GENOTYPE-ENVIRONMENTAL RESPONSE OF INBRED LINES – PARENTAL COMPONENTS OF MAIZE HYBRIDS IN CHANGING CLIMATE CONDITIONS

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INTRODUCTION

Today, creating new self-pollinated maize lines is a pressing issue. A self-pollinated line is a group of genetically identical homozygous individuals descended from a single plant. Self-pollinated lines (inbred lines) are obtained through forced self-pollination over 6–8 generations. This process results in the original material becoming homozygous, which is unnatural for cross-pollinated plants. Homozygous plants exhibit reduced vitality, weakened growth, low yield, and a feeble root system. The seeds of self-pollinated lines remain in the soil for one and a half to two times longer before seedlings emerge. The rate of vegetative growth in these lines is significantly lower than in hybrids. The leaf area is three to five times smaller[1].

In breeding for heterosis (hybrid vigor), the selection of parental pairs for crossbreeding is of paramount importance. Maximum heterosis effect is achieved only when specifically selected lines are hybridized. R. A. Vozhegova, Yu. O. Lavrinenko, and others argue that one of the most significant avenues for increasing maize grain production is the development and implementation of high-yielding hybrids characterized by stable crop yields under changing environmental conditions, resistance to lodging, diseases, and pests, and efficient moisture utilization–completely meeting the requirements of industrial crop cultivation and harvesting technology. To breed hybrids of this type, it is necessary to have genetically diverse material–new self-pollinated maize lines adapted to the soil and climatic conditions of the region, as well as an appropriate methodology for their evaluation and use[2].

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Maize parental components, as a product of prolonged forced self-pollination, are more demanding in terms of growing conditions. They are characterized by increased sensitivity to adverse factors and have a smaller plant size compared to hybrids. The genotype-specific features of the lines affect the phenotypic expression of traits. Therefore, it is necessary to take into account the biological characteristics of parental components and technological recommendations for cultivating hybridization plots. As a result, research into optimizing the technological methods of growing maize lines-parental components of prospective hybrids-is gaining particular relevance[3].

Contemporary maize parental components must meet production requirements for specific technological parameters. This is especially relevant for plant density and the use of modern biopreparations. Research conducted at various plant densities has allowed for the provision of production parameters tailored to specific agroecological and technological conditions[4].

Within the complex of agronomic measures for maize cultivation, which significantly affect crop yield and quality, plant stand density plays a crucial role. A substantial yield can be obtained by achieving high individual productivity and the maximum permissible stem density in a specific cultivation area[5].

Optimal plant density is a crucial factor for achieving high maize yields[6, 7]. There is a variety of reactions among maize genotypes to planting density, and it is possible to select forms that do not reduce yield with increased plant

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density up to a certain limit. Research institutions have tested individual lines and hybrids at different planting densities[8].

It is particularly important when cultivating parental forms of maize hybrids to select the appropriate plant density for each line or hybrid in line with its genotype. While some researchers recommend optimal densities for lines and hybrids based on their maturity group, these recommendations have a wide range. For each specific line or hybrid, it is necessary to individually select the optimal plant density based on their biological characteristics[9].

It has been established that for each agroclimatic zone, there is an appropriate optimum plant density. Any other density, whether greater or less than the recommended range, has a negative impact. Increased plant density leads to the emergence of undersized, suboptimal plants, while insufficient density results in inefficient use of land and sunlight, leading to reduced yields[10]. Hybrids with longer vegetative periods generally require sparser planting compared to hybrids with shorter vegetative periods. Early-maturing hybrids have less leaf and stem mass and require less water and nutrients for growth, plant development, and grain formation. Self-pollinated lines respond better to increased planting density than hybrids of the same maturity group[11].

Many scientists believe that a key factor in modern maize seed production and achieving high yields on hybridization or multiplication plots is the use of a variety of preparations (biopreparations, microfertilizers, stimulants). These preparations enable the production of high-quality, healthy seed material. Foliar feeding, as an additional technological technique in maize cultivation, improves the absorption of nutrients, allowing a reduction in the application of mineral fertilizers[12].

The use of biopreparations helps realize the genetic program of plants, enhances their resistance to biotic and abiotic stress factors, leading to increased yields and improved product quality. The application of new

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biopreparations to stimulate plant growth and development, balanced nutrition, and stress protection in the cultivation of parental components of maize hybrids is a current direction in crop technology and requires relevant research[13, 14, 15].

1. Leaf area index (LAI) is a crucial factor when it comes to maize hybrid parental components, and it depends on various research factors

An increase in the leaf surface area in a crop canopy is not always advantageous, as denser planting can result in shading of lower leaves by upper ones. This can lead to reduced radiation exposure and decreased photosynthesis intensity in the crop. In the theory of the production process, an essential ecological indicator is LAI, which is determined as the ratio of leaf surface area to the crop's planted area.

You conducted research to study the changes in the LAI, which characterizes the photosynthetic activity of the crop. The values ranged from 2.44 to 4.12 and depended on the influence of biopreparations, FAO group, and crop density. The results indicate an increase in LAI due to the action of biopreparations, as shown in Table 1.

The maximum Leaf Area Index (LAI) values during the flowering phase of corn cobs were observed in lines DK 411 and 445. In the control group, the LAI ranged from 3.52 to 3.63, while in the treated groups, it ranged from 3.62 to 3.80. This confirms existing data suggesting a larger assimilation surface area in later-maturing varieties.

Higher LAI values were observed in the parental components of plants across all maturity groups at a plant density of 90,000 plants/ha (ranging from 3.12 to 4.04), while the lowest LAI values were noted at a density of 70,000 plants/ha (ranging from 2.57 to 3.41). Therefore, increased plant density in the crop canopy expanded the assimilation surface area of the crop.

The research results indicate that, similar to single-plant leaf area, the treatment of plants in the FAO 190 and 290 groups with both preparations had

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a more significant effect on LAI compared to the FAO 420 group. This effect amounted to an increase of 0.21–0.30 for FAO 190 and 290 and 0.10–0.19 for FAO 420, on average. Under the influence of biopreparations, LAI increased by 5.3 % when the Bio-Gel preparation was used and by 7.2 % with the Helafit Combi preparation.

Table 1

Leaf Area Index of maize hybrid parental components during the flowering phase depending on the research factors (average for 2018–2020)

Parent Component (Factor A)	Plant Density (thousands per ha) (Factor B)	Treatment with Preparations (Factor C)			Average for Factor	
		Control, no treatment	Bio-Gel	Helaphyte Combi	A	B
DK 281 (FAO 190)	70	2,44	2,60	2,67	2,85	2,57
	80	2,66	2,92	3,02		2,87
	90	2,93	3,16	3,26		3,12
Average		**2,68**	**2,89**	**2,98**		
DK 247 (FAO 290)	70	2,63	2,86	2,92	3,10	2,80
	80	2,94	3,15	3,25		3,11
	90	3,20	3,47	3,49		3,39
Average		**2,92**	**3,16**	**3,22**		
DK 411 (FAO 420)	70	3,24	3,30	3,35	3,62	3,30
	80	3,54	3,62	3,74		3,63
	90	3,79	3,94	4,04		3,92
Average		**3,52**	**3,62**	**3,71**		
DK 445 (FAO 420)	70	3,33	3,42	3,49	3,73	3,41
	80	3,67	3,77	3,79		3,74
	90	3,89	4,10	4,12		4,04
Average		**3,63**	**3,76**	**3,80**		
Average for Factor C		**3,19**	**3,36**	**3,42**		
Assessment of the Significance of Partial Differences						
HIP_{05}, t/ha		A=0,11–0,13; B=0,27–0,29; C=0,12–0,15				

To investigate the correlation between corn grain productivity and the crop's LAI, the correlation coefficient was calculated. It was found that there is a nonlinear correlation between grain yield and LAI ($\eta = 0.50 \pm 0.15$). The curvilinear relationship between yield and LAI suggests that the increase in LAI in the conditions of your experiment has certain limits: after exceeding the value of 3.5, grain productivity decreases (Figure 1).

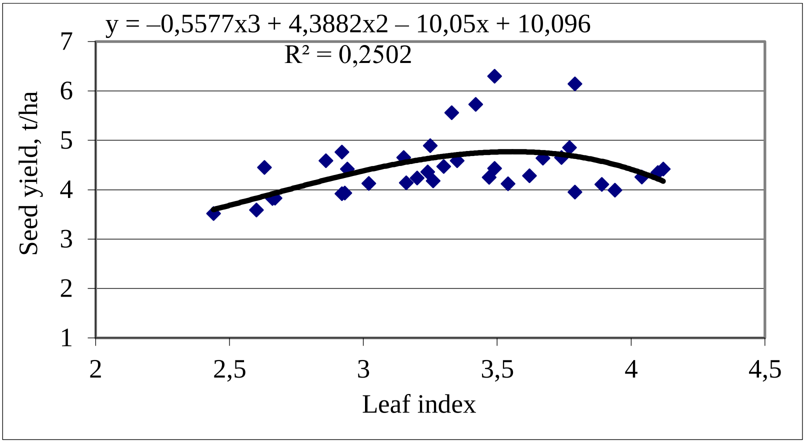

Fig. 1. Relationship of grain yield of maize hybrid parental lines to crop leaf area index (average for 2018–2020)

The analysis of variance showed that the maturity group had the most significant influence on grain yield, followed by planting density, with the least impact being due to treatment with biopreparations (Fig. 2).

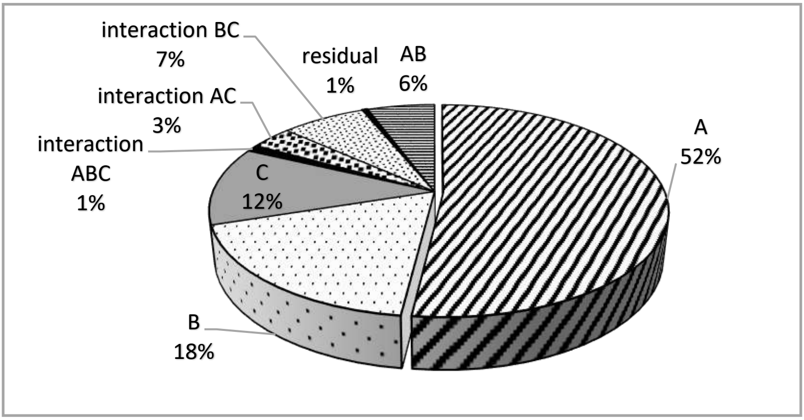

Fig. 2. Analysis of variance of the impact of maturity group (A), planting density (B), plant treatment with bioactive preparations, and their interaction on the grain yield of maize hybrid parental lines

While the effect of treatment with biologically active compounds was the least, its positive influence on the leaf area index of early- and mid-maturing lines suggests the potential for increased yield with such treatment. It is known that the increase in the leaf area index promotes enhanced sunlight absorption and effective utilization of solar energy[16, 17]. This, in turn, can contribute to the accumulation of dry matter post-flowering[18]. The positive effect of physiologically active substances can be associated with their regulatory and adaptogenic influence on plants[19, 20], as well as their impact on the genetic potential[21].

Therefore, our results indicate that the leaf area index can influence the photosynthetic performance of plants and is an important characteristic that affects maize yield[22].

2. Photosynthetic Potential of Maize Hybrid Parental Lines Depending on Experimental Factors

The photosynthetic potential of maize crops increases with the extension of the vegetation period, reaching maximum values in the mid-late maturity group DK 445 at a planting density of 90,000 plants/ha and treatment with the Helafit Combi preparation (Table 2).

The maximum photosynthetic potential of maize crops in all FAO maturity groups was observed at a planting density of 90,000 plants/ha, ranging from

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1994.7 thousand m^2days (line DK 281) to 3431.2 thousand m^2days (line DK 445).

Table 2

Photosynthetic Potential of Maize Hybrid Parental Lines during Vegetation (average for 2018–2020), thousand m^2*days

Parent Component (Factor A)	Plant Density (thousands per ha) (Factor B)	Treatment with Preparations (Factor C)			Average for Factor	
		Control	Bio-Gel	Helaphyte Combi	A	B
DK 281 (FAO 190)	70	1561,6	1664,0	1708,8	1824,7	1644,8
	80	1702,4	1868,8	1932,8		1834,7
	90	1875,2	2022,4	2086,4		1994,7
Average		**1713,1**	**1851,7**	**1909,3**		
DK 247 (FAO 290)	70	1867,3	2030,6	2073,2	2201,8	1990,4
	80	2087,4	2236,5	2307,5		2210,5
	90	2272,0	2463,7	2477,9		2404,5
Average		**2075,6**	**2243,6**	**2286,2**		
DK 411 (FAO 420)	70	2754,0	2805,0	2847,5	3075,1	2802,2
	80	3009,0	3077,0	3179,0		3088,3
	90	3221,5	3349,0	3434,0		3334,8
Average		**2994,8**	**3077,0**	**3153,5**		
DK 445 (FAO 420)	70	2830,5	2907,0	2966,5	3171,4	2901,3
	80	3119,5	3204,5	3221,5		3181,8
	90	3306,5	3485,0	3502,0		3431,2
Average		**3085,5**	**3198,8**	**3230,0**		
Average for Factor C		**2467,3**	**2592,8**	**2644,8**		
Assessment of the Significance of Partial Differences						
HIP_{05}, t/ha		A=150,5–180,5; B=95–110; C=85,0–92,3				

Treatment with biopreparations contributed to an increase in photosynthetic potential by 5.1 % for the Bio-Gel treatment and 7.2 % for the Helafit Combi treatment.

The correlation coefficient between photosynthetic potential and seed yield was r=+0.594 (Figure 2).

The significant coefficient indicates a positive but not significant impact of the photosynthetic potential on yield. A sharp decrease in yield was observed with an increase in photosynthetic potential beyond 3000 thousand m2*days. This suggests that increasing the photosynthetic potential of the maize canopy through agronomic practices may not always guarantee a synchronous increase in the yield of parental lines. Therefore, an optimal planting density should be determined for each maize parental line based on its genetic characteristics to maximize the productivity of the photosynthetic potential.

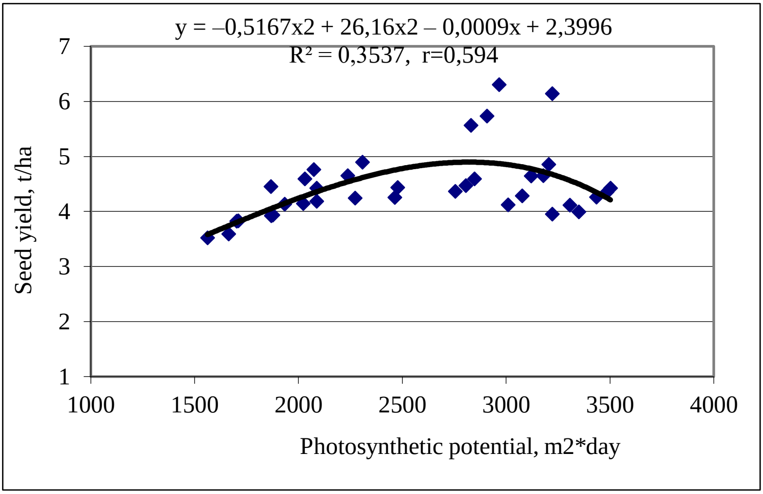

Fig. 3. Polynomial trend line depicting the relationship between the photosynthetic potential of maize hybrid parental lines and seed yield under irrigation, averaged for 2018–2020

3. The Impact of Plant Density and Biopreparations on Seed Yield Formation in Maize Parental Lines Under Irrigation

One of the critical components of maize plant productivity affecting seed yield and seed quality is the “1000-grain weight." Therefore, studying this trait and its relationships with other traits in parental lines has significant practical importance for seed production and determining priority selection parameters for breeding new high-yielding biotypes for specific agro-ecological zones.

The trait “1000-grain weight” was investigated in parental lines of various genetic backgrounds and FAO groups under irrigation. Observations conducted from 2018 to 2020 revealed that the 1000-grain weight depends on the line’s genotype, plant density, and biopreparation treatments.

Among the parental components, the highest average 1000-grain weight was observed in the mid-maturing line DK 445 of the Mixed genetic plasma

(FAO 420) with an average of 277.3 g. The lowest average weight was recorded by the Mixed genetic plasma line DK 247, with 229.6 g (Table 3).

Table 3

1000-Grain Weight of Maize Hybrid Parental Lines, g (average for 2018–2020)

Factor A (parent component)	**Factor C (plant density, thousand plants/ha)**	**Factor B (treatment with preparation)**			**Average for Factor**	
					A	**C**
		Control, no treatment	**Bio-Gel**	**Helaphyte Combi**		
DK 281 (Mixed plasma)	70	229	233	239		257
	80	226	231	238	232	252
	90	225	229	234		244
Average		**227**	**231**	**237**		
DK 247 (Mixed plasma)	70	232	234	243		
	80	225	228	235	229	
	90	216	221	230		
Average		**225**	**228**	**236**		
DK 411 (Iodent plasma)	70	266	274	281		
	80	255	271	276	267	
	90	251	267	264		
Average		**257**	**270**	**274**		
DK 445 (Mixed plasma)	70	279	286	293		
	80	276	281	285	**277**	
	90	262	264	270		
Average		**272**	**277**	**283**		
Average for Factor C		245	252	**257**		
Assessment of the Significance of Partial Differences						
HIP_{05}, г		A= 2,2; B=1,3; C=1,5				

The genotype of the parental line had the most significant impact on the 1000-grain weight of maize. On average across the years, the highest weight was exhibited by the mid-maturing line DK 445, which serves as the maternal form for new innovative hybrids such as Arabat, Vira, and Gileya, with an average of 285.9 g under a plant density of 70,000 plants/ha. Treatment with HelaFit Combi contributed to a 10.6 g increase in the 1000-grain weight, totaling 282.7 g. The maximum 1000-grain weight was observed in line DK 445 (Mixed Genetic Plasma, FAO 420) at 292.6 g under a plant density of 70,000 plants/ha and HelaFit Combi treatment. Increasing the plant density to 80,000 plants/ha led to a slight 2 % decrease in the 1000-grain weight compared to 70,000 plants/ha, with an average of 280.7 g. Treatment with Bio-Gel allowed for an increase in the 1000-grain weight to 281.4 g compared to the control (275.7 g). HelaFit Combi increased the 1000-grain weight to 285.0 g, an increase of 2.2 %. However, increasing the plant density to 90,000 plants/ha resulted in a significant decrease in the 1000-grain weight, with an average of 265.2 g. Bio-Gel treatment increased the trait by 2.1 g or 0.8 % to 263.7 g compared to the control. HelaFit Combi treatment increased the trait to 270.4 g, which is 8.8 g or 3.3 % higher compared to the control.

It was observed that line DK 445 negatively responded to increased planting density. In the study, all parental lines exhibited the maximum 1000-grain weight under a plant density of 70,000 plants, at 257.6 g. Increasing planting density to 80,000 plants resulted in a decrease to 252.3 g, and at a density of 90,000 plants/ha, it dropped to 244.6 g. The optimal planting density for the maximum expression of the "1000-grain weight" trait was found to be 70,000 plants/ha. Under a density of 90,000 plants/ha, all lines from different FAO groups and genetic plasmas showed minimal expression of the trait.

4. Laboratory Similarity of Seed in Maize Hybrid Parental Lines

It was established that the studied preparations, Bio-Gel and HelaFit Combi, effectively influenced the processes of grain formation in the lines, resulting in increased laboratory similarity of the obtained seeds (Table 4).

Table 4

Laboratory Similarity of Seed in Maize Hybrid Parental Lines, % (average for 2018–2020)

Factor A (parent component)	Factor B (treatment with preparations)			Average for Factor A
	Control, no treatment	Bio-Gel	Helaphyte Combi	
DK 281 (FAO 190)	96,9	97,2	98,5	97,5
DK 247 (FAO 290)	96,2	97,8	98,2	97,4
DK 411 (FAO 420)	94,5	96,9	97,2	96,2
DK 445 (FAO 420)	93,8	95,4	96,8	95,3
Average for Factor B	**95,4**	**96,8**	**97,7**	

Regarding seed similarity indices, the following was observed: the treatment of the hybrid parental lines with Bio-Gel and HelaFit Combi led to an increase in seed similarity. The use of Bio-Gel, on average, increased the seed similarity index by 1.5 %. Treatment with HelaFit Combi was more effective, with the seed similarity increasing by 2.4 %. The increase in seed similarity was attributed to reduced seed infection by Fusarium fungi (Fusarium moniliforme Scheld).

An analysis of the relationship between seed similarity in maize and the genotype of the parental components showed that late-maturing lines (FAO 420) DK 411 (Aiodent plasma) and DK 445 (Mixed plasma) exhibited lower similarity compared to early-maturing lines of Mixed plasma DK 281 (FAO 190) and DK 247 (FAO 290). Although the effect of treatment with biologically active agents was less pronounced than the genotype factor, its positive influence on seed similarity suggests the potential for increased similarity through such treatment.

5. Seed Yield of Maize Hybrid Parental Components Depending on Plant Density and the Action of Biological Preparations

It was determined that the highest seed yield was achieved in the mid-maturing line DK 445, ranging from 4.11 to 6.30 t/ha (parental components of the Vera, Arabat, Gileya hybrids), which is associated with an extended vegetation period and optimized technology under irrigation conditions.

Biological preparations significantly influenced the increase in seed yield compared to untreated controls. In the DK 445 line, the yield increase ranged from 0.14 to 0.46 t/ha or 3.2 % to 10.3 %. Among the preparations, HelaFit Combi proved to be the most effective. In the mid-maturing parental component group, the highest seed yield was recorded in the DK 445 line when using this preparation, reaching 5.62 t/ha (a yield increase of 0.85 t/ha or 17.8 %). In the DK 411 line, the yield reached 4.50 t/ha (a yield increase of 0.36 t/ha or 8.0 %). The mid-early parental component line DK 247 showed slightly lower yield, 4.69 t/ha when using the same preparation (a yield increase of 0.32 t/ha or 6.8 %). The early-maturing line DK 281 exhibited a yield of 4.05 t/ha when treated with HelaFit Combi (a yield increase of 0.29 t/ha or 7.2 %). The yield increase from Bio-Gel was significantly lower (Table 5).

Plant density is a crucial factor in the complex of agronomic practices for maize cultivation that significantly impacts crop yield. Achieving a substantial seed yield for maize lines depends on both individual plant productivity and the plant density that is environmentally appropriate for specific growing conditions.

On average for the years, the highest seed yield was achieved by the mid-maturing line DK 445 at a plant density of 70,000 plants/ha, reaching 5.86 t/ha. When the plant density increased to 80,000 plants/ha, the yield decreased to 5.21 t/ha. Further increasing the plant density to 90,000 plants/ha resulted in a sharp reduction in yield to 4.29 t/ha. The mid-maturing line DK 411 also demonstrated the maximum yield at a plant density of 70,000 plants/ha, producing 4.47 t/ha. When the plant density was increased to 90,000 plants/ha, the yield decreased to 4.07 t/ha. The mid-early line DK 247 achieved its highest yield at a plant density of 80,000 plants/ha, while the early-maturing line DK 281 exhibited its highest yield at a plant density of 90,000 plants/ha.

Table 5

Seed Yield of Maize Hybrid Parental Components Depending on Plant Density and the Action of Biological Preparations, t/ha (average for 2018–2020)

Parent Component (Factor A)	Plant Density (thousands per ha) (Factor B)	Treatment with Preparations (Factor C)			Average for Factor	
		Control, no treatment	Bio-Gel	Helaphyte Combi	A	B
DK 281 (FAO 190)	70	3,52	3,59	3,83	3,91	3,65
	80	3,82	3,92	4,13		3,96
	90	3,93	4,14	4,18		**4,08**
Average		**3,76**	**3,88**	**4,05**		
DK 247 (FAO 290)	70	4,45	4,59	4,76	4,52	4,60
	80	4,42	4,65	4,89		**4,65**
	90	4,24	4,25	4,43		4,31
Average		**4,37**	**4,50**	**4,69**		
DK 411 (FAO 420)	70	4,36	4,47	4,65	4,29	**4,47**
	80	4,12	4,28	4,59		4,35
	90	3,95	3,99	4,26		4,07
Average		**4,14**	**4,25**	**4,50**		
DK 445 (FAO 420)	70	5,56	5,73	6,30	**5,12**	**5,86**
	80	4,64	4,85	6,14		5,21
	90	4,11	4,35	4,42		4,29
Average		**4,77**	**4,98**	**5,62**		
Average for Factor C		**4,26**	**4,40**	**4,72**		
Assessment of the Significance of Partial Differences						
HIP_{05}, t/ha		A=0,22–0,25; B=0,19–0,21; C=0,12–0,15				

To investigate the relationship between the 1000-grain weight of the parental maize lines and seed yield, a correlation analysis was conducted. It was determined that a linear correlation exists ($r = 0.618 \pm 0.13$) between seed yield of the parental maize lines and the 1000-grain weight. (Figure 5).

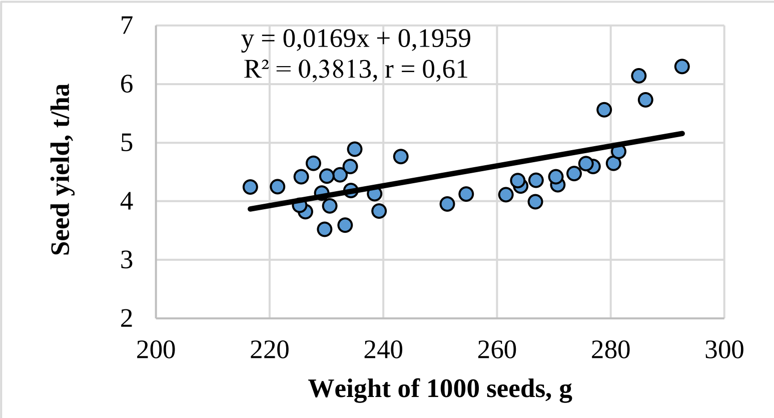

Figure 5. Correlation-Regression Model Depicting the Relationship between Seed Yield and 1000-Grain Weight (Average for 2018–2020)

Therefore, increasing the 1000-grain weight, influenced by both the genotype of the lines and the application of biologically active agents such as Bio-Gel and HelaFit Combi, has a positive impact on the seed yield of the parental components of the hybrids. On the other hand, increasing plant density in the crop negatively affects the "1000-grain weight", and, therefore, for each parental line component of the hybrid, the optimal plant density must be experimentally determined to achieve maximum seed yield and high sowing qualities.

Analyzing the obtained data, it can be concluded that plant density is closely associated with seed yield. Each maturity group has an optimal plant density for achieving maximum seed yield, which is related to the proper allocation of nutrient resources per plant. Mid-maturing parental components are most productive, but they negatively respond to overly dense plantings.

CONCLUSIONS

1 Our research results indicate that under the influence of bio-preparations, the leaf index increased by 5.3 % due to the action of the Bio-Gel preparation and by 7.2 % due to the Helaphyte Combi preparation. The extension of the vegetation period of the lines from FAO 190 to 420 resulted in an increase in leaf area of 16.9–23.7 %.

2 The correlation coefficient between the leaf index and seed yield was r = +0.309. A moderate correlation coefficient suggests that the positive influence of the leaf index on the yield of parent maize lines is significantly smaller compared to the impact of leaf area per plant on seed yield. Therefore, it is necessary to adjust the leaf index for each parent line to ensure maximum photosynthetic productivity and increased seed yield in seed production technologies.

3 The photosynthetic potential of corn crops increases with the lengthening of the vegetation period and reached maximum values in the mid-late group, line DK 445, at a planting density of 90,000 plants/ha, and treatment with the Helaphyte Combi preparation – 3502.0 thousand m2·days. The maximum photosynthetic potential of maize crops of all FAO groups was observed at a planting density of 90,000 plants/ha – from 1994.7 thousand m2·days (line DK 281) to 3431.2 thousand m2·days (line DK 445).

4 Treatment with biopreparations contributed to an increase in photosynthetic potential by 5.1 % due to treatment with Bio-Gel and by 7.2 % due to treatment with Helaphyte Combi. The analysis of variance showed that the maximum impact on grain yield of lines was made by the maturity group – 52 %, followed by planting density – 18 %, and the smallest impact was from treatment with biopreparations – 12 %.

5 It was established that treatment of parent line components with Bio-Gel and Helaphyte Combi preparations led to an increase in the laboratory similarity of seeds. The use of the Bio-Gel preparation increased the similarity index on average by 1.5 %. Treatment with the Helaphyte Combi preparation was more effective, as the similarity of seeds in this experimental variant increased by 2.4 %. The increase in laboratory similarity was observed due to a reduction in seed infection with Fusarium moniliforme Scheld. fungi.

6 For the maximum expression of the "1000-grain weight” feature, a planting density of 70,000 plants/ha was found to be optimal. At a density of 90,000 plants/ha, all lines from different FAO groups and genetic plasmas showed minimal expression of this feature. All parent lines demonstrated the maximum 1000-grain weight at a planting density of 70,000 plants – 257.6 g. Increasing the planting density to 80,000 plants led to a decrease in 1000-grain weight to 252.3 g, and at a density of 90,000 plants/ha, it decreased to 244.6 g.

SUMMARY

The main components of high yield are the productivity of individual plants and the number of plants per unit area. Excessive planting density leads to increased competition among plants for light, water, and nutrients. At the same time, in sparse plantings, the productivity of individual plants can be

maximized for a given genotype, but overall yield may decrease. Biopreparations, through physiologically active substances, allow for targeted influence on specific stages of ontogenesis to mobilize the genetic potential of the plant organism and ultimately increase productivity and harvest quality. It has been proven that the treatment of parent line components with the Bio-Gel and Helaphyte Combi preparations resulted in increased laboratory similarity of seeds, assimilation surface area, photosynthesis, and yield. The maximum seed yield in the early-maturing parent line DK 281 was recorded at a planting density of 90,000 plants/ha and treatment with the Helaphyte Combi preparation, yielding 3.65 t/ha. The maximum yield in the parent line component DK 247 was observed at a density of 80,000 plants/ha and treatment with the Helaphyte Combi preparation, yielding 4.89 t/ha. The mid-late parent line, DK 411, showed the highest yield at a density of 70,000 plants/ha and treatment with the Helaphyte Combi preparation, producing 4.65 t/ha. The maximum yield in the study was observed in the parent line component DK 445, yielding 6.30 t/ha at a planting density of 70,000 plants/ha and treatment with the Helaphyte Combi preparation.

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