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Non-traditional fertilizers to optimize winter rape nutrition

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Abstract. The relevance of the topic is due to the need to optimize the nutrition of winter rape (*Brassica napus* L.), including the use of non-traditional fertilizers, taking into account the limited amount of low-cost mineral fats. The purpose of the research was to study the influence of a mixture of production by-products (wood ash and digestate) on the yield and quality of winter rapeseed. Field experiments were conducted at the "Peterlauki" research farm (Latvia). In agriculture, both wood ash and biomass digestate are used separately as materials for liming and fertilizers, while a high-quality fertilizer can be obtained from their mixture. The authors evaluated mixtures of cattle manure digestate and wood ash in different ratios. Analyzes from the groups of systemic, statistical and comparative were used. The next research methods are applied: generally accepted in crop production, field and laboratory – to clarify the interaction of the object of research with agrotechnical and natural abiotic factors; calculated and weighted - to determine the productivity of crops; calculation and comparison; mathematical and statistical (dispersion) – in order to estimate the probability of research results. It was determined that, using mixtures of wood ash and digestate, it is possible to obtain appropriate crops of winter rapeseed without the use of mineral fertilizers. A higher yield of this crop – 2.45 t/ha was obtained in cases where fertilizer rates of 10 t/ha were used for fertilization. Winter rape seeds had a higher oil content in variants with the use of a fertilized mixture of 5 t/ha, but without ammonium nitrate. The bulk weight (nature) of winter rapeseed in the investigated variants slightly exceeded 670 g/l. The scientific novelty is that the influence of the mixture of digestate and wood ash on productivity, including the oiliness of winter rapeseed, was evaluated. The practical value lies in the improvement of the technology of cultivation of the researched culture by means of a correctly selected mixture to optimize nutrition and obtain high-quality oil

Keywords: *Brassica napus*; digestate; wood ash; yield; oil content; harvest quality

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INTRODUCTION

Winter rapeseed (*Brassica napus* L.) is widely cultivated in Latvia, while the yield is increasing (from 2.5 t/ha in 2010 to 3.3 t/ha in 2020) and the total cultivation area (from 67.6 thousand ha in 2010 to 127.7 thousand ha in 2020) (Areas, gross harvests..., 2020). According to the State Statistics Service of Ukraine, the area of winter rapeseed crops in Ukraine reached 1.4 million hectares in 2022, which is 40% more than in the previous year. The average annual yield of rapeseed in Ukraine is 2.67 t/ha (Areas, gross harvests..., 2022), which indicates the interest of farmers in the cultivation of winter rapeseed and the development of its cultivation technologies.

For the production of winter canola, special attention should be paid to agronomically and economically justified use of fertilizers, thus reducing costs and potential risks of environmental pollution (Litke *et al.*, 2019).

E. Shahini *et al.* (2022) studied that the use of "smart" fertilizers is an important approach to increasing the volume of food production, which is extremely necessary both to provide it to the population and to support proper economic development. Scientists say based on their research that such fertilizers can be a solution to the problems of both biodiversity and food security in difficult times. Different types and doses of fertilizers are used to optimize the feeding conditions of rapeseed.

According to the conclusion of O.O. Matsera (2020), the best conditions for the synthesis of organic matter, thanks to which plant productivity is formed, is the rate of fertilizers $N_{240}P_{120}K_{240}$.

According to V.V. Bazalii *et al.* (2015) in the years of research (2009-2010, 2010-2011, 2012-2013) determined changes in the yield of winter rape in a very wide range - from 0.39 to 2.82 t/ha. A higher seed yield (on average 2.18 t/ha) was formed in the model where the estimated dose of mineral fertilizers was applied together with the use of complex organo-mineral liquid biofertilizer Rostkoncentrat, which exceeded the benchmark by 100.5%, and other fertilized options by 15.3-59.1%.

Fertilizer application efficiency varies from year to year depending on the fertilization system (Garbar *et al.*, 2018; Hospodarenko *et al.*, 2022).

M. Kolomiets (2001) analyzed a number of literary sources and concluded that increasing the dose of nitrogen fertilizers contributes to the increase in yield. At the same time, the absolute value of the yield increase per unit of applied nitrogen decreases.

Currently, biogas cogeneration plants and various solid fuel boilers, whose byproducts are digestate and wood ash, are widely used in Latvia for heat and energy production. Until now, these materials have been used in agriculture separately as liming materials and fertilizers (Patterson *et al.*, 2004; Koszel *et al.*, 2020).

At the same time, mixtures of wood ash and digestate can provide a high-quality fertilizer that can be used to fertilize a wide range of agricultural crops (including winter rape), providing increased productivity and crop quality (Hejcman *et al.*, 2011; Koszel *et al.*, 2020).

Therefore, the *purpose* of the research was to study the influence of a mixture of digestate and wood ash on the yield and quality of winter rapeseed.

LITERATURE REVIEW

Rapeseed (*Brassica napus* L.) is an annual herbaceous plant belonging to the cabbage family (*Brassicaceae*). Currently, rapeseed is recognized as the second oil content in its composition after soy. It is considered a strategic crop for oil production. Oil products are primarily used in the food industry. Due to its properties, rapeseed oil competes with olive oil. Rapeseed oil is used as a raw material for the production of such products as biodiesel, lubricants, and plastic. It is in demand in the paint industry. Two types of resin are extracted from rapeseed, which is used for the production of ink. Beekeepers consider this culture to be one of the most common honey plants, because the period when rape blossoms lasts more than 30 days. One hectare of rapeseed can provide the opportunity to collect about 100 kg of honey (Malyna, 2020; Food and Agriculture Organization of the United Nations, 2019).

O. Malyarchuk (2012) conducted a study of the growth and development of winter rapeseed plants in the fields of short-rotational crop rotations. The soils under the experiment are dark chestnut. It has been established that in the southern region, the most favorable conditions for the formation of winter rape seeds can be considered systems of various depth of the main fallowing of the soil, or differentiated treatment with the use of deep loosening for rape seeding. Fine processing can be carried out if 40 cm deep slits are made under the previous crop. According to the scientist, the dose of nitrogen fertilizers is necessary in the range of N_{100}-N_{130} for the formation of a high yield.

J. Beres *et al.* (2019) confirmed a statistically significant effect of fertilization in the autumn period on the increase in aboveground biomass and root growth. The influence of nitrogen application on the formation of the seed crop was also statistically confirmed. When applying 40 kg/ha of nitrogen, the yield was the highest, on average 10.6% higher than the control (5.7-6.5 t/ha), on the other hand, the dose of N_{80} kg/ha increased seed yield by only 7.4% on average (5.4-6.3 t/ha), that is, it was less effective. It is emphasized that the above dose of N_{40} complies with the rules of the Nitrates Directive, supports the strengthening of oilseed rape before winter and intensifies its growth and development to increase seed yield.

K. Jankowski & M. Sokolski (2018) on the basis of research conducted at the agricultural experimental station in Balcyny (north-eastern Poland), assure that it is advisable to apply mineral fertilizers as a starter or strip, which is effective. Thanks to these methods, the doses of fertilizers are reduced (the costs of their application) and the environmental risk is minimized (the stratification of nutrients is reduced, their emissions into surface water, ground water and the environment are reduced). Local application of fertilizers leads to increased

drought resistance of plants. At the same time, foci with an increased content of nutrients are formed in the soil, where active root branching occurs.

Foliar feeding of winter rapeseed at the stage of formation of 4-6 leaves (VVSN 14-16) is effective, which helps increase winter hardiness by 8-11%. Autumn fertilizing with non-root macro- and micronutrient fertilizers leads to an increase in seed yield, significantly increases the content of crude fat (by 1.3-7.4 g/kg of dry matter), increases the content of oleic acid, reduces the concentration of linoleic acid, and the content of glucosinolates (Jankowski *et al.*, 2019).

E. Gutiérrez-Moya *et al.* (2021) found that the actual level of fertilizer application in different countries of the world is quite different. Most of them are made in the Netherlands. In this country, a total of 258 kg of fertilizers are used for 1 hectare of arable land for agricultural production. Somewhat less of them are applied in Great Britain – 247 kg, Germany – 202 kg, France – 169 kg, USA – 137 kg, Turkey – 107 kg.

According to M. Makadi *et al.* (2012), a fertilizer in which plant nutrients are present in a more easily assimilated form plays an important role in the production of competitive crops. The digestate contains a relatively large amount of nutrients that are easily absorbed by plants, and has a high level of nitrogen and phosphorus mineralization. During the fermentation process, various changes occur (ammonium content, pH, carbon and nitrogen ratio, etc.), which affect the amount of trace and macroelements available to plants.

Literary sources testify to the fluctuation of opinions regarding the norms and doses of fertilizers for winter rapeseed, their application methods, insufficient amount of cheap drugs to optimize the nutrition of the studied crop, which can be considered an unused reserve for increasing the productivity of plants of this species.

MATERIALS AND METHODS

Field experiments were conducted at the educational and research farm "Peterlauki" (56°53'N, 23°71'S) of the Latvian University of Natural Sciences and Technologies: the soil is turf-carbonate, heavy loam; soil reaction pH 6.7%; the content of plant-available phosphorus (P_2O_5) – 60 mg/kg; potassium content (K_2O) - 144 mg/kg; the content of organic matter is 2.6%.

Sowing of winter rape was carried out using fat mixtures of cattle digestate (D) (obtained from Ziedi JP JSC) and wood ash (P) (obtained from Gren Jelgava LLC) in different ratios:

B1 – D;
B2 – D+P1:1;
B3 – D+P2:1;
B4 – D+P3:1;
B5 – D+P3:1+$N_{16}P_{40}K_{60}$;
B6 – D+P3:1+$N_{68,8}$;
B7 – D+P4:1.

Innovative results from the introduction of a mixture of digestate and wood ash were noted according to the norms A1 – 5 t/ha, A2 – 10 t/ha and A3 – 20 t/ha.

The chemical composition of the digestate and wood ash mixture is shown in Table 1, according to which the amount of nutrients applied with each fertilizer mixture and the rate can be calculated.

Table 1. *Nutrient content in digestate and wood ash mixtures*

Nutrients	Content in dry matter, %				
	D	D+P1:1	D+P2:1	D+P3:1	D+P4:1
Nitrogen in a natural sample (N)	0.29	0.27	0.30	0.51	0.34
Ammonium nitrogen (N/NH4), g/kg	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

Note: *D – digestate from cattle manure; P – wood ash*
Source: *author's development*

As a control, unfertilized plots of winter rape and different application rates of digestate from cattle manure (D) were used. Variants in two-factor studies were randomized in three replications. In total, 66 sites were laid in the experiment, the area of each site was 30 m^2.

Winter wheat (*Triticum aestivum* L.) was the predecessor of winter rape. To prepare the experimental plots, plowing was carried out to a depth of 22 cm, and before sowing, pre-prepared mixtures of digestate and wood ash and mineral fertilizers were applied in option 5 – D+P3:1+$N_{16}P_{40}K_{60}$ kg/ha.

Fertilizers were spread on the prepared plots of winter rapeseed, which were wrapped in the soil with the unit of pre-sowing soil treatment - the universal rotary harrow Zirkon 8. It is characterized by positive qualities. So, with the help of the optional DUAL-Shift gearbox, it is possible to change the rotation of the rotors from 300 to 400. If necessary, the direction of their rotation is also changed – from aggressive to gentle, moreover, without tools.

For sowing, the Visby winter rapeseed variety was used with a sowing rate of 80 similar seeds per m^2. Winter

rapeseed was sown to a depth of 1.5-2 cm. In the spring, when plant vegetation was recovering, N 68.8 kg/ha of ammonium nitrate was applied to the plots of the experimental variant A6. Harvesting from each plot was carried out separately with a small-sized "Sampo" harvester.

After the test plots were harvested, the harvest from each plot was weighed and cleaned using a PFEUFFER SLN3 automatic sample cleaner. This sample cleaning complex is capable of weighing the initial seed sample (approx. 1.5 liters) in one cycle, running the SLN3 sample cleaner, removing the coarse fiber, opening and closing the bottom to remove the coarse fiber, performing a time-controlled cleaning and automatically weighing two fractions - fine grain and quality grain, i.e. cleaned sample. Available modern software allows you to view the obtained masses and their corresponding percentage ratios on the display. Then, average samples were taken from each version of the two-fold repetition for chemical analysis. Analyzes were carried out in the accredited scientific laboratory of biotechnology of the Latvian University of Natural Sciences and Technologies (LBTU BZL). Using standard methods, dry matter content (%), total protein (%), seed oil content (%), seed volume weight (g/l) and weight of 1000 seeds were determined.

According to the obtained results, the yield (t/ha) and the amount of oil (t/ha) were calculated at standard humidity (8%) and full (100%) purity of the samples. Data processing was carried out with the help of two-factor variance analysis of computer programs Microsoft Excel and R-Studio.

RESULTS AND DISCUSSION

Tips for applying fertilizers for rape are quite diverse. Thus, in the experiments of V. Parkhuts (2015), conducted in the conditions of typical chernozem of the Khmelnytsky region, it was established that the highest yield of rapeseed (3.94 t/ha), on average over three years of research, was formed under the model of the main application of mineral fertilizers with the rate of $N_{60}P_{80}K_{130}$ with the following by feeding plants N_{60}. The yield increase under the specified model was 2.10 t/ha (or 114.1%).

In Latvia, four-year research by O. Balodis & Z. Gaile (2011) proved the significant dependence of plant growth and development, in particular the germination of winter rape seeds, on precipitation and air temperature.

The average yield of winter rape in the experimental plots was relatively low (1.97-2.48 t/ha) compared to the potential of the variety. This was caused by dry and hot weather conditions during the emergence of seedlings and the beginning of vegetation. It is described in the literature that abiotic stress - drought reduces the diameter and length of the rape stem and negatively affects the seed yield (Sangtarash *et al.*, 2009).

In the study, the lowest winter rape yield of 1.97 t/ha was obtained directly from control field plots (Table 2).

Table 2. *The influence of different rates of fertilizers from mixtures of digestate and wood ash on the yield of winter rapeseed, t/ha*

Fertilizer rate (F_A)	The ratio of digestate and wood ash in the mixture (F_B)							(FA)p=0.003 $LSD_{0.05}$=0.149
	D	D+P1:1	D+P2:1	D+P3:1	D+P3:1+NPK	D+P3:1+N	D+P4:1	
Control				1.97				1.97
5 t/ha	1.85	2.21	1.94	2.24	2.12	1.77	2.30	2.05
10 t/ha	2.76	2.47	2.45	2.24	2.53	2.06	2.66	2.45
20 t/ha	2.26	2.67	2.13	2.03	2.11	2.25	2.50	2.28
On average p=0.046 $LSD_{0.05}$(B)=0.230 $LSD_{0.05}$(AB)=0.393	2.29	2.45	2.17	2.17	2.26	2.03	2.48	×

Note: *D – digestate from cattle manure; P – wood ash*

Source: *author's development*

Significantly higher ($p<0.05$) average yields of winter rapeseed were obtained when applying fertilizer rates of 10 and 20 t/ha. At the lowest fertilizer rate of 5 t/ha, a lower yield was formed in variants D, D+P2:1 and D+P3:1+N than in the control variants; however, the differences were significant ($p>0.05$). The variants D, D+P1:1, D+P3:1+NPK, D+P4:1 had significantly higher ($p<0.05$) average yields of winter rape, of which the highest yields were obtained from fertilizer in variants D+P1:1 and D+P4:1.

Research by M. Koszel *et al.* (2020) also showed that the use of liquid digestate, at least 25,000 l/ha as fertilizer, can significantly ($p<0.05$) to increase the yield of rapeseed, and due to the increase in digestate rates, the yield increases.

The use of organic fertilizers such as digestate can lead to the formation of small anaerobic zones in the soil. Thus, the use of digestate can increase N_2O emissions compared to the use of mineral fertilizers (Jones *et al.*, 2007).

The cultivation of rapeseed during the winter is closely related to the problems of N_2O emissions arising from the use of nitrogen fertilizers in the cultivation of rapeseed. Nitrification is one of the main sources of N_2O formation in soil (Hoefnagels *et al.*, 2010).

D. Fangueiro *et al.* (2009) found that the application of organic fertilizers with nitrification inhibitors increases nitrogen use efficiency and increases yield.

In the study, compared to the control, the use of digestate alone increased the average yield of winter

canola at a fertilizer rate of 10 t/ha in all mixed fertilizer treatments, indicating that nutrient deficiency was not a yield-limiting factor in the test years. The observed conclusion is also supported by the fact that the average increase in seed yield when using a mixture of digestate and wood ash with the addition of nitrogen fertilizers only slightly increased the yield.

It should be noted that there are conclusions in the literature according to which an increase in nitrogen fertilizers up to 60 kg/ha also led to a significant increase in the yield of winter barley, regardless of the trial year (Litke, 2019).

One of the main indicators of the quality of winter rapeseed is the oil content of its seeds.

The analysis of the results showed that significantly higher (p=0.07) average oil content in winter rapeseed was obtained at the rate of 5 t/ha of digestate and ash mixture. Between the average values of all variants of fertilizer mixtures, the oil content is significantly higher (p=0.001) in the variants D+P1:1, D+P2:1, D+P3:1, D+P.3:1+NPK; while a significantly lower (p=0.001) oil content was obtained in variants where ammonium nitrate was additionally used for feeding (Table 3).

Table 3. *The influence of different rates of fertilizers from mixtures of digestate and wood ash on the oil content of winter rapeseed, %*

Fertilizer application rate, t/ha (factor A)	The ratio of digestate and wood ash in the mixture (factor B)							On average (factor A) p=0.007 $LSD_{0.05}$= 0.295
	D	D+P1:1	D+P2:1	D+P3:1	D+P3:1+NPK	D+P3:1+N	D+P4:1	
Control				47.3				47.3
5 t/ha	47.70	48.03	48.06	48.06	48.03	46.27	47.27	47.63
10 t/ha	47.23	47.50	47.70	47.63	47.57	45.87	47.40	47.27
20 t/ha	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	×

Note: *D – digestate from cattle manure; P – wood ash*
Source: *author's development*

This trend was also observed in other studies, where increasing the rate of nitrogen fertilizers significantly reduced the oil content of winter rapeseed (Farahbakhsh *et al.*, 2006). In a trial (Kesenheimer *et al.*, 2021) conducted in Germany, N_2O emissions were investigated when digestate fertilizers with and without nitrification inhibitors were used in rapeseed cultivation. The studies did not reveal a positive effect of nitrification inhibitors on the yield of winter rape, as well as the yield of oil from 1 ha. The yield of rapeseed varied from 2.8 to 5.7 t/ha, and the yield of oil varied from 1.2 to 2.7 t/ha, depending on the location of the experiment and the year. These results were probably influenced by the high rate of fertilizer application (180 kg NH4±N ha-1 per year) when using liquid digestate.

At the same time, in the experiments of J. Beres *et al.* (2019), it was established that the effect of fertilizer on oiliness and weight of 1000 seeds was statistically insignificant. And according to V.V. Bazalii *et al.* (2015), the application of mineral fertilizers in the calculated dose and feeding with Rostkoncentrate led to the formation of the largest mass of 1000 winter rape seeds, an increase in the content of fat, protein, fiber and raw ash.

Studies show that the use of a mixture of wood ash and digestate as fertilizer did not have a significant effect (p=0.334) on the average oil content of rapeseed. But, on the other hand, increasing the rate of fertilizers to 10 and 20 t/ha led to an increase (p=0.004) in the collection of oil of the studied crop (Table 4).

Table 4. *The influence of different rates of fertilizers from mixtures of digestate and wood ash on the collection of winter rapeseed oil, t/ha*

Fertilizer application rate, t/ha (factor A)	The ratio of digestate and wood ash in the mixture (factor B)							On average (factor F_A) p=0.004 $LSD_{0.05}$=0.128
	D	D+P1:1	D+P2:1	D+P3:1	D+P3:1+NPK	D+P3:1+N	D+P4:1	
Control				0.93				0.93
5 t/ha	0.88	1.06	0.93	1.07	1.02	0.80	1.11	0.98
10 t/ha	1.30	1.17	1.17	1.07	1.21	0.94	1.26	1.16
20 t/ha	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	×

Note: *D – digestate from cattle manure; P – wood ash*
Source: *author's development*

An important indicator of seed quality is the nature of the grain (volumetric mass). This is the mass of seeds in a volume of 1 liter. The higher this indicator is, the higher the seed quality.

The analysis of changes in the volumetric weight of winter rape seeds showed that increased rates of fertilizers from mixtures of wood ash and digestate significantly (p=0.001) reduce this indicator compared to the control. A comparison of the mixture variants showed a significantly greater (p=0.001) volume mass with the additional introduction of ammonium nitrate. In this variant, a bulk density of 679.6 g/l was achieved, which is similar to the control variant (Table 5).

Table 5. *The effect of fertilizer rates from mixtures of digestate and wood ash on the volumetric weight of winter rapeseed, g/l*

Fertilizer application rate, t/ha (factor A)	The ratio of digestate and wood ash in the mixture (factor B)							On average (FA) p=0.001 $LSD_{0.05}$=1.62
	D	D+P1:1	D+P2:1	D+P3:1	D+P3:1+NPK	D+P3:1+N	D+P4:1	
Control	679.3							
5 t/ha	671.0	673.3	672.7	672.0	672.0	680.3	673.3	673.5
10 t/ha	671.7	668.3	675.0	671.7	669.3	679.3	675.0	672.9
20 t/ha	671.3	671.3	669.7	672.3	672.0	679.3	672.3	672.6
On average p = 0.001 $LSD_{0.05}$ (B) = 2.1 $LSD_{0.05}$ (AB) = 4.3	671.3	671.0	672.5	672.0	671.1	679.6	673.5	×

Note: *D – digestate from cattle manure; P – wood ash*
Source: *author's development*

The experiment evaluated the effect of a mixture of wood ash and digestate on the weight of 1000 winter rape seeds. The average weight of 1000 seeds of the samples ranged from 4.37 to 4.79 g. Small differences between fertilizer treatments were observed, but they were significant (p=0.671).

At the same time, V. Parkhuts (2015) claims that the highest indicators of the structure of the winter rapeseed crop (number of pods – 99.7 pcs./plant, seeds in a pod – 20.0 pcs./plant, number of seeds – 1994 pcs./plant, weight 1000 of seeds – 3.49 g, weight of seeds from 1 plant – 7.0 g) was noted in the version of the experiment for the application of mineral fertilizers at the rate of $N_{60}P_{80}K_{130}$ followed by N_{60} plant feeding, which led to a higher yield under this model of fertilization.

Also, no significant differences (p=0.095) were found between the samples of winter rape according to the introduced norms of fat mixture. The relatively low 1000-seed weight values obtained in the trial can be explained by the dry conditions of the season, which prevented development in the spring and caused heat stress in the plants at the end of flowering before full maturity of canola.

L. Shkarivska *et al.* (2021), scientists of the NSC "Institute of Agriculture of the National Academy of Sciences of Ukraine" also assure that it is possible to use digestates as fertilizers, but it is necessary to control the presence of heavy metals and trace elements in them, because thanks to the agrochemical examination of digestates and their by-product (liquid fraction) a high their nutrient content.

Some laboratory studies have confirmed significant reductions in N_2O emissions when using nitrification inhibitors in the digestate (Wolf *et al.*, 2014; Severin *et al.*, 2016).

Digestate, depending on the source and type of materials used, can also contain heavy metals, which can significantly affect its use in food production (Kupper *et al.*, 2014; Govasmark *et al.*, 2011). It may contain compounds that stimulate or inhibit microbiological soil activity (Risberg *et al.*, 2017).

When analyzing the content of heavy metals in rapeseed and soil after three years of using the digestate, their increase was not detected. The content of heavy metals in the soil, as well as in rapeseed, met EU standards (Rozylo *et al.*, 2019).

H. Riedel & C. Marb (2008) conducted a comparison of composts obtained by different methods for the content of heavy metals in them. Composted digestate from food waste was analyzed, as well as compost obtained from the same waste. They found that there was no difference between the two samples in terms of heavy metal content for almost all indicators. Both composts met German quality requirements.

The impact may be different in groundwater conservation zones, where farmers must reduce nitrogen application rates. Overall, research findings show that the use of organic fertilizers such as digestate can help reduce greenhouse gas emissions during the industrial production of synthetic nitrogen fertilizers (Kesenheimer *et al.*, 2021).

A. Comparetti *et al.* (2013) note that the production of agricultural products must be carried out in accordance with the requirements of environmental protection. It is important to support the safe use of fertilizers in the agricultural environment, especially nitrogen fertilizers. The nutrients contained in the digestate are in a form that is convenient for plants and is a suitable

fertilizer for them. The organic matter contained in the digestate has a positive effect on the physical and chemical properties of the soil and its fertility in general.

Therefore, the results of research indicate the possibility of replacing high-value mineral fertilizers with non-traditional fertilizers. In addition, it is common knowledge that mineral fertilizers are assimilated by only 30-50%, and biofertilizers – almost completely, simultaneously increasing the yield of agricultural crops, in particular, winter rapeseed.

CONCLUSIONS

It has been established that under modern farming conditions, a large amount of organic waste is accumulated in the form of cattle manure and wood shavings, which causes the need for their disposal. These wastes are mostly used for the production of heat and energy by biogas cogeneration plants and various solid fuel boilers. By-products of these enterprises are digestate and wood ash.

According to the results of the conducted research, it was established that using a mixture of wood ash and digestate as alternative fertilizers, it is possible to obtain good crops of winter rape even without the use of mineral fertilizers.

A higher yield of winter rapeseed – 2.45 t/ha was obtained in variants treated with fertilizers at the rate of 10 t/ha, while in the control (without fertilizers) this indicator was 1.97 t/ha, or 24.4% less.

The highest oil content of winter rapeseed was also formed on variants treated with a norm of 10 t/ha of fat mixture (1.16 t/ha), while on the control (without fertilizers) this indicator was noted at the level of 0.93 t/ha, or 24.7% less. Significantly lower oil content was obtained in variants where ammonium nitrate was additionally used for feeding. A higher average oil content in the seeds of the studied crop was obtained by applying 5 t/ha of a mixture of digestate and ash. The volumetric weight of winter rape seeds in the investigated variants was slightly higher at 670 g/l. No significant difference between the studied options was found.

Applying a digestate mixture of cattle manure and wood ash to optimize nutrition for winter rape, instead of a large amount of mineral fertilizers, can be expected to reduce the risk of environmental pollution by production waste, which includes heavy metals, radionuclides, and organic pollutants.

The use of mixtures of digestate from cattle manure and wood ash contributes to the processing of the above-mentioned biomass and the return of organic matter to the soil to preserve or even increase its fertility, therefore it is advisable to use mixtures of wood ash and digestate to optimize the nutrition of winter rapeseed in agro-formations. It is quite important to determine the specific benefit from them, the impact on the surrounding natural environment, in which terms it is better to apply the studied mixtures, which will be the goal of further research.

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CONFLICT OF INTEREST

The authors declare that the study was conducted in the absence of any commercial or financial relationships that could be interpreted as a potential conflict of interest.

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Нетрадиційні добрива для оптимізації живлення ріпаку озимого

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Анотація. Актуальність теми обумовлена необхідністю оптимізації живлення ріпаку озимого (*Brassica napus* L.), у тому числі й із застосуванням нетрадиційних добрив, враховуючи обмежену кількість мінеральних туків з низькою вартістю. Метою досліджень було вивчити вплив суміші побічних продуктів виробництва (деревної золи та дигестату) на врожайність та якість насіння ріпаку озимого. Проведено польові досліди в навчально-дослідному господарстві "Peterlauki" (Латвія). У сільському господарстві як деревна зола, так і дигестат біомаси використовуються окремо як матеріали для вапнування та добрива, тоді як із їх суміші можна отримати високоякісне добриво. Авторами оцінені суміші з дигестату гною великої рогатої худоби та деревної золи у різних співвідношеннях. Використані аналізи із груп системних, статистичних та порівняльних. Застосовано наступні методи дослідження: загальноприйняті в рослинництві польовий та лабораторний – для з'ясування взаємодії об'єкта досліджень з агротехнічними та природними абіотичними факторами; розрахунково-ваговий – для визначення продуктивності посівів; розрахунково-порівняльний; математично-статистичний (дисперсійний) – з метою оцінки ймовірності результатів досліджень. Визначено, що, використовуючи суміші деревної золи та дигестату, можна отримувати відповідні врожаї ріпаку озимого без застосування мінеральних добрив. Вищу врожайність цієї культури – 2.45 т/га було отримано у випадках, де для підживлення використовували норми добрив 10 т/га. Насіння ріпаку озимого мало більший вміст олії у варіантах із застосуванням удобреної суміші 5 т/га, але без аміачної селітри. Об'ємна маса (натура) насіння ріпаку озимого в досліджуваних варіантах трохи перевищувала 670 г/л. Наукова новизна полягає в тому, що оцінено вплив суміші дигестату та деревної золи на продуктивність, у тому числі олійність ріпаку озимого. Практична цінність полягає в удосконаленні технології вирощування досліджуваної культури шляхом правильно підібраної суміші для оптимізації живлення і отримання високоякісної олії

Ключові слова: *Brassica napus*; дигестат; деревна зола; врожайність; олійність; якість урожаю