, the variety 'Visby' was used at a seeding rate of 80 germinating seeds per m^2 at a depth of 1.5–2 cm. In the spring, when vegetation recovers, N 68.8 kg ha^{-1} ammonium nitrate was applied to the B6 variant plots. After threshing the winter rape, the yield of each plot was weighed and purified using a "PFEUFFER SLN3" sample cleaner. Afterwards, the moisture, and seed oil content (%) and volume mass (kg hL^{-1}) of samples were determined using a FOSS "Infratec NOVA" analyser. Basing on the results, the yield (t ha^{-1}) and the amount of oil (t ha^{-1}) obtained were calculated at standard moisture (8%) and 100% purity of samples. The mass of 1000 grain was determined using a standard method (LVS EN ISO 520). Data processing was performed using "Microsoft Excel" and "R-Studio" computer programs.

RESULTS AND DISCUSSION

The average winter oilseed rape yield of 1.97–2.48 t ha^{-1} in the experimental plots studied was low compared to varietal potential (Table 2). This was due to the dry and hot weather conditions during winter oil rapeseed emergence and the start of vegetation. According to the data in the literature, drought stress in oilseed rape reduces stem diameter and length, negatively affecting the seed yield (Sangtarash et al., 2009). In our study, the lowest winter rapeseed yield of 1.97 t ha^{-1} was directly obtained from control field plots (Table 2).

Table 2.The effect of different digestate and wood ash mixture rates on winter rape seed yield, t ha^{-1}

Fertilizer rate, t ha^{-1} (F_A)	Digestate and wood ash ratio in the mixture (F_B)							(FA) p=0.003 RS(LSD) $_{0.05}$ = 0.149
	D	D+P 1:1	D+P 2:1	D+P 3:1	D+P 3:1 + NPK	D+P 3:1 + N	D+P 4:1	
Control	1.97							**1.97**
5 t ha^{-1}	1.85	2.21	1.94	2.24	2.12	1.77	2.30	**2.05**
10 t ha^{-1}	2.76	2.47	2.45	2.24	2.53	2.06	2.66	**2.45**
20 t ha^{-1}	2.26	2.67	2.13	2.03	2.11	2.25	2.50	**2.28**
On average p=0.046 RS(LSD) $_{0.05}$ (B) = 0.230 RS(LSD) $_{0.05}$ (AB) = 0.393	**2.29**	**2.45**	**2.17**	**2.17**	**2.26**	**2.03**	**2.48**	×

D – *cattle manure digestate*; P – *wood ash*

Significantly higher ($p<0.05$) average seed yields of winter rape in the trial years were obtained when fertilizer norm rates of 10 un 20 t ha^{-1} were used. The lowest fertilizer norm rate of 5 t ha^{-1} in variants D, D + P 2:1, and D + P 3:1 + N gave lower yields than in the control variants; however, the differences were not significant ($p>0.05$). Significantly higher ($p<0.05$) average winter rapeseed yields were for variants D, D + P 1:1, D + P 3:1 + NPK, and D + P 4:1, of which the highest yields were obtained from the fertilizer variants D + P 1:1 and D + P 4:1 (Table 2). Studies have shown that the use of liquid digestate of at least 25.000 L ha^{-1} as a fertilizer can significantly ($p<0.05$) increase the yield of winter rapeseed, and by increasing the digestate rates, the yield also increases (Koszel et al., 2020).

In the present trial, compared to the control, the use of digestate alone increased the average winter rapeseed yields at a fertilizer rate of 10 t ha^{-1} in all mixed fertilizer treatments, which suggests that nutrient deficiency was not a yield-limiting factor.in the trial years. The observed conclusion is also supported by the fact that the average increase in seed yield applying the digestate-wood ash mixture supplemented with N fertilizer only slightly increased the yield, although there are findings in the literature that the increase in N fertilizer to 60 kg ha^{-1} has also resulted in a significant increase in winter rapeseed yield regardless of the trial year (Litke, Gaile, Ruža, 2019).

One of the main indicators of winter rapeseed quality is the oil content of rape seeds. The analysis of the results showed that a significantly higher ($p=0.07$) average oil content in winter rape seeds was obtained using the 5 t ha^{-1} digestate and wood ash mixture rate. Among the average values of all mixture fertilizer variants, a significantly higher ($p=0.001$) oil content was obtained in the variants D + P 1:1, D + P 2:1, D + P 3:1, and D + P 3:1 + NPK; whereas, a significantly lower ($p=0.001$) oil content was obtained in the variants where ammonium nitrate (Table 3) was additionally used for fertilization. Such trend has also been observed in other studies where the increase in N fertilizer rate significantly decreased the oil content of winter rape seeds (Farahbakhsh, Pakgohar, Karimi, 2006).

Table 3.The effect of different digestate and wood ash mixture rates on oil content of winter rape seeds, %

Fertilizer rate, t ha^{-1} (F_A)	Digestate and wood ash ratio in the mixture (F_B)							On average (F_A)
	D	D+P 1:1	D+P 2:1	D+P 3:1	D+P 3:1 + NPK	D+P 3:1 + N	D+P 4:1	p=0.007 LSD $_{0.05}$ = 0.295
Control	47.3							**47.3**
5 t ha^{-1}	47.70	48.03	48.06	48.06	48.03	46.27	47.27	**47.63**
10 t ha^{-1}	47.23	47.50	47.70	47.63	47.57	45.87	47.40	**47.27**
20 t ha^{-1}	47.43	47.73	47.76	47.93	47.87	46.37	48.06	**47.59**
On average LSD $_{0.05}$ (B) = 0.390 LSD $_{0.05}$ (AB) = 0.781	**47.45**	**47.75**	**47.84**	**47.87**	**47.82**	**46.17**	**47.58**	×

D – *cattle manure digestate;* P – *wood ash*

The research suggests that the usage of wood ash and digestate mixtures as a fertilizer had no significant effect (p=0.334) on the average oil content in winter rapeseed. But on the other hand, increasing the fertilizer rates to 10 and 20 t ha^{-1} resulted in higher (p=0.004) oil yields in winter rapeseed (Table 4).

Table 4. The influence of different digestate and wood ash mixture rates on winter rapeseed oil yield, t ha^{-1}

Fertilizer rate, t ha^{-1} (F_A)	Digestate and wood ash ratio in the mixture (F_B)							On average (F_A)
	D	D + P 1:1	D + P 2:1	D + P 3:1	D + P 3:1 + NPK	D + P 3:1 + N	D + P 4:1	p=0.004 LSD $_{0.05}$ = 0.128
Control	0.93							**0.93**
5 t ha^{-1}	0.88	1.06	0.93	1.07	1.02	0.80	1.11	**0.98**
10 t ha^{-1}	1.30	1.17	1.17	1.07	1.21	0.94	1.26	**1.16**
20 t ha^{-1}	1.07	1.28	1.02	0.97	1.01	1.04	1.18	**1.08**
On average p=0.334	**1.08**	**1.17**	**1.04**	**1.04**	**1.08**	**0.93**	**1.18**	×

D – *cattle manure digestate*; P – *wood ash*

Analysis of the changes in seed volume mass showed that increased wood ash and digestate fertilizer norms significantly reduced (p=0.001) winter rapeseed volume mass compared to the control. Comparing the mixture variants, a significantly higher (p=0.001) volume mass was observed when additional ammonium nitrate fertilizer was applied. In this particular variant, the bulk density reached 67.96 kg hL^{-1}, which is similar to the control variant (Table 5).

Table 5.The influence of digestate and wood ash mixture rates on the volume mass of winter rape seeds, kg hL^{-1}

Fertilizer rate, t ha^{-1} (F_A)	Digestate and wood ash ratio in the mixture (F_B)							On average (FA)
	D	D + P 1:1	D + P 2:1	D + P 3:1	D + P 3:1 + NPK	D + P 3:1 + N	D + P 4:1	p=0.001 LSD $_{0.05}$ =0.162
Control	**67.93**							
5 t ha^{-1}	67.10	67.33	67.27	67.20	67.20	68.03	67.33	**67.35**
10 t ha^{-1}	67.17	66.83	67.50	67.17	66.93	67.93	67.50	**67.29**
20 t ha^{-1}	67.13	67.13	66.97	67.23	67.20	67.93	67.23	**67.26**
On average p=0.001 LSD $_{0.05}$ (B)=0.210 LSD $_{0.05}$ (AB)=0.430	**67.13**	**67.10**	**67.25**	**67.20**	**67.11**	**67.96**	**67.35**	×

D – *cattle manure digestate*; P – *wood ash*

In the trial, the effect of wood ash and digestate mixtures on 1000 grain weight of winter rapeseed was evaluated. The average 1000 seed mass of the samples ranged between 4.37 and 4.79 grams. Slight differences between fertilizer treatments were observed, but they were not significant (p=0.671). Also, no significant differences (p=0.095) were found between winter rapeseed samples and the applied fertilizer mixture rates. The low 1000 grain weight values obtained in the trial could be explained by the dry conditions these seasons, which hindered plant development in the spring and caused heat stress in plants at the end of flowering, before full maturity of rapeseed.

CONCLUSIONS

Using wood ash and digestate mixtures as a fertilizer, good winter rapeseed yields can be obtained without using mineral fertilizers.

The highest winter rapeseed yields in the trial years were obtained in the variants treated with 10 t ha^{-1} fertilizer mixture rates.

The highest oil content of winter oilseed rape was obtained in the variants treated with 5 t ha^{-1} fertilizer mixture rates.

The volume mass of winter rapeseed in the variants studied was slightly higher than 67.0 kg hL^{-1}.

REFERENCES

Farahbakhsh H., Pakgohar N., Karimi A. (2006). Effects of nitrogen and sulphur fertilizer on yield, yield components and oil content of oilseed rape (*Brassica napus* L.). *Asian Journal of Plant Sciences,* Vol. 5, p. 112–115.

Hejcman M., Ondracek J., Smrz Z. (2011). Ancient waste pits with wood ash irreversibly increase crop production in Central Europe. *Plant and Soil,* Vol. 339(1), p. 341–350.

Koszel M., Parafiniuk S., Szparaga A., Bochniak A., Kocira S., Atanasov A., Kovalyshyn S. (2020). Impact of Digestate Application as a Fertilizer on the Yield and Quality of Winter Rape Seed. *Agronomy,* Vol. 10(6), p. 878–896.

Litke L., Gaile Z., Ruza A. (2019). Effects of nitrogen fertilizer and soil tillage on winter oilseed rape yield and quality. *Balanced agriculture*: Proceedings of the LLU LF, LAB and LLMZA scientific-practical conference (February 21, 2019), Jelgava: LLU, 44-49. (In latvian).

Patterson S. J., Acharya S. N., Bertschi A. B., Thomas J. (2004). Application of Wood Ash to Acidic Boralf Soils and its Effect on Oilseed Quality of Canola. *Agronomy Journal,* Vol. 96(5), p. 1344–1348.

Sangtarash M. H., Qadri M. M., Chinnapa C. C., Reid D. M. (2009). Differential sensitivity of canola (*Brassica napus*) seedlings to ultraviolet-B radiation, water stress and abscisic acid. *Environmental and Experimental Botany,* Vol. 66, p. 212 – 219.