Influence of plant density and biological products on the formation of seed yield of maize lines under irrigation conditions

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Abstract. Treatment with biological products resulted in an increase in the area of the assimilation apparatus by 1.7 to 2.4 thousand m²/ha.The application of Bio-gel led to an increase in leaf surface by 1.7 thousand m^2/ha or 5.3%, and the treatment with Helafit combi by 2.4 thousand m^2/ha or 7.5%. The treatment with biological products contributed to an increase in photosynthetic potential by 5.1% compared to the treatment with Bio-gel and by 7.2% compared to the treatment with Helafit combi. It was found that the treatment of parental lines with Bio-gel and Helafit combi caused an increase in laboratory germination of seeds. When using Bio-gel, the laboratory germination rate increased by an average of 1.5%. The treatment with Helafit combi was more effective, as the germination rate in this experimental variant increased by 2.4%. The increase in laboratory germination was observed due to a decrease in the infection of seeds of the lines by Fusarium moniliforme Scheld. The maximum seed yield in the early maturing line - the parent component of DK 281 was recorded at a density of 90 thousand plants/ha and treatment with Helafit combi - 3.65 t/ha. The maximum yield in the line - the parent component of DK 247 was observed at a density of 80 thousand plants/ha and treatment with Helafit combi - 4.89 t/ha. The medium-late line - the parent component DK 411 showed the highest yield at a density of 70 thousand plants/ha and treatment with Helafit combi - 4.65 t/ha. The maximum yield in the experiment was observed in the line

Keywords: treatment, biological, genotypic, maize, climate change

1 Introduction

1.1 Problem statement

The study of the effect of biopreparations with growth-regulating properties is promising and relevant, especially in the context of climate change. Analysis of literary data shows

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that the use of biopreparations contributes to the implementation of potential capabilities inherent in the body, including certain immune reactions, increases plant productivity and contributes to the implementation of genotypic traits of varieties and hybrids. The issue of the widespread use of biopreparations in agriculture is given considerable attention in most economically developed countries: France, Great Britain, Germany, Switzerland, the USA, etc [1-3].

In Ukraine, post-industrial agricultural production is developing using biotechnological alternatives to fertilizers and biological plant protection, precision farming, and minimization of soil structure degradation. The use of biopreparations allows reducing the anthropogenic impact of agricultural production on the environment, while simultaneously reducing energy and material costs and improving product quality.

Parental components of maize, as a product of prolonged forced self-pollination, are more demanding to growing conditions, are characterized by increased sensitivity to adverse factors, and have a smaller plant habitus compared to hybrids. Genotypic features of the line affect the phenotypic manifestation of traits, so it is necessary to take into account the biological characteristics of the parental components and technological recommendations for growing hybridization sites. In this regard, scientific developments on optimization of technological methods of growing seeds of maize lines - parental components of promising hybrids – are becoming increasingly important.

Modern parental components of corn, created for irrigation conditions, must be provided to production with certain parameters of technological requirements. This is especially true for sowing density and treatment with modern biological products. The studies conducted at different sowing densities made it possible to provide the production with parameters of adaptability of parental components to specific agroecological and technological features.

Cereals play a leading role in the food supply for humanity, with corn being particularly significant. Its distribution in almost all countries of the world is associated with high environmental plasticity and the ability of plants to produce high yields under different climatic conditions [5-7]. The high genetic potential of maize hybrids leads to intensive growth and development of plants, formation of biomass of a particular genotype. The physiological basis for the formation of their productivity is photosynthesis. Maize has a developed photosynthetic apparatus, which is used to accumulate organic matter from inorganic [8, 9]. In its ontogeny, the plant functions as a complex system, where a balance is maintained between shoots and roots in the use of water, nutrients and the exchange of nutrients between them. The main components of high yields are the productivity of an individual plant and the number of plants per unit area. Excessive thickening leads to increased competition between plants for light, water, and nutrition, while in a sparse crop, the productivity of an individual plant can be maximized for a given genotype, but the overall yield can decrease [8-10].

1.2 The aim

The aim of the research is to determine the effect of biological products on the elements of productivity and seed quality of lines of parental components of maize hybrids.

2 Research materials and methods

The research was conducted during 2018–2020 on the experimental field of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, located in the southwestern part of the Kherson region, 12 km from the city of Kherson, on the lands of the Ingulets irrigation system. The three-factor experiment (factor A – line maturity

group, B – plant density in the sowing, C – treatment of plants with biologically active preparations) was set up using the method of randomized split blocks. The sown area of the plots was 30.0 m^2, the accounting area was 20.0 m^2. The study was conducted in quadruplicate.

The material for the research was the parental forms of lines of different maturity groups: DK 445 (parental component of Arabat, Vira, Gilea hybrids); DK 411 (parental component of Chongar, Lamasan hybrids); DK 281 (parental component of Stepovyi hybrid); DK 247 (parental component of Skadovskyi, Oleshkivskyi hybrids). The sowing density of all parental forms was 70, 80, 90 thousand plants/ha.

The parental components of corn were treated with two biological products: Helafit combi and Bio-gel, both of which are included in the State Register of Pesticides and Agrochemicals Authorized for Use in Ukraine. The plants were treated twice with Helafit combi: at the stage of 7–8 leaves and panicle ejection (application rate – 1 l/ha), Bio-gel was used to treat seeds (at the rate of 2 l/t) and sprayed plants (1.5 l/ha) at the stage of 7–8 leaves.

The composition of Helafit combi includes: trace elements, ions of biogenic metals, free amine acid, humates, fatty acids, fatty acid esters, polysaccharides, steroid glucosides, vitamins, 3-indoleacetic acid, epibrassinolide, zeatin, alginic acid, hydroxycinnamic acid.

Main active ingredients of Bio-gel organic fertilizer: nitrogen, amino acids, threonine, phosphorus oxide, potassium oxide, manganese, zinc, molybdenum, copper, zinc, cobalt, saprophytic microorganisms.

3 Research results

The leaf area of the crop was quite variable and depended on the factors studied (Table 1).

Table 1. Area of assimilation surface of lines - parental components of maize in the flowering phase (average for 2018–2020), thousand m^2/ha

Parental component (factor A)	Plant density thousand plants/ha (factor B)	Treatment with drugs (factor C)			On average, by factor	
		Control, no tillage	Bio-gel	Halafit combo	A	B
DK 281 (FAO 190)	70	24.4	26.0	26.7	28.5	25.7
	80	26.6	29.2	30.2		28.6
	90	29.3	31.6	32.6		31.1
Average		**26.7**	**28.9**	**29.8**		
DK 247 (FAO 290)	70	26.3	28.6	29.2	31.0	28.0
	80	29.4	31.5	32.5		31.1
	90	32.0	34.7	34.9		33.8
Average		**29.2**	**31.6**	**32.2**		
DK 411 (FAO 420)	70	32.4	33.0	33.5	36.1	32.9
	80	35.4	36.2	37.4		36.3
	90	37.9	39.4	40.4		39.2
Average		**35.2**	**36.2**	**37.1**		
DK 445 (FAO 420)	70	33.3	34.2	34.9	37.3	34.1
	80	36.7	37.7	37.9		37.4
	90	38.9	41.0	41.2		40.3
Average		**36.3**	**37.6**	**38.0**		
Average by factor C		**31.8**	**33.5**	**34.2**		
Assessing the materiality of partial differences						
LSD_{05}, t/ha		A=2.0-2.3; B=1.5-1.8; C=0.5-0.8				

It was found that the leaf surface reaches its maximum development during the flowering period, respectively, in all the studied variants. However, there is also a significant difference between the effects of the factors studied.

Treatment with biological products provided an increase in the area of the assimilation apparatus by 1.7-2.4 thousand m^2/ha. The treatment with Bio-gel provided an increase in leaf surface by 1.7 thousand m^2/ha or 5.3%, and the treatment with Helafit combi by 2.4 thousand m^2/ha or 7.5%.

The increase in the area of the assimilation apparatus from the thickening of crops from 70 to 80 and 90 thousand plants/ha was 2.5–6.3 thousand m^2/ha, or 8.6–18.2%, depending on the variant of the experiment.

The genotype of the line influenced the leaf area. The largest leaf area of plants was 37.3 thousand m^2/ha in the medium-late DK 445 line, and the smallest was in the DK 281 variant and was equal to 28.5 thousand m^2/ha.

The maximum leaf surface area was observed in Line DK 445 at a density of 90 thousand plants/ha and treatment with Helafit combi – 41.2 thousand m^2/ha.

However, an increase in leaf surface area in cenosis may not always be a positive sign, since in case of thickening of crops, shading and, as a result, an increase in intraspecific competition, a decrease in photosynthetic activity are possible.

The photosynthetic potential of maize crops increases with the extension of the growing season and reached its maximum in the medium-late line DK 445 at a sowing density of 90 thousand plants/ha and treatment with Helafit combi – 3502.0 thousand m^2*day (Table 2).

The maximum photosynthetic potential of maize lines of all FAO groups was observed at the density of crops up to 90 thousand plants/ha – from 1994.7 thousand m^2*day (line DK 281) to 3431.2 thousand m^2*day (line DK 445).

Table 2. Photosynthetic potential of the line - parental components for the growing season (average for 2018–2020), thousand m^2*days

Parental component (factor A)	Plant density thousand plants/ha (factor B)	Treatment with drugs (factor C)			On average, by factor	
		Control, no tillage	Bio-gel	Halafit combo	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 by factor C		**2467.3**	**2592.8**	**2644.8**		
Assessing the materiality of partial differences						
LSD_{05}, t/ha		A=150.5-180.5; B=95-110; C=85.0-92.3				

The treatment with biological products contributed to an increase in photosynthetic potential by 5.1% compared to the treatment with Bio-gel and by 7.2% compared to the treatment with Helafit combi.

A significant coefficient indicates a positive but insignificant effect of photosynthetic potential on yield. A sharp decrease in yield was observed with an increase in photosynthetic potential from 3000 thousand m^2*days. This indicates that increasing the photosynthetic potential of maize cenosis by agronomic methods may not always guarantee a synchronized increase in yield in the parental lines. Therefore, for each parental line of maize, depending on the genotypic characteristics, there should be an optimum density of sowing cenosis, which ensures maximum efficiency of photosynthetic potential productivity.

Increasing the leaf surface area in the cenosis is not always positive, as in the case of thickening of crops, lower leaves may be shaded by upper leaves and, as a result, deterioration of radiation conditions and a decrease in the intensity of crop photosynthesis. It is known that in the theory of the production process, special importance is attached to an important cenotic indicator - the leaf index, which is defined as the ratio of the leaf surface area to the plant area. Therefore, we studied changes in the leaf index, which characterizes the photosynthetic activity of the crop. Its values ranged from 2.44 to 4.12 and depended on the effect of biological products, FAO group and cenosis density. The results obtained indicate an increase in the leaf index under the influence of biological products (Table 2).

The maximum values of leaf index in the flowering phase of cobs were observed in lines DK 411 and 445 (from 3.52–3.63 in the control variant to 3.62–3.80 in the treated variants). This confirms the known data on the larger assimilation surface area of later maturing varieties.

Table 3. Leaf index of lines - parental components of maize hybrids in the flowering phase depending on the factors of the experiment (average for 2018–2020).

Parental component (factor A)	Plant density thousand plants/ha (factor B)	Treatment with drugs (factor C)			On average, by factor	
		Control, no tillage	Bio-gel	Halafit combo	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 by factor C		**3.19**	**3.36**	**3.42**		
Assessing the materiality of partial differences						
LSD_{05}, t/ha		A=0.11-0.13; B=0.27-0.29; C=0.12-0.15				

Higher values of the leaf index of plants of parental components of all maturity groups, in contrast to the leaf area of one plant, were observed at a density of 90 thousand plants/ha (3.12–4.04), and the lowest – at a density of 70 thousand plants/ha (2.57–3.41). Thus, the thickening of crops increased the area of the assimilation surface of the crop.

The results of the research showed that, as for the area of one plant, the treatment of plants with FAO 190 and 290 with both preparations had a greater effect on the leaf index than with FAO 420: by 0.21–0.30 and 0.10–0.19, respectively. On average, under the influence of biological products, the leaf index increased by 5.3% under the influence of Bio-gel, and by 7.2% under the influence of Helafit combi.

Although the effect of treatment with biologically active compounds was the smallest, its positive effect on the leaf index of early and mid-season lines indicates the possibility of increasing their yields with such treatment. It is known that an increase in leaf index contributes to an increase in the absorption and efficiency of solar energy use. This, in turn, can contribute to the accumulation of dry matter in the period after flowering. The positive effect of physiologically active substances can be associated with both their growth-regulating and adaptogenic effects on plants and their effect on genetic potential.

Thus, our results show that the area of green leaves can affect the photosynthetic performance of plants and is an important characteristic that affects maize yield.

One of the important elements of maize plant productivity that affects the formation of yield and sowing qualities of seeds is the “weight of 1000 grains”. Therefore, the study of the manifestation of this trait and the relationship with other traits in lines is of great practical importance for seed production and determination of priority selection parameters in the selection of a new generation of high-yielding biotypes for specific agroecological zones of cultivation.

The trait “weight of 1000 grains” was studied in lines - parental components of different genetic plasmids and FAO groups under irrigation conditions. Observations conducted in 2018-2020 showed that the weight of 1000 seeds depends on the genotype of the line, plant density and treatment with drugs.

Among the parental components, the highest weight of 1000 grains was observed in the mid-season line Mixed genetic DC 445 (FAO 420), averaging 277.3 g. The lowest weight on average was shown by the plasma line Mixed DK 247 - 229.6 g (Table 4).

The genotype of the parental line had the most significant effect on the weight of 1000 corn kernels. Thus, on average over the years, the medium-late line DK 445, which is the mother form of new innovative hybrids Arabat, Vira, Gilea, showed the highest weight at a density of 70 thousand plants/ha, an average of 285.9 g. Treatment with Helafit combi contributed to an increase in the weight of 1000 grains by 10.6 g and amounted to 282.7 g. The maximum weight of 1000 grains was observed in the line DK 445 (Mixed genetic plasma, FAO 420) – 292.6 g at a plant density of 70 thousand plants/ha and treatment with Helafit combi. With an increase in density to 80 thousand plants/ha, the weight of 1000 grains of this line tended to decrease by 2% compared to the density of 70 thousand plants/ha and averaged 280.7 g. Treatment with Bio-gel allowed to increase the weight of 1000 grains to 281.4 compared to the control (275.7 g). The preparation Helafit combi increased the weight of 1000 grains to 285.0 or 2.2%. Increasing the density to 90 thousand plants/ha led to a sharp drop in the weight of 1000 grains to 265.2 g on average. Treatment with Bio-gel allowed to increase the manifestation of the trait compared to the control by 2.1 g or 0.8% to 263.7 g. Treatment with Helafit combi increased the manifestation of the trait compared to the control to 270.4 g, i.e. by 8.8 g or 3.3%.

Table 4. Weight of 1000 grains of lines - parental components of maize hybrids, g (average for 2018–2020).

Parental component (factor A)	Plant density thousand plants/ha (factor B)	Treatment with drugs (factor C)			On average, by factor	
		Control, no tillage	Bio-gel	Halafit combo	A	C
DK 281 (FAO 190)	70	229	233	239	232	257
	80	226	231	238		252
	90	225	229	234		244
Average		**227**	**231**	**237**		
DK 247 (FAO 290)	70	232	234	243	229	
	80	225	228	235		
	90	216	221	230		
Average		**225**	**228**	**236**		
DK 411 (FAO 420)	70	266	274	281	267	
	80	255	271	276		
	90	251	267	264		
Average		**257**	**270**	**274**		
DK 445 (FAO 420)	70	279	286	293	**277**	
	80	276	281	285		
	90	262	264	270		
Average		**272**	**277**	**283**		
Average by factor C		245	252	**257**		
Assessing the materiality of partial differences						
LSD_{05}, g		A= 2.2; B=1.3; C=1.5				

It was found that the line DK 445 negatively reacts to the density of crops.

In the experiment, all lines – parental components showed the maximum weight of 1000 grains at a density of 70 thousand plants – 257.6 g. Increasing the sowing density to 80 thousand plants led to a decrease in the weight of 1000 grains to 252.3 g, and at a density of 90 thousand plants/ha – to 244.6 g.

For the maximum manifestation of the trait "weight of 1000 grains", the density of 70 thousand plants/ha was optimal. At a density of 90 thousand plants/ha, all lines of different FAO groups and genetic plasmids showed a minimum manifestation of the trait.

It was established that the studied preparations Bio-gel and Helafit combi effectively influenced the processes of kernel formation of the lines, which ensured an increase in the laboratory germination of the obtained seeds (Table 5).

Table 5. Laboratory germination of seeds of lines – parental components of corn hybrids, % (average for 2018–2020).

Parental component (factor A)	Treatment with drugs (factor B)			On average, by factor
	Control, no tillage	Bio-gel	Halafit combo	
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 by factor B	**95.4**	**96.8**	**97.7**	

As for the laboratory germination of seeds, the following was found: treatment of parental lines with Bio-gel and Helafit combi caused an increase in laboratory germination of seeds. When using Bio-gel, the laboratory germination rate increased by an average of 1.5%. The treatment with Helafit combi was more effective, as the germination rate in this experimental variant increased by 2.4%. The increase in laboratory germination was observed due to a decrease in the infection of seeds of the lines by *Fusarium moniliforme* Scheld.

The analysis of the dependence of maize seed germination on the genotype of the parental components shows that later maturing lines (FAO 420) DK 411 (Ayodent plasma) and DK 445 (Mixed plasma) showed lower germination compared to earlier maturing lines of mixed plasma DK 281 (FAO 190) and DK 247 (FAO 290). Although the effect of treatment with biologically active preparations was less than the genotypic factor, its positive effect on the value of laboratory germination of lines indicates the possibility of increasing their germination with such treatment.

It was established that the highest seed yield was formed in the medium-late line DK 445 at the level of 4.11–6.30 t/ha (parental component of hybrids Vira, Arabat, Gilea), which is associated with the increased duration of the growing season and optimized technology under irrigation conditions.

The increase in seed yield, compared to the untreated control, was significantly influenced by biological products – the increase in seed yield in the DK 445 line was at the level of 0.14–0.46 t/ha or 3.2–10.3%.

The most effective among the preparations was Helafit combi. Thus, in the medium-late group of parental components, the highest seed yield was established in the line DK 445 with the use of this preparation – 5.62 t/ha (yield increase of 0.85 t/ha or 17.8%), in the line DK 411 - 4.50 t/ha (yield increase of 0.36 t/ha or 8.0%). The line-parent component of the medium early group – DK 247 showed a slightly lower yield – 4.69 t/ha using the same preparation (yield increase of 0.32 t/ha or 6.8%). The early maturing line DK 281 showed a yield of 4.05 t/ha with the use of Helafit combi (yield increase of 0.29 t/ha or 7.2%). The yield increase from the Bio-gel preparation was significantly lower (Table 6).

Plant density plays an important role in the complex of agronomic measures for growing corn, which determines the yield. A significant seed yield of the lines can be obtained due to high individual productivity and maximum permissible stem density under specific growing conditions.

On average over the years, the highest seed yield was in the medium-late line DK 445 at a density of 70 thousand plants/ha – 5.86 t/ha. At a density of 80 thousand plants/ha, the yield was 5.21 t/ha, with a thickening of crops to 90 thousand plants/ha, a sharp decrease in yield to 4.29 t/ha was observed. The medium-late line DK 411 also showed the maximum yield at a density of 70 thousand plants/ha – 4.47 t/ha. At a density of 90 thousand plants/ha, the minimum yield was observed – 4.07 t/ha.

The medium early line DK 247 showed the maximum yield at a plant density of 80 thousand plants/ha. The early maturing line DK 281 showed the maximum yield at a density of 90 thousand plants/ha.

Thus, the increase in the weight of 1000 grains, caused by both the genotype of the lines and the use of biologically active preparations Bio-gel, Helafit combi, has a positive effect on the seed yield of the lines - the parental components of hybrids. Increasing the density of plants in the sowing negatively affects the indicator “weight of 1000 grains”, so for each line - the parent component of the hybrid, it is necessary to experimentally establish the optimum plant density to obtain maximum seed yield and high sowing qualities.

Table 6. Seed yield of parental components of maize hybrids depending on plant density and the effect of biological products, t/ha (average for 2018–2020).

Parental component (factor A)	Plant density thousand plants/ha (factor B)	Treatment with drugs (factor C)			On average, by factor	
		Control, no tillage	Bio-gel	Halafit combo	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 by factor C		**4.26**	**4.40**	**4.72**		
Assessing the materiality of partial differences						
LSD_{05}, t/ha		A=0.22-0.25; B=0.19-0.21; C=0.12-0.15				

Analyzing the data obtained, it can be concluded that plant density is closely related to yield. Each maturity group has an optimal plant density to maximize the seed yield by maintaining the optimal feeding area per plant. The most productive medium-late parental components react negatively to crop density [7].

5 Conclusions

It was found that the leaf surface reaches its maximum development during the flowering period, respectively, in all the studied variants.

The genotype of the line influenced the leaf area. The largest leaf area of plants was 37.3 thousand m^2/ha in the medium-late line DK 445, and the smallest was in the variant DK 281 and was equal to 28.5 thousand m^2/ha. The maximum leaf surface area was observed in the DK 445 line at a density of 90 thousand plants/ha and treatment with Helafit combi - 41.2 thousand m^2/ha.

Treatment with biological products provided an increase in the area of the assimilation apparatus by 1.7-2.4 thousand m^2/ha. The treatment with Bio-gel provided an increase in leaf surface by 1.7 thousand m^2/ha or 5.3%, and the treatment with Helafit combi by 2.4 thousand m^2/ha or 7.5%.

Treatment with biological products resulted in an increase in photosynthetic potential of 5.1% compared to Bio-gel and 7.2% compared to Helafit Combi.

The photosynthetic potential of corn crops increases with the extension of the growing season and reached its maximum in the medium-late DK 445 line at a sowing density of 90 thousand plants/ha and treatment with Helafit combi - 3502.0 thousand m^2*day. The maximum photosynthetic potential of maize lines of all FAO groups was observed at the

density of crops up to 90 thousand plants/ha – from 1994.7 thousand m^2*day (line DK 281) to 3431.2 thousand m^2*day (line DK 445).

The results of our research show that under the influence of biological products, the leaf index increased by 5.3% under the action of Bio-gel, and by 7.2% under the action of Helafit combi. The increase in the growing season of lines from FAO 190 to 420 provided an increase in the area of the leaf apparatus by 16.9–23.7%.

It was found that the treatment of parental lines with Bio-gel and Helafit combi caused an increase in laboratory germination of seeds. When using the Bio-gel preparation, the laboratory germination rate increased by an average of 1.5%. The treatment with Helafit combi was more effective, as the germination rate in this experimental variant increased by 2.4%. The increase in laboratory germination was observed due to a decrease in the infection of seeds of the lines by Fusarium moniliforme Scheld.

For the maximum manifestation of the "weight of 1,000 grains" characteristic, the optimal density was 70,000 plants/ha. At a density of 90,000 plants/ha, all lines of different FAO groups and genetic plasmas showed minimal manifestation of the trait. All lines – parental components showed the maximum mass of 1000 grains at a density of 70 thousand plants – 257.6 g. An increase in the sowing density to 80 thousand plants led to a drop in the mass of 1000 grains to 252.3 g, and at a density of 90 thousand plants/ha-up to 244.6 g.

The maximum seed yield in the early ripening line - parent component DK 281 was recorded at a density of 90,000 plants/ha and treatment with Helafit combi - 3.65 t/ha. The maximum yield in the line - parent component DK 247 was observed at a density of 80,000 plants/ha and treatment with Helafit combi – 4.89 t/ha. The mid-late line — the parental component DK 411 showed the highest yield at a density of 70,000 plants/ha and treatment with Helafit Combi – 4.65 t/ha. The maximum yield in the experiment was observed in the line - parental component DK 445 – 6.30 t/ha at a density of 70 thousand plants/ha and treatment with the drug Helafit combi.

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