UDC 631.527.5:633.15:581.13:631.8:631.547.8 https://doi.org/10.31867/2523-4544/0367

EFFECT OF DIGESTATE ON THE PRE-HARVEST GRAIN MOISTURE CONTENT OF MAIZE

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Topicality. *Maize was and remains one of the main fodder-grain crops, the increase in yields of which is possible primarily due to optimisation of plant nutrition through the application of fertilisers.* ***Purpose****. To determine the effect of digestate application and annual climatic conditions on the pre-harvest grain moisture content of maize hybrids of different maturity groups.* ***Methods****. Field, laboratory, and combined laboratory-field methods were used in the research. The study was conducted under the conditions of Organic-D LLC in cooperation with the Department of Crop Production and Horticulture of Vinnytsia National Agrarian University during 2023–2024. The experiments involved maize hybrids of different maturity groups: mid-early – Amaroc (FAO 230), R8754 (FAO 240), Bigbit (FAO 290), Bohatyr (FAO 290); mid-ripening – KWS 381 (FAO 350), KWS Inteligens (FAO 380); and mid-late – DN Anshlah (FAO 420), R0217 (FAO 460).* ***Results****. The digestate of biogas plants was obtained by anaerobic digestion of pig manure for 14 days. The chemical composition of the digestate obtained in this way was characterised by slightly alkaline reaction (pH 7.5–8.2), the presence of macro- and microelements, and a positive microbiological composition. As part of the fertilization system, the micronutrient fertilizer Nanovit maize was applied, which contains macronutrients such as nitrogen, phosphorus, magnesium, and sulfur, micronutrients such as zinc and copper, and a biologically active complex Nanoactiv. We found that the level of pre-harvest moisture content depended on the climatic conditions of the year. In particular, on average in the experiment, the pre-harvest moisture content of grain was 26.05 % in 2023, and it decreased by 6.06 % and reached 19.9 % in 2024 due to a prolonged dry period. The highest grain moisture content was 27–27.03 % in mid-late maize hybrids (FAO 420–460), while it was 8.93–9.22 % lower in the group of mid-early hybrids (FAO 230–240) and averaged 17.78–18.10 % over the two years of the experiment. The highest grain moisture content was found in the experimental variant, which included the introduction of digestate into the basal fertilisation (60 t/ha) + pre-sowing fertilisation (60 t/ha) + foliar feeding (60 t/ha), for Amaroc variety (FAO 230) – 18.80 %, R8754 (FAO 240) – 20.05 %, Bigbit (FAO 290) – 24.40 %, Bohatyr (FAO 290) – 25.15 %, KWS 381 (FAO 350) – 26.25 %, KWS Inteligens (FAO 380) – 27.30 %, DN Anshlah (FAO 420) – 28.15 % and R0217 (FAO 460) – 28.90 %.* ***Conclusions****. Grain moisture content was closely related to the maturity group of the studied maize hybrids, so an increase in pre-harvest grain moisture content was associated with an increase in the length of the growing season. Climatic conditions in the years of research (2023–2024) had a significant effect on the pre-harvest grain moisture content across all hybrids. Fertilizer application contributed to an increase in grain moisture content in the tested maize hybrids. However, higher grain moisture content requires additional costs for post-harvest drying.*

Key words: *digestate, nutrients, moisture content, maize, fertilization system, macronutrients, micronutrients*

Introduction. Pre-harvest grain moisture content plays an important role in the cost structure of maize cultivation technologies. In particular, harvesting is carried out at a grain moisture content of 30–40 %, while long-term storage of grain is only possible when the moisture content is reduced to 14 %. Thus, high pre-harvest moisture content of grain is a source of additional costs for drying the product to the required condition. In the overall structure of maize cultivation costs, grain drying can account for up to 40 %.

A relevant issue for the crop production industry is the development of technological

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solutions that would ensure the realization of the high genetic potential of maize yield while reducing grain moisture content at harvest time. In this context, particular attention should be paid selecting hybrids of the appropriate maturity group, allows us to assess the economic efficiency of these technological elements. Such studies are particularly relevant in the context of rising mineral fertiliser prices and limited availability of traditional organic resources.

Maize remains one of the main grain crops in Ukraine, this being confirmed by consistently high cultivation areas: 3.895 million hectares in 2024 and 4.325 million hectares in 2022. For maize for silage, the average annual area sown was about 195,000 hectares over the last three years [1].

One of the factors affecting the efficiency of maize cultivation is the moisture content in the grain at the harvesting time. The high moisture content, which can reach 35–40 %, requires artificial drying, which significantly increases the cost of production. In some cases, up to 60–70 % of the total fuel consumption is spent on drying the grain, requiring 40–60 kg per 1 tonne of cobs and 30–35 kg per 1 tonne of grain [2–4].

Another important factor is the maturity group of maize hybrids, as the extension of the growing season leads to increased grain moisture content at harvest time, which in turn leads to higher drying costs [4, 7, 8].

The importance of the maturity group of hybrids in the formation of the pre-harvest moisture content of maize grain is indicated in the studies by R. A. Vozhegova and Ya. V. Belov [9, 10]. They note that new maize hybrids with FAO 200–500 are characterised by grain yields of 12–14 t/ha at a moisture content of 12–14 %, facilitate harvesting with minimal costs for additional drying, and ensure their implementation in energyefficient technological schemes.

The rate of moisture loss and grain moisture content in maize hybrids largely depend on genetic characteristics, which can be enhanced by the interaction of the genotype with external environmental conditions, in particular, depending on the response of a specific hybrid to temperature conditions and precipitation during the grain ripening period [11].

The moisture content of grain during harvesting, as well as grain yield, is key criteria for the effectiveness of maize cultivation technology [6].

to the plant fertilisation system as one of the key elements of the technology.

Studying the effect of providing maize with nutrients by applying digestate, as well as nology [6].

Different levels of grain moisture content during ripening and storage affect the rate of biochemical reactions and the intensity of maize grain respiration. Depending on the moisture content and duration of aerobic respiration, the loss of organic reserves in the grain can exceed 20 %. During storage, moist grain undergoes self-heating already from the first days, and on the third or fourth day grain can sprout and be affected by various pathogens (common smut, Fusarium blight, mould, bacterial disease), the harmfulness of which, at the same time, increases significantly [6].

One effective way to increase maize yields is the application of fertilisers, such as digestate produced at biogas plants. This bioorganic fertiliser is quickly absorbed by crops, contains a wide range of macro- and microelements, has a neutral or slightly alkaline reaction, and contains no weed seeds or harmful microorganisms [12].

Opinions of scientists regarding the impact of fertilisation methods on pre-harvest moisture content of maize grain are not unanimous. Some researchers [13] indicate that mineral nutrition does not significantly affect pre-harvest moisture content of maize grain. Others, on the contrary, note an increase in the pre-harvest moisture content of grain, which is associated with improved plant nutrition conditions due to the application of mineral and organic fertilisers [5, 6]. In particular, R. A. Vozhegova and Ya. V. Belov [14] point out that the application of nitrogen and phosphorus fertilisers leads to an increase in the harvest moisture content of maize grain by 0.9– 3.4 percentage points, i.e. to 14.0–16.4 %, compared to the control – 12.6 %. In other words, the application of nitrogen and phosphorus fertilisers ensures an increase in the linear dimensions of plants, aboveground mass and leaf area of maize plants [9, 10].

The research was aimed at establishing the effect of digestate application and climatic conditions of the year on the pre-harvest moisture content of grain in the studied maize hybrids of different maturity groups.

Materials and Methods. The research

was conducted by the Department of Plant Production and Horticulture of Vinnytsia National Agrarian University at the Organic-D LLC facility in 2023–2024. Geographically, this is the central part of the Right-Bank Forest-Steppe of Ukraine.

In order to determine the effect of digests on the pre-harvest moisture content of grain, we used maize hybrids of different maturity groups for the study: mid-early varieties Amaroc (FAO 230), R8754 (FAO 240), Bigbit (FAO 290), Bohatyr (FAO 290), mid-ripening varieties – KWS 381 (FAO 350), KWS Intelegens (FAO 380), mid-late varieties – DN Anshlah (FAO 420), R0217 (FAO 460).

Digestate was obtained from biogas plants by anaerobic fermentation of pig manure for 14 days. In terms of chemical composition, the digestate obtained in this way had a slightly alkaline reaction (pH 7.5–8.2), macroelements (nitrogen, phosphorus, potassium, calcium, sulphur) and microelements (zinc, iron, copper, molybdenum, boron, etc.), and a positive microbiological composition. The fertilisation system involved applying digestate at different times (basic, pre-sowing fertilisation and top dressing) at a rate of 60 t/ha and applying a compound mineral fertiliser, nitroammophoska, at a rate of $N_{90}P_{90}K_{90}$ in combination with the microfertiliser Nanovit for maize – 1.5 l/ha for feeding during the 5–7 leaf stage of maize.

The fertilisation system included the application of microfertiliser Nanovit for maize, which contains the following microelements: nitrogen, phosphorus, magnesium, sulphur, zinc, copper, and the biologically active complex NANOACTIV. In addition, this microfertiliser contains 15 L-amino acids (lysine, glycine, alanine, methionine, proline, cystine, valine, tryptophan, isoleucine, leucine, lenylalanine, glutamine, tyrosine, histidine, and glutamic acid), phytohormones, monosaccharides and organic acids (Table 1).

In addition, microfertiliser Nanovit for maize contains a polysaccharide adhesive. Application of microfertiliser Nanovit for maize was carried out at a rate of 1.5 l/ha in the 5–7 leaf stage of maize, using a backpack sprayer with a working fluid consumption rate of 5 l/100 m².

Table 1. Chemical composition of microfertiliser Nanovit for maize*

Nutrient elements	Total nitrogen	Phosphorus (P_2O_5)	Magnesium (MgO)	Sulphur (SO_3)	Boron (B)	Copper (Cu)	Ferrum (Fe)	Manganese (Mn)	Zinc (Zn)	Amino acids	Organic acids	Phytohormones	Monosaccharides
Content, g/l	39.9	79.8	13.3	39.9	5.32	9.31	1.33	2.66	33.25	35.5	8.4	0.0050	0.046

*Note: * according to data from the manufacturer Agrovit Group.*

The soil of the experimental plot is grey forest soil with a light loamy mechanical composition, with agrochemical indicators typical for this type of soil.

The climatic conditions during the years of research differed significantly. Thus, in 2023, conditions were more favorable for the formation of the yield of the studied maize hybrids in terms of temperature regime and precipitation during the growing season. In 2024, there was a prolonged dry period and temperatures rose to 42–44 °C, which had a negative impact on the productivity of maize hybrids.

The maize cultivation technology is generally accepted for this area, with the exception of the elements that were studied. Three to four repetitions of the experiment were used for the studied maize hybrids. The plots were arranged using the randomised block method. The area of the registration plot was 10.5 m^2, and the total plot area was 25 m^2.

Soybeans were the predecessor in the experiment. After harvesting the previous crop, the main soil cultivation system included stubble cultivation with heavy disc harrows BDT-7 and subsequent ploughing with PLN-3-35 plough.

The crop maintenance system included the application of the soil-applied herbicide Harness at a rate of 3 l/ha and the post-emergence herbicide Milagro (active ingredient – nicosulfuron) in combination with the adhesive Trend in the 5–7 leaf stage of maize at a rate of 1.25 l/ha to control annual and perennial grasses and dicotyledonous weeds.

The physical and mechanical properties of grain, such as linear dimensions, grain moisture content and 1000-grain weight, were determined using standard methods [15, 16].

Results and Discussion. Based on the results of the research, a correlation between the application of different fertiliser options, maturity groups, genetic characteristics of hybrids, and the pre-harvest moisture content of maize grain was found (Table 2).

It was found that the pre-harvest moisture content depended on the climatic conditions of

Table 2. Pre-harvest grain moisture content of maize hybrids depending on fertilisation method, % (for 2023–2024)

Hybrid	Fertilisation method	Pre-harvest grain moisture content, %		
		2023	2024	Average for 2023–2024 pp. ± Sx
1	2	3	4	5
Amaroc (FAO 230)	1 (K)	18.2	14.9	16.55±2.33
	2	19.1	18.5	18.80±0.42
	3	18.9	17.2	18.05±1.20
	4	19.7	17.5	18.60±1.56
	5	18.4	15.7	17.05±1.91
	6	18.9	16.4	17.65±1.77
R8754 (FAO 240)	1 (K)	17.7	13.0	15.35±3.32
	2	21.4	18.7	20.05±1.91
	3	19.4	16.0	17.70±2.40
	4	20.3	17.1	18.70±2.26
	5	19.3	17.5	18.40±1.27
	6	19.9	16.9	18.40±2.12
Bigbit (FAO 290)	1 (K)	22.6	20.7	21.65±1.34
	2	27.7	21.1	24.40±4.67
	3	23.6	20.9	22.25±1.91
	4	26.9	22.5	24.70±3.11
	5	23.1	21.3	22.20±1.27
	6	24.7	21.5	23.10±2.26
Bohatyr (FAO 290)	1 (K)	20.3	19.9	20.10±0.28
	2	26.0	24.3	25.15±1.20
	3	23.5	20.8	22.15±1.91
	4	25.4	21.6	23.50±2.69
	5	23.4	22.3	22.85±0.78
	6	25.6	20.0	22.80±3.96
KWS 381 (FAO 350)	1 (K)	24.5	14.4	19.45±7.14
	2	30.8	21.7	26.25±6.43
	3	29.4	18.6	24.00±7.68
	4	29.6	19.9	24.75±6.86
	5	25.8	16.3	21.05±6.72
	6	28.7	20.8	24.75±5.59
KWS Inteligens (FAO 380)	1 (K)	26.2	16.4	21.30±6.93
	2	31.8	22.8	27.30±6.36
	3	30.4	19.9	25.15±7.42
	4	30.9	24.2	27.55±4.74
	5	28.9	19.1	24.00±6.93
	6	29.7	20.5	25.10±6.51
DN Anshlah (FAO 420)	1 (K)	29.6	22.9	26.25±4.74
	2	34.1	22.2	28.15±8.41
	3	31.4	23.6	27.50±5.52

Continuation of Table 2

1	2	3	4	5
	4	32.6	24.1	28.35±6.01
	5	29.7	20.8	25.25±6.29
	6	30.9	22.4	26.65±6.01
R0217 (FAO 460)	1 (K)	30.1	22.1	26.10±5.66
	2	34.7	23.1	28.90±8.20
	3	31.9	21.5	26.70±7.35
	4	32.8	23.5	28.15±6.58
	5	30.5	21.4	25.95±6.43
	6	31.5	20.9	26.20±7.50

***Notes**: Fertilisation variations: 1 – Control (no fertiliser); 2 – Main fertilisation with digestate (60 t/ha) + pre-sowing fertilisation with digestate (60 t/ha) + top dressing (60 t/ha); 3 – Top dressing with digestate (60 t/ha); 4 – Pre-sowing fertilisation with digestate (60 t/ha); 5 – Main fertilisation with digestate (60 t/ha); 6 – Application of mineral fertilisers ($N_{90}P_{90}K_{90}$) in combination with microfertiliser Nanovit for maize (application rate 1.5 l/ha at the 5–7 leaf stage).*

the year. In particular, on average for the experiment, the pre-harvest moisture content of grain was 26.05 % in 2023, and in 2024, due to a prolonged dry period, it decreased by 6.06 % and was equal to 19.9 %.

The data in Table 2 show that the moisture content of grain in maize hybrids at harvest time, averaged over two years of research, was as follows: Amaroc (FAO 230) – 17.78 %, R8754 (FAO 240) – 18.10 %, Bigbit (FAO 290) – 23.05 %, Bohatyr (FAO 290) – 22.76 %, KWS 381 (FAO 350) – 23.38%, KWS Intelegens (FAO 380) – 25.07 %, DN Anshlah (FAO 420) – 27.03 % and R0217 (FAO 460) – 27.00 %. The highest grain moisture content was observed in mid-late maize hybrids with FAO 420-460 – 27.00–27.03 %, while it was 8.93–9.22 % lower in the group of mid-early hybrids with FAO 230–240 and averaged 17.78–18.10 % over two years. Thus, literary sources confirm that an increase in the duration of the growing season leads to an increase in grain moisture content before harvest.

The effect of fertilisation methods on the pre-harvest moisture content in grain of maize hybrids was also established. In particular, the highest grain moisture content was identified in the fertilization variant that involved the application of digestate in the main (60 t/ha) + pre-sowing (60 t/ha) + top dressing (60 t/ha) regimes over two years, so in Amaroc (FAO 230) – 18.80 %, R8754 (FAO 240) – 20.05 %, Bigbit (FAO 290) – 24.40 %, Bohatyr (FAO 290) – 25.15 %, KWS 381 (FAO 350) – 26.25 %, KWS Intelegens (FAO 380) – 27.30 %, DN Anshlah (FAO 420) – 28.15 % and R0217 (FAO 460) – 28.90 %, while in the control (without fertilisers), the average pre-harvest grain moisture content was 16.55%, 15.35%, 21.65%, 20.10%, 19.45%, 21.30%, 26.25% and 26.10%, respectively.

In the variant where mineral fertilisers $N_{90}P_{90}K_{90}$ were applied in combination with the microfertiliser Nanovit for maize, the pre-harvest moisture content of the grains of the studied maize hybrids also increased by 0.1–5.3 % compared to the control.

Conclusions. The moisture content of the grain was closely related to the maturity group of the studied maize hybrids, i.e., an increase in the duration of the growing season was accompanied by an increase in the pre-harvest moisture content of the grain. The highest pre-harvest grain moisture content was observed in mid-late maize hybrids with FAO 420–460 – 27–27.03 %, while it was 8.93–9.22 % lower in the group of mid-early hybrids with FAO 230–240 and averaged 17.78–18.10 % over two years of experiments.

Climatic conditions in 2023–2024 significantly affected the pre-harvest moisture content of maize hybrids. In particular, in a stressful 2024 in terms of moisture availability and temperature, grain moisture content decreased by 6.06 % compared to 2023, which was more favourable in terms of these indicators.

The application of fertilisers also resulted in an increase in the pre-harvest grain moisture content of maize hybrids. In particular, the highest grain moisture content was found in the fertilisation variant, which involved the application of digestate in the main treatment (60 t/ha) +

pre-sowing (60 t/ha) + top dressing (60 t/ha): Amaroc (FAO 230) – 18.80 %, R8754 (FAO 240) – 20.05 %, Bigbit (FAO 290) – 24.40 %, Bohatyr (FAO 290) – 25.15 %, KWS 381 (FAO 350) – 26.25 %, KWS Intelegens (FAO 380) – 27.30 %, DN Anshlah (FAO 420) – 28.15 % and R 0217 (FAO 460) – 28.90 %, while the pre-harvest moisture content in the control (without fertilisers) averaged 16.55 %, 15.35 %, 21.65 %, 20.10 %, 19.45 %, 21.30 %, 26.25 % and 26.10 % for the hybrids, respectively. In the variant with the application of mineral fertilisers $N_{90}P_{90}K_{90}$ in combination with the microfertiliser Nanovit for maize (1.5 l/ha), the increase in pre-harvest grain moisture content was 0.1–5.3 %, compared to the control.

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UDC 631.527.5:633.15:581.13:631.8:631.547.8

Паламарчук В. Д., Скакун М. В. Вплив дигестату на передзбиральний рівень вологості зерна кукурудзи. *Зернові культури. 2025. 9 (1). 97–103.*

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Вступ. Кукурудза була і залишається однією із основних зернофуражних культур, і зростання її

урожайності можливе, перш за все, за рахунок оптимізації живлення рослин за рахунок використання добрив. **Метою досліджень** було встановити вплив застосування дигестату та кліматичних умов року на рівень передзбиральної вологості зерна гібридів кукурудзи. **Методи.** Польовий, лабораторний, лабораторно-польовий. Дослідження проводились протягом 2023-2024 рр. в умовах ТОВ «Органік-Д» на кафедрі рослинництва та садівництва Вінницького національного аграрного університету на гібридах кукурудзи різних груп стиглості: середньоранньої Амарос (ФАО 230), Р8754 (ФАО 240), Бігбіт (ФАО 290), Богатир (ФАО 290), середньостиглої – КВС 381 (ФАО 350), КВС Інтелегенс (ФАО 380), середньопізньої – ДН Аншлаг (ФАО 420), Р 0217 (ФАО 460). **Результати.** Дигестат біогазових станцій отримували шляхом анаеробного зброджування свинячого гною протягом 14 діб. За хімічним складом, отриманий таким чином дигестат, характеризувався слаболужною реакцією (pH 7,5-8,2), наявністю макро-, мікроелементів, позитивним мікробіологічним складом. У системі удобрення застосовувалося мікродобриво Нановіт кукурудза яке містило у своєму складі такі макроелементи, як азот, фосфор, магній, сірку, мікроелементи: цинк і мідь та біологічно-активний комплекс «NANOACTIV». Нами встановлено, що рівень передзбиральної вологості залежав від кліматичних умов року. Зокрема, у середньому по досліду, рівень передзбиральної вологості зерна в 2023 р. становив – 26,05 %, а у 2024 р. за рахунок тривалого посушливого періоду, він знизився на 6,06 %, і складав – 19,9 %. Найбільшу вологість зерна відмічено у середньопізніх гібридів кукурудзи із ФАО 420-460 – 27,00-27,03 %, тоді як у групі середньоранніх гібридів із ФАО 230-240 вона була на 8,93–9,22 % нижчою і становила, у середньому за два роки – 17,78-18,10 %. Залежно від удобрення найвищий рівень вологості зерна виявлено у варіанті, який передбачав внесення дигестату в основне удобрення (60 т/га) + передпосівне дигестатом (60 т/га) + підживлення (60 т/га) – Амарос (ФАО 230) – 18,80 %, Р8754 (ФАО 240) – 20,05 %, Бігбіт (ФАО 290) – 24,40 %, Богатир (ФАО 290) – 25,15 %, КВС 381 (ФАО 350) – 26,25 %, КВС Інтелегенс (ФАО 380) – 27,30 %, ДН Аншлаг (ФАО 420) – 28,15 % та Р 0217 (ФАО 460) – 28,90 %. **Висновки.** Рівень вологості зерна мав тісний зв'язок із групою стиглості досліджених гібридів кукурудзи – із збільшенням тривалості вегетаційного періоду спостерігалося підвищення передзбиральної вологості зерна. Кліматичні умови у 2023–2024 рр. досліджень істотно впливали на рівень передзбиральної вологості зерна гібридів кукурудзи. Внесення добрив призводило до зростання показника передзбиральної вологості зерна досліджуваних гібридів кукурудзи.

Ключові слова: *дигестат, елементи живлення, вологість, кукурудза, система удобрення, макроелементи, мікроелементи*