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Formation of grain yield in corn hybrids of different FAO groups depending on sowing dates and plant density

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Abstract. Formation of productivity of any agricultural crop depends on many factors. First of all, the soil and climatic conditions of the crop growing area, varietal or hybrid composition, seed quality, sowing dates and plant density, and strict adherence to all methods of cultivation technology are important. Corn hybrids of different maturity groups differ in morphological and biological properties. Thus, obtaining the potential yield of an individual genotype is possible under favorable conditions for the growth and development of plants, including high-variety agricultural machinery and natural conditions. The maximum yield of high-quality corn grain is formed under the condition of the optimal ratio of all structural elements: weight of 1,000 grains, number of rows of grains in an ear, number of grains in a row, number of grains on one ear, length and diameter of an ear. If one structural element is insufficiently developed, the yield can be compensated by other components. Since individual elements of the structure are formed at different stages of organogenesis, different conditions are necessary for their successful development. The hybrids used in our research revealed peculiarities in the formation of elements of the crop structure, depending on the timing of sowing and stand density. The sizes of the cobs that formed on the corn plants varied little under the influence of sowing dates and plant stand density, but were characteristic of a certain biotype. Studies have shown that all factors of the experiment affect the growth, development of plants and the formation of elements of the structure of the corn grain crop. According to the results of the measurements, it was established that the best indicators of all structural elements were observed for sowing hybrids of different maturity groups in the optimal period - the third decade of April. The highest values of all indicators were observed in the Olkani hybrid, which is explained by the genotypic features of this hybrid.

Key words: corn, hybrid, maturity group, productivity, crop structure, mass of 1,000 grains.

INTRODUCTION

Formation of productivity of any agricultural crop depends on many factors. First of all, the soil and climatic conditions of the crop growing area, varietal or hybrid composition, seed quality, sowing dates and plant density, and strict adherence to all methods of cultivation technology are important (Alley, 2013).

The harvesting moisture content of the corn grain is influenced by the maturity group of the hybrid, the elements of the crop cultivation technology, as well as the cultivation zone. In the conditions of Ukraine, it is necessary to take into account the features of the genotypic and environmental reaction of the hybrid to changes in the temperature regime during the period of grain filling and ripening, and to adjust the provision of technological requirements due to the selection of the best hybrids and improvement of the elements of growing technology (Bagan et al., 2019; Maslak, 2023).

Low harvesting moisture of corn grain is primarily determined by the duration of the vegetation period, while the factor of early maturity is dominant. It is for these reasons that we involved promising hybrids of different maturity groups with high potential yield and adaptability to growing conditions (Bagan et al., 2022; Lavrynenko, 2023).

Corn hybrids of different maturity groups differ in morphological and biological properties. Thus, obtaining the potential yield of an individual genotype is possible under favorable conditions for the growth and development of plants, including high-variety agricultural technology and natural conditions (Bezugliy, 2012; Gadzalo, 2023).

Today, new domestically bred corn hybrids have high adaptive properties. In terms of productivity, they are at the level of foreign hybrids and are characterized by genetically determined adaptation to the soil and climatic conditions of a certain region of Ukraine (Dzyubetsky, 2007; Vlaschuk, 2021).

During the period of constant climate changes, there is an increase in the average daily air temperature, the amount of precipitation decreases, and this, in turn, leads to a decrease in moisture reserves in the soil. The difference between day and night air temperatures becomes noticeable. In summer, there is often a sharp fluctuation in temperature during the day. This leads, respectively, to a decrease in the intensity of growth and development of plants during the day and at night, which causes a significant loss of moisture (Konashchuk, 2013; Vlaschuk, 2022).

Thus, a lack of moisture and excessively high temperatures contribute to a decrease in structural indicators. The low height of the cob attachment, in turn, leads to significant losses of grain during harvesting, but the high attachment of the cob on the plant is also an undesirable phenomenon. Therefore, the morphology of corn plants can affect the level of productivity, and also requires the use of some elements of cultivation technology (Kolpakova, 2021).

So far, domestic breeders have created a number of corn hybrids that differ among themselves in morphological features, biological features, indicators of yield and grain quality, and have a high level of adaptive potential to adverse environmental conditions (Tryhub et al., 2020).

Therefore, the study of modern corn hybrids of domestic selection in order to establish the level of manifestation of their productivity in certain soil and climatic conditions, depending on the time of sowing, the density of plant standing, remains relevant.

The goal is to establish the level of manifestation of the elements of the crop structure and the productivity of corn hybrids according to the FAO number, depending on the timing of sowing and plant density.

Research goals: to investigate the influence of sowing dates and plant density on the elements of the structure of the crop of corn hybrids; to determine the yield level of corn hybrids depending on research factors; establish correlations between the investigated indicators.

Subject of research: corn hybrids Milady (FAO 170), Spokusa (FAO 330) and Olkani (FAO 340) of the Lidea company.

MATERIALS AND METHODS

The research was conducted in the conditions of the Poltava region during 2021–2023 in the Central Forest Steppe of Ukraine (Poltava region). The climate of this region is moderately continental with high temperature and uneven distribution of precipitation in the spring and summer period. The soil is typical chernozem.

The object of research were three hybrids of different ripeness groups - Temptation, Milady and Olkani. Sowing dates for corn hybrids were: 2nd decade of April, 3rd decade of April, 1st decade of May. The density of plants - 70, 80 and 90 thousand units ha^{-1} was for each hybrid.

The registered area of the plot was 50 m^2. Repetition - four times. Placement of plots is randomized. The predecessor is winter wheat. Variants of the experiment were studied according to such indicators as: the number of rows of grains in the cob (pcs), the length of the cob (cm) and the diameter of the cob (mm), the weight of the grain from the cob (g), the weight of 1,000 grains (g), yield (t ha^{-1}). Field and laboratory research was carried out according to generally accepted methods, statistical data processing was determined by the method of correlation - regression analysis (Vlaschuk, 2023).

During the experiment, the following research methods were used: field - to determine the yield level of corn hybrids according to the experiment options; laboratory - to determine the elements of productivity of corn plants according to the studied factors; statistical - to determine the least significant difference (LSD_{05}) by the method of variance analysis.

The data obtained from the laboratory and field studies, such as yield and structure elementswas, analyzed by ANOVA statistical analysis packages (Yeshchenko et al., 2005).

RESULTS AND DISCUSSION

The results of yield accounting showed that, under the influence of agrotechnical elements, the productivity of the investigated corn hybrids, on average for 2021–2023, ranged from 9.98 to 13.69 t ha^{-1} (Table 1).

Table 1. Grain yield of corn hybrids of different maturity groups depending on sowing dates and plant density, t ha^{-1} (average for 2021–2023)

Factor A, sowing time	Factor B, hybrid	Factor C, plant stand density, thousand pieces ha^{-1}	Average productivity, t ha^{-1}	By factor		
				A	B	C
II decade of April	Spocusa	70	10.23	11.30	10.46	11.38
		80	10.51			11.57
		90	10.64			11.46
	Miledi	70	11.16		11.25	
		80	11.34			
		90	11.45			
	Olkani	70	12.20		12.70	
		80	12.36			
		90	11.78			
III decade of April	Spocusa	70	10.16	11.77		
		80	10.67			
		90	10.96			
	Miledi	70	11.38			
		80	11.80			
		90	11.92			
	Olkani	70	13.69			
		80	13.35			
		90	12.02			
I decade of May	Spocusa	70	9.98	11.34		
		80	10.42			
		90	10.59			
	Miledi	70	10.26			
		80	10.75			
		90	11.20			
	Olkani	70	13.39			
		80	12.95			
		90	12.54			
Assessment of the significance of partial differences						
LSD_{05} (A) t ha^{-1}		A =	0.09			
		B =	0.06			
		C =	0.08			
Assessment of the significance of average (main) effects						
LSD_{05} (A) t ha^{-1}		A =	0.03			
		B =	0.02			
		C =	003			

These tables show that for all maturity groups of corn hybrids, there is a dependence of grain yield on sowing time and stand density. According to the results of research conducted in 2021–2023, it was established that the use of sowing in the third decade of April contributes to the formation of the highest yield of corn grain, which, on average, amounted to 11.77 t ha^{-1}. For sowing in the second decade of April and in the first decade of May, the yield of corn grain had a tendency to decrease - 11.30 and 11.34 t ha^{-1}, or was 4.0 and 3.7% lower, respectively. This regularity was observed during the entire period of research (Vozhegova, 2017).

The maximum yield of corn grain was obtained for sowing in the third decade of April, which, on average, for all studied hybrids in 2021 was 11.26, in 2022 – 12.03 t ha^{-1}, and in 2023 – 12.02 t ha^{-1}.

During the sowing of the crop in the second decade of April and the first decade of May, the grain yield was somewhat lower and was 10.90 and 11.22 t ha^{-1} in 2021, and 11.48 and 11.28 t ha^{-1} in 2022, and in 2023 – 11.51 and 11.52 t ha^{-1}.

Olkani hybrid, on average for 2021–2023, turned out to be the most productive - the average grain yield was 12.70 t ha^{-1}. A slightly lower yield was obtained in variants with the Milady hybrid - 11.25, and the lowest values of this indicator were set in the Spokusa hybrid - 10.46 t ha^{-1}, which is explained by the biological features of the hybrid maturity group. A similar trend was observed separately for each year of research.

The genotype of the hybrid had a specific reaction to the density of plant stands. The early-ripening hybrid Temptation showed the highest yield at a stand density of 90,000 units ha^{-1} for all sowing periods.

The mid-early hybrid Milady also produced the maximum yield at a stand density of 90,000 pieces ha^{-1} both in the optimal and relatively early and late sowing periods.

The mid-ripe Olkani hybrid showed the maximum yield of 13.69 t ha^{-1} when sown in the third decade of April and the density of plants standing at 70,000 plants ha^{-1}. Dispersion processing of yield indicators made it possible to determine the share of the influence of the studied factors on the formation of this indicator for corn hybrids of different maturity groups (Fig. 1).

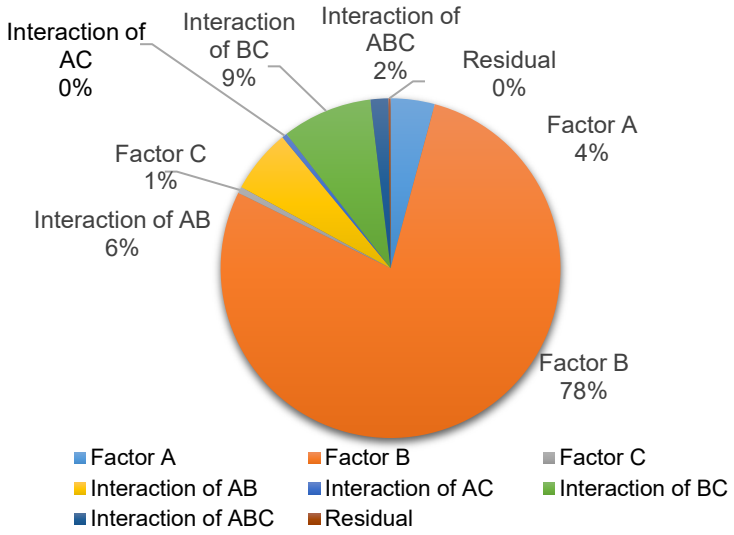

Figure 1. The share of influence of research factors on the formation of grain yield of corn hybrids of different maturity groups, % (average for 2021–2023): factor A – sowing dates; factor B – corn hybrids of different maturity groups; factor C is the density of plant stands.

Based on the results of dispersion analysis, it was established that factor B had the greatest influence on the formation of grain productivity of hybrids of the culture, the share of its influence was 78.2%. The effect of factors A and C was much smaller, respectively - 4.2 and 0.6%.

The interaction of factors turned out to be weak - 0.6–8.5%, and the influence of other factors on yield formation was 0.2%. From this, it was established that the hybrid composition had a significant influence on obtaining a high yield of corn grain.

Therefore, the maximum grain yield of corn hybrids of different maturity groups can be achieved by sowing in the 3rd decade of April the early-ripening hybrid Spokusa with a stand density of 90 thousand units ha^{-1}, the mid-early hybrid Milady - 90 thousand units ha^{-1}, the medium-ripening hybrid Olkani - 70 thousand pieces ha^{-1}. It was determined that the Olkani hybrid is sown in the early season to obtain dry grain, and the Spokusa and Milady hybrids are sown in the late season to obtain organic products without the use of herbicides (Vozhegova, 2017).

Summarizing the above data, it should be noted that among the factors studied in this experiment, the group of hybrid maturity had the most significant influence on the formation of grain productivity of the crop. The share of influence of this factor (B) was 78.2%. Sowing time (factor A) and stand density (factor C) had a much smaller influence on the formation of corn grain yield, the share of their influence was, respectively, 4.2% and 0.6%.

Structural indicators occupy an important place among the large number of economically important characteristics of corn hybrids, which have a significant impact on the formation of actual and potential yield.

The maximum yield of high-quality corn grain is formed under the condition of the optimal ratio of all structural elements: weight of 1,000 grains, number of rows of grains in an ear, number of grains in a row, number of grains on one ear, length and diameter of an ear. If one structural element is insufficiently developed, the yield can be compensated by other components. Since individual elements of the structure are formed at different stages of organogenesis, unequal conditions are necessary for their successful development (Vlaschuk, 2021).

In general, the weather conditions of 2021–2023 during the observations were favorable for the growth of corn plants - both at the first stages of development, i.e. laying and the formation of vegetative and generative buds, and at the later ones, when the potential of these elements was already being realized. Optimum supply of crop plants with moisture ensured the development of all structural elements (Table 2).

The hybrids used in our research revealed peculiarities in the formation of elements of the crop structure, depending on the timing of sowing and stand density. The sizes of the cobs that formed on the corn plants varied little under the influence of sowing dates and plant stand density, but were characteristic of a certain biotype.

When setting the parameters of the length of the cobs, only the seeded part of the beginning was taken into account. According to the results of biometric measurements, the smallest average indicator of the length of the cob was established in the early-ripening hybrid Spokusa - 16.7–17.9 cm. As the maturity group increased, the indicator of the length of the cob increased, which is explained by the characteristics of the hybrids.

Thus, the value of this indicator for the Milady hybrid, on average for the 2021–2023 observation period, was 17.8–20.1 cm, for the medium-ripening Olkani hybrid - 18.4–22.6 cm.

Table 2. Indicators of the structure of the yield of corn hybrids depending on the timing of sowing and stand density (average for 2021–2023)

Factor A, sowing time	Factor B, hybrid	Factor C, plant stand density, thousand pieces ha^{-1}	Length of cob, cm	Diameter of cob, mm	Number of rows of grains, pcs	Weight of grain from cob, g
Decade of April	Spocusa	70	17.3	40.7	15.4	158.3
		80	17.1	41.4	15.2	156.9
		90	16.8	39.9	15.8	154.6
	Miledi	70	18.5	43.8	15.1	173.2
		80	18.3	44.1	14.6	172.0
		90	17.9	44.6	15.3	169.4
	Olkani	70	19.0	47.9	18.0	245.8
		80	18.7	48.2	18.4	241.3
		90	18.4	47.8	18.1	236.5
II decade of April	Spocusa	70	17.9	35.6	14.7	160.1
		80	17.6	37.2	14.3	159.3
		90	17.2	38.5	14.4	157.8
	Miledi	70	20.1	41.9	15.8	182.6
		80	19.7	43.0	14.9	180.9
		90	19.4	44.3	15.2	176.4
	Olkani	70	22.6	52.4	18.6	289.7
		80	21.1	51.8	18.5	285.8
		90	20.3	50.6	19.1	278.0
I decade of May	Spocusa	70	17.1	40.2	14.5	152.4
		80	17.0	38.9	14.6	151.0
		90	16.7	39.5	13.9	148.9
	Miledi	70	18.6	41.1	15.7	181.3
		80	18.1	42.4	14.8	178.5
		90	17.8	42.8	15.0	176.4
	Olkani	70	20.5	52.0	18.4	289.1
		80	20.2	50.9	18.5	285.0
		90	19.8	49.7	18.9	277.6
Assessment of the significance of partial differences, LSD_{05}		A	0.42	0.85	0.12	5.21
		B	0.35	0.96	0.18	6.14
		C	0.21	0.79	0.15	4.83

The indicator of the diameter of the cob practically did not change under the influence of the studied factors, but it depended on the genotypic characteristics of the hybrids and was, on average for 2021–2023, for the hybrid Spokusa - 35.6–41.4 mm, for the hybrid Milady - 41.1–44.3 mm, for the Olkani hybrid - 47.8–52.4 mm.

The study of the correlation dependence between it and other main economic and valuable features is of practical importance for determining the optimal parameters in the process of developing agrotechnology of corn hybrids for specific agro-climatic growing zones.

According to the results of the correlation-regression analysis, a high correlation of dependence between indicators of corn grain structure and yield was established. Thus, the correlation between grain yield and cob length was $r = 0.87$, cob length $r = 0.92$, number of rows of grains $r = 0.82$, and grain weight per cob $r = 0.91$.

Such a close connection allowed us to build correlation polynomial models of the dependence between productivity and various indicators of its structure (Figs 2, 3, 4, 5).

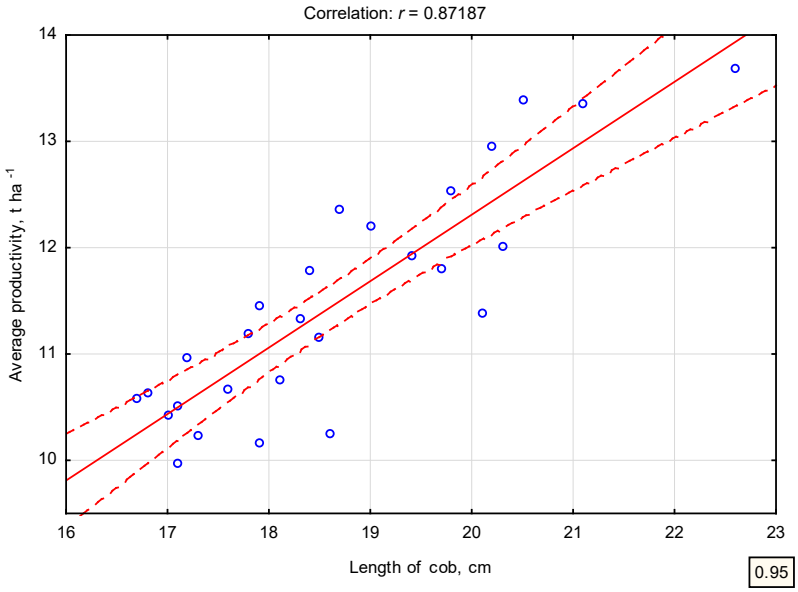

Figure 2. Correlation between grain yield and cob length (average for 2021–2023).

According to the conducted modeling, it was proved that the parameters of the cob diameter of corn hybrid plants differed significantly at different sowing times.

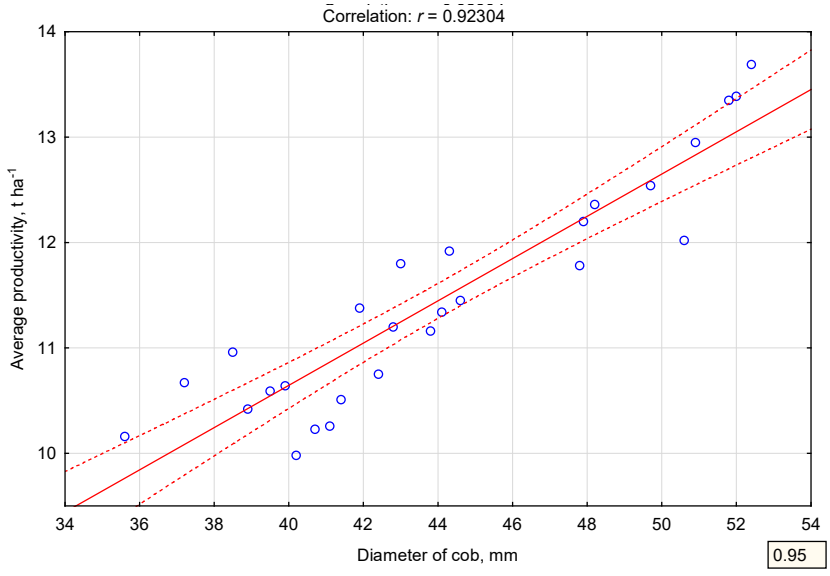

Figure 3. Correlation between grain yield and cob diameter (average for 2021–2023).

The obtained model made it possible to establish a close relationship between the grain yield of corn hybrids and the number of rows of grains, the correlation coefficient is 0.82.

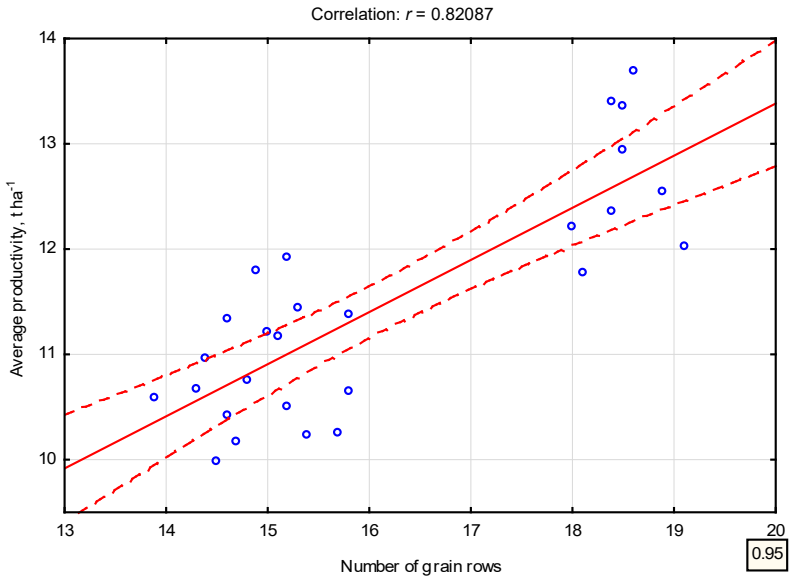

Figure 4. Correlation between grain yield and the number of grain rows (average for 2021–2023).

Modeling between the yield of corn grain and the mass of grain from one cob made it possible to establish a significant difference between the investigated hybrids and sowing dates.

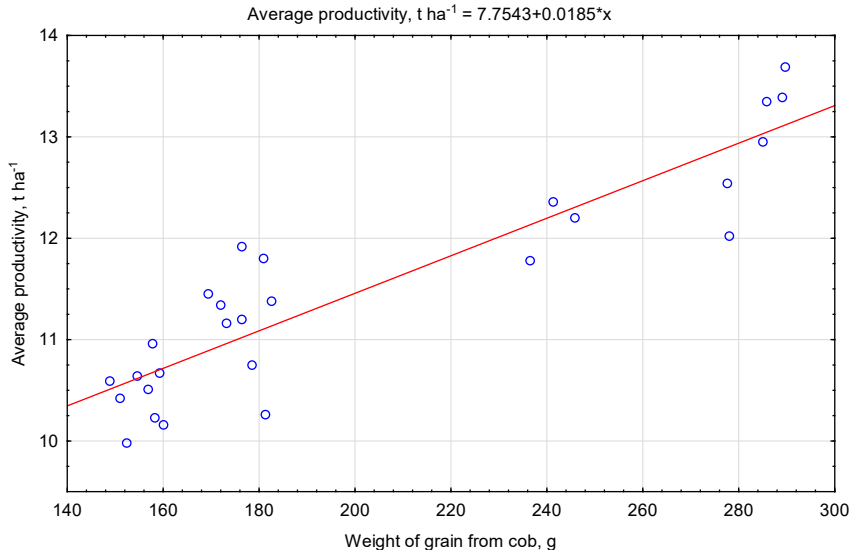

Figure 5. Correlation between grain yield and the mass of grain from the cob (average for 2021–2023).

The weight of 1,000 grains is one of the important indicators of the elements of the structure of corn, which influence the creation of high productivity.

In our studies, this indicator fluctuated under the influence of research factors, but their influence was not the same (Table 3).

Table 3. Weight of 1,000 grains of corn hybrids of different maturity groups depending on sowing dates and stand density, g (average for 2021–2023)

Factor A, sowing time	Factor B, hybrid	Factor C, plant stand density, thousand pieces ha^{-1}	Average, g	By factor		
				A	B	C
II decade of April	Spocusa	70	248.9	272.3	242.8	278.3
		80	245.1			274.5
		90	240.7			269.8
	Miledi	70	263.8		262.9	
		80	259.2			
		90	256.1			
	Olkani	70	318.3		317.0	
		80	312.8			
		90	305.5			
III decade of April	Spocusa	70	250.2	277.6		
		80	246.4			
		90	242.9			
	Miledi	70	270.5			
		80	267.0			
		90	261.1			
	Olkani	70	326.3			
		80	319.8			
		90	316.4			
I decade of May	Spocusa	70	234.2	272.7		
		80	240.5			
		90	236.1			
	Miledi	70	267.9			
		80	262.7			
		90	258.0			
	Olkani	70	324.6			
		80	317.3			
		90	313.4			
Assessment of the significance of partial differences						
LSD_{05} (A), t ha^{-1}		A =	0.82			
		B =	0.75			
		C =	0.26			
Assessment of the significance of average (main) effects						
LSD_{05} (A), t ha^{-1}		A =	0.19			
		B =	0.41			
		C =	0.12			

From the table, we can see that the use of later sowing dates contributed to an increase in the mass of 1,000 grains, while increasing the stand density, on the contrary, reduced its number. The thickening of corn crops caused a decrease in the weight of 1,000 grains. Thus, with a stand density of 70 thousand units ha^{-1}, on average, this

indicator was higher by 3.8–8.5 g, compared to similar indicators when using a stand density of 80–90 thousand units ha^{-1}.

The sowing period had little effect on the change in the mass of 1,000 grains of corn hybrids. The value of this indicator for sowing in the 2nd decade of April was 272.3 g, for sowing in the 3rd decade of April and 1st decade of May, 277.6 and 272.7 g, respectively. The weight of 1,000 grains was most affected by the morphobiotype - depending on the maturity group hybrid, grain weight changed significantly. The highest average weight of 1,000 grains is 317 g, determined in the Olkani hybrid, which is 17.1 and 23.4% more than in the Milady and Spokus hybrids, respectively.

The maximum weight of 1,000 grains, on average over the years of research, 326.3 g, was obtained when sowing the Olkani hybrid in the third decade of April and using a stand density of 70,000 seeds ha^{-1}.

The analysis of the obtained experimental data showed that there is a close relationship between the productivity indicators and the weight of 1,000 grains of corn hybrids of different maturity groups. The correlation coefficient is 0.90 (Fig. 6).

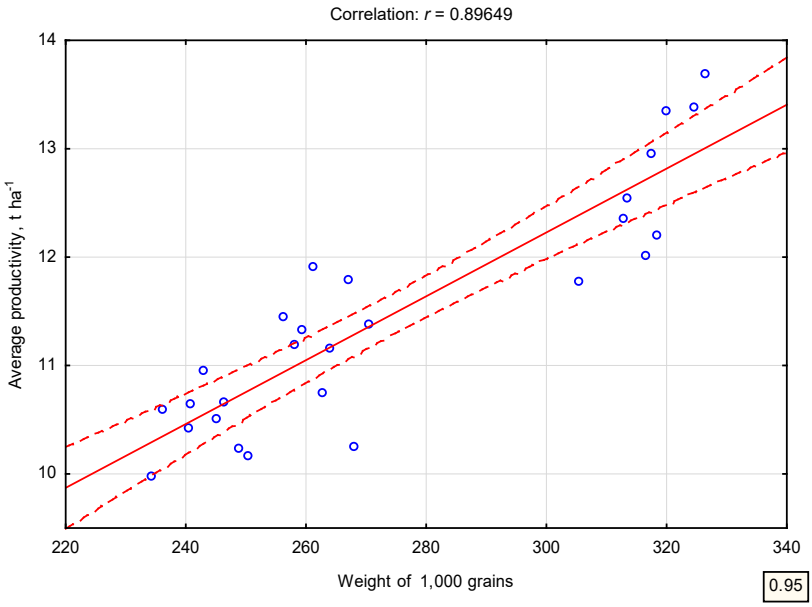

Figure 6. Correlation between grain yield and weight of 1,000 grains (average for 2021–2023).

Studies have shown that all factors of the experiment affect the growth, development of plants and the formation of elements of the structure of the corn grain crop. According to the results of the measurements, it was established that the best indicators of all structural elements were observed for sowing hybrids of different maturity groups in the optimal period - the third decade of April. The highest values of all indicators were observed in the Olkani hybrid, which is explained by the genotypic features of this hybrid.

CONCLUSION

1. Conducted research on the cultivation of new hybrids of corn of different maturity groups showed that the sowing period and the density of standing have a significant effect on the formation of the crop and the quality of the corn grain. Depending on the weather conditions - the time of sowing affects the yield of corn, especially on the average daily air temperature and the temperature of soil warming. In order to obtain a high yield, the sowing density should be optimal, since thinned and thickened sowings reduce this indicator.

2. According to the results of the dispersion analysis, it was established that factor B (hybrid composition) had the greatest influence on the formation of grain productivity of hybrids of the culture, the share of its influence was 78.2%. The effect of factors A (sowing dates) and C (planting density) was much smaller, respectively - 4.2 and 0.6%.

3. The maximum average yield of corn grain over the years of research - 13.69 t ha^{-1} was formed by the mid-ripening hybrid Olkani sown in the 3rd decade of April and with a density of 70,000 plants ha^{-1}. The average value of the yield indicator in the experiment is 11.47 t ha^{-1}.

4. Experimental studies have established that maximum grain yield indicators of corn hybrids of different maturity groups can be achieved during sowing in the 3rd decade of April. The optimal stand density for hybrids of the early-ripening and medium-early maturity groups should be 90,000 units ha^{-1}, for medium-ripening - 70,000 units ha^{-1}.

5. Olkani hybrid must be sown relatively early to obtain dry grain. Spokusa and Milady hybrids can be sown relatively late to obtain organic products without the use of herbicides.

6. Observations showed that all factors of the experiment affect the growth, development of plants and the formation of elements of the structure of the corn grain crop. According to the results of the measurements, it was established that the best indicators of all structural elements were observed for sowing hybrids of different maturity groups in the optimal period - the third decade of April. The highest values of all indicators were observed in the Olkani hybrid, which is explained by the genotypic features of this hybrid.

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