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## STATISTICAL ANALYSIS OF THE HEIGHT OF HYBRID PLANTS KN-517 AND KN-613 DEPENDING ON MINERAL FERTILIZATION AND CROP DENSITY

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### Abstract

The study was conducted between 2020 and 2022 in the experimental field of the Maize Research Institute-Knezha. The subject of the study is the following hybrids: Kn-517 group 500-600 FAO with a density 5500 p/da and 6000 p/da; Kn-613 group over 600 FAO with a density of 5200 p/da and 5700 p/da. The cultivated hybrids of each variation measured the height of 10 plants. The maize was grown under control variant  $T_0$  - without fertilization and two fertilization levels:  $T_1 - N_{8.5}P_{5.4}K_{6.4}$  and  $T_2 - N_{17}P_{10.8}K_{12.8}$ . On average for the period 2020-2022 on the Kn-517 hybrid the highest average height of  $x_{\text{average}} = 268.33$  cm was measured at a density of 6000 p/da and fertilized with  $N_{17}P_{10.8}K_{12.8}$ . The best result of  $x_{\text{average}} = 276.00$  cm at the average height in years was in 2021 and the density was 5500 p/da. In the same year, seed density and fertilization with  $N_{17}P_{10.8}K_{12.8}$  was measured maximum height  $Max = 285.00$  cm. The coefficient of variation was the lowest of  $CV=3.61\%$  for fertilization with  $N_{8.5}P_{5.4}K_{6.4}$  and the highest of  $CV=4.77\%$  for fertilizer  $N_{17}P_{10.8}K_{12.8}$  and a density 5500 p/da. This quantity changed by years from  $CV=2.57\%$  in 2020 to  $CV=4.35\%$  in 2022 and 6000 p/da. On average for the period 2020-2022 the Kn-613 hybrid for both densities of 5200 p/da and 5700 p/da was the largest average height of  $x_{\text{average}} = 279.33$  cm and  $x_{\text{average}} = 279.67$  cm measured by fertilizing with  $N_{17}P_{10.8}K_{12.8}$ . The study indicator had the best score in 2021. In the same year a maximum height of  $Max=296.00$  cm was measured at 5700 p/da and fertilization with  $N_{17}P_{10.8}K_{12.8}$ . The coefficient of variation changed from  $CV=3.37\%$  for  $N_0P_0K_0$  to  $CV=4.90\%$  for  $N_{17}P_{10.8}K_{12.8}$  and a density of 5200 p/da. For the years this quantity ranged from  $CV=2.53\%$  in 2022 to  $CV=3.67\%$  in 2021 and 5200 p/da.

**Keywords:** maize hybrids, density, fertilization, height of the plants

### INTRODUCTION

Maize has higher and unmet productive potential compared to other field crops. Regarding the conditions of the external environment, corn is demanding in terms of heat and moisture. In our country, for a large part of the country, the temperature conditions are favorable for its cultivation, but the limiting factor is the precipitation, which is why it is of crucial importance (Koteva et al., 2014). Maize is distinguished by a very high genetically determined productivity, the realization of which is influenced by the region with its characteristic soil and climate conditions and

the applied agro technical measures, among which the mineral fertilization is of dominant importance (Nenova, 2010; Kuneva, Bazitov, 2014; Traikov et al., 2017; Glogova, 2018). The interest in corn is based on its wide and varied use not only as feed for farm animals, but also in a number of productions of the food and chemical industries. Compared to other cultural species, it has one of the richest reserves of genetic resources (Pencheva, 2018; Aslam, M. et al., 2013). The presence of a large set of hybrids, which science offers to practice with different vegetation periods, makes it possible to use them most effectively by combining them in one varietal structure, depending on the soil,

climatic and agro technical factors for the individual regions of the country (Angelov, Glogova, 2010; Pencheva, 2019; Glogova, Nankov, 2020).

In the case of corn, intensive selection work is being carried out to create genotypes that combine high potential for productivity with relatively good resistance to adverse environmental conditions. Of great importance is the cultivation of maize hybrids of different maturity groups, which form the yield and give a high yield of grain and green mass for silage. One of the main agro technical factors for the formation of higher yields is fertilization.

The creation of new hybrids and their implementation in production requires doing research on their productivity and other important economic characteristics. Based on these studies, new maize hybrids with high genetic potential are included in production (Yordanov, 2019). In the studies of the Maize Research Institute – Knezha, experiments aimed at inheriting important elements of the productivity and yield of maize have been conducted for a long time (Vulchinkov and Vulchinkova, 2013; Vulchinkova and Vulchinkov, 2021; Petrovska and Valkova, 2016; Yordanov, 2013).

The aim of the research is to make a statistical analysis of the plant height of Kn-517 and Kn-613 hybrids, depending on the mineral fertilization and seeding density.

## MATERIALS AND METHODS

The study was conducted during the period 2020-2022 in the experimental field of the Maize Research Institute-Knezha. The object of research are the hybrids: Kn-517 group 500-600 according to FAO and density 5500 p/da and 6000 p/da; Kn-613 group above 600 according to FAO and densities 5200 p/da and 5700 p/da. On the grown hybrids of each variant, the height of 10 plants was measured. Maize was grown under control variant T0 - no fertilization and two levels of fertilization: T<sub>1</sub> –

N<sub>8.5</sub>P<sub>5.4</sub>K<sub>6.4</sub> and T<sub>2</sub> - N<sub>17</sub>P<sub>10.8</sub>K<sub>12.8</sub>. The experiment was based on a soil type of typical chernozem according to the block method in three repetitions with the size of the experimental plot 30 m<sup>2</sup>, and the harvest plot 25 m<sup>2</sup>. The main tillage is plowing with a plow at 23-25 cm, and the pre-sowing one - double cultivation with harrowing at 10-12 and 6-8 cm. The following herbicides were used to control weeds: Gardoprim plus Gold - 400-450 ml/da after sowing before crop emergence; Mistral Plus – 110 ml/da at a weed height (*Sorghum halepense*) of 20 cm and the 8<sup>th</sup> leaf of the corn.

Maize was sown after predecessor wheat, and for the study period – as a short-duration monoculture.

The mathematical processing of the data is done according to previous studies (Genchev, G. et al. 1975). The statistical analysis of the plant height was averaged over the period 2020-2022, both by cultivation options and by years on average from the control N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> and the two fertilization levels N<sub>8.5</sub>P<sub>5.4</sub>K<sub>6.4</sub> and N<sub>17</sub>P<sub>10.8</sub>K<sub>12.8</sub>.

On the cultivated hybrids of each variant the height of 10 plants was measured. The following indicators were studied:

$\bar{x}$  – average height of 10 plants

x – height of each plant

Min – minimum height

Max – maximum height

Amplitude:  $D = X_{\max} - X_{\min}$

Standard deviation:  $S = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$

Coefficient variation:  $CV\% = \frac{S \times 100}{\bar{x}}$

Average error:  $S\bar{x} = \frac{S}{\sqrt{n}}$

Relative value of the mean error:

$$S\bar{x}\% = \frac{S\bar{x}}{\bar{x}} \times 100$$

**Table 1.** Statistical analysis of plant height of maize hybrids Kn-517 and Kn-613 average for the period 2020-2022

Variants		Statistical magnitudes							
		$\bar{x}$	S	$S\bar{x}$	$S\bar{x}\%$	Min	Max	D	CV%
Kn-517	T <sub>0</sub>	248.67	11.44	6.61	2.66	235.00	263.00	28.00	4.60
5500 p/da	T <sub>1</sub>	267.00	9.63	5.57	2.09	257.00	280.00	23.00	3.61
	T <sub>2</sub>	267.00	12.75	4.25	1.59	257.00	285.00	28.00	4.74
Kn-517	T <sub>0</sub>	248.33	10.62	6.14	2.47	235.00	261.00	26.00	4.28
6000 p/da	T <sub>1</sub>	267.33	9.74	5.63	2.11	259.00	281.00	22.00	3.64
	T <sub>2</sub>	268.33	11.44	6.61	2.46	257.00	284.00	27.00	4.26
Kn-613	T <sub>0</sub>	259.33	8.73	5.05	1.95	250.00	271.00	21.00	3.37
5200 p/da	T <sub>1</sub>	275.00	13.49	7.80	2.84	258.00	291.00	33.00	4.90
	T <sub>2</sub>	279.33	11.95	6.91	2.47	266.00	295.00	29.00	4.28
Kn-613	T <sub>0</sub>	259.00	10.20	5.89	2.27	249.00	273.00	24.00	3.94
5700 p/da	T <sub>1</sub>	274.33	12.26	7.09	2.58	259.00	289.00	30.00	4.47
	T <sub>2</sub>	279.67	12.12	7.01	2.51	267.00	296.00	29.00	4.33

 T<sub>0</sub> – N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> – control

 T<sub>1</sub> – N<sub>8,5</sub>P<sub>5,4</sub>K<sub>6,4</sub>

 T<sub>2</sub> – N<sub>17</sub>P<sub>10,8</sub>K<sub>12,8</sub>

## RESULTS AND DISCUSSION

When growing the Kn-517 hybrid at a seeding density of 5500 p/da with the largest average plant height  $\bar{x} = 267.00$  cm, the fertilized variants T<sub>1</sub> and T<sub>2</sub> stood out (*Table 1*). The same pattern was observed at the higher density of 6000 p/da. The average plant height measured for her was  $\bar{x} = 267.33$  cm for using N<sub>8,5</sub>P<sub>5,4</sub>K<sub>6,4</sub> and  $\bar{x} = 268.33$  cm for N<sub>17</sub>P<sub>10,8</sub>K<sub>12,8</sub>, respectively. At both densities, the standard deviation was the lowest at S=9.63 cm and S=9.74 cm when fertilized with the lower T<sub>1</sub> fertilizer rate. For studies hybrid Kn-517 and density 5500 p/da, the numerical value of the average error varied from  $S\bar{x} = 4.25$  cm to  $S\bar{x} = 6.61$  cm, respectively, for fertilization with N<sub>17</sub>P<sub>10,8</sub>K<sub>12,8</sub> and for the control variant N<sub>0</sub>P<sub>0</sub>K<sub>0</sub>. At the higher seeding density of 6000 p/da, the studied value changed in a range from  $S\bar{x} = 5.63$  cm for variant T<sub>1</sub> to  $S\bar{x} = 6.61$  cm for T<sub>2</sub>. From the data shown in the Table, it can be seen that the relative value of the standard error was the lowest  $S\bar{x}\% = 1.59$  for the double dose of fertilizer N<sub>17</sub>P<sub>10,8</sub>K<sub>12,8</sub> and the lower seeding density, and the highest  $S\bar{x}\% = 2.66$  for the option without fertilization. The measured

minimum plant height ranged from Min = 235.00 for the control at both densities to Min = 259.00 cm for the variant with 6000 p/da and N<sub>8,5</sub>P<sub>5,4</sub>K<sub>6,4</sub> fertilization. Averaged over the study period, the maximum value of maize height was the greatest Max = 285.00 cm to Max = 285.00 cm to Max = 284.00 cm for densities 5500 p/da and 6000 p/da and fertilization respectively with N<sub>17</sub>P<sub>10,8</sub>K<sub>12,8</sub>. The smallest difference between the maximum and minimum height of the plants was found at the lower dose of the fertilizer N<sub>8,5</sub>P<sub>5,4</sub>K<sub>6,4</sub>. Its numerical value was D=23.00 cm for the first and D=22.00 cm for the second density. The same variation trend was observed for the coefficient of variation, CV=3.61% and CV=3.64%, respectively.

When growing hybrid Kn-613 at both densities 5200 p/da and 5700 p/da, the lowest average height  $\bar{x} = 259.00$  cm was measured in the variant without fertilization T<sub>0</sub>. The maximum value  $\bar{x} = 279.67$  cm of the same indicator was found when using a larger amount of N<sub>17</sub>P<sub>10,8</sub>K<sub>12,8</sub> fertilizer. For the lower density, the standard deviation ranged from S=8.73 cm for the control to S=13.49 cm for the use of N<sub>8,5</sub>P<sub>5,4</sub>K<sub>6,4</sub>. The same trend of change was observed when growing the maize with 5700

p/da respectively  $S=10.20$  cm for the variant without fertilization  $T_0$  to  $S=12.26$  cm for the variant  $T_1$ . When growing maize under natural conditions (without fertilization), the value of the standard error was  $S\bar{x} = 5.05$  cm for the first and  $S\bar{x} = 5.89$  cm for the second density. Under the influence of mineral fertilization, the maximum result  $S\bar{x} = 7.80$  cm was obtained from the use of  $N_{8.5}P_{5.4}K_{6.4}$  and a density of 5200 p/da. A similar regularity was observed in relation to the relative value of the indicator studied. It varied from  $S\bar{x}\% = 1.95$  for the control  $T_0$  to  $S\bar{x}\% = 2.84$  for the lower fertilizer dose  $T_1$ . From the three-year study period, the data showed that the minimum plant height measured was the lowest  $Min = 250.00$  cm and  $Min = 249.00$  cm for densities 5200 p/da and 5700 p/da and variant  $T_0$ , respectively. When using mineral fertilizer, the value of the specified indicator increased. Compared to variant  $T_0$ , the percentage increase from the use of  $N_{8.5}P_{5.4}K_{6.4}$  was 32% and 4.0% for densities

of 5200 p/da and 5700 p/da. The effect of twice the amount of  $N_{17}P_{10.8}K_{12.8}$  fertilizer was 6.4% and 7.2% for the indicated densities. At 5200 p/da, the measured maximum plant height of hybrid Kn-613 ranged from  $Max = 271.00$  cm for the control to  $Max = 295.00$  cm for the  $T_2$  variant. The increase resulting from this dose of fertilizer was 8.8%. For 5700 p/da, the studied indicator changed within the limits from  $Max = 273.00$  cm to  $Max = 296.00$  cm. As a result of the action of the fertilizer rates  $T_1$  and  $T_2$ , the plant height increased by 5.9% and 8.4%. From the data in the Table, it can be seen that regarding the height of the plants, the difference between their maximum and minimum size was the smallest  $D=24$  cm for variant  $T_0$  and the largest  $D=30$  cm for  $T_1$ . The data for the coefficient of variation are similar. Its numerical value was the smallest  $CV=3.9\%$  for growing maize without fertilization and the largest  $CV=4.47\%$  for fertilization with  $N_{8.5}P_{5.4}K_{6.4}$ .

**Table 2.** Statistical analysis of plant height of maize hybrids Kn-517 (2020-2022)

Statistical magnitudes	density – 5500 p/da				density – 6000 p/da			
	2020	2021	2022	Average	2020	2021	2022	Average
$\bar{x}$	257.00	276.00	249.67	260.89	258.33	275.33	250.33	261.33
S	6.63	9.42	10.37	8.81	6.65	10.21	10.88	9.25
$S\bar{x}$	3.83	5.44	5.99	5.09	3.84	5.90	6.29	5.34
$S\bar{x}\%$	1.49	1.97	2.40	1.95	1.49	2.14	2.51	2.05
Min	248.00	263.00	235.00	248.67	249.00	261.00	235.00	248.33
Max	264.00	285.00	257.00	268.67	264.00	284.00	259.00	269.00
D	16.00	22.00	22.00	20.00	15.00	23.00	24.00	20.67
CV%	2.58	3.41	4.15	3.38	2.57	3.71	4.35	3.54

When growing hybrid Kn-517 with 5500 p/da, the measured average height varied in a range from  $\bar{x} = 249.67$  cm for 2022 to  $\bar{x} = 276.00$  cm for 2021 (**Table 2**). On average for the research period, the indicator had a value of  $\bar{x} = 260.89$  cm. The calculated standard deviation had the lowest numerical value  $S=6.63$  cm for the first and the highest  $S=10.37$  cm for the third year of the experiment. A similar regularity was observed for the standard error, which varied within the limits from  $S\bar{x} = 3.83$  cm for 2020 to  $S\bar{x} = 5.99$  cm for 2022.

Regarding its relative value, these results are respectively: - from  $S\bar{x}\% = 1.49$  for the first to  $S\bar{x}\% = 2.40$  cm for the third year of the study. In the individual years of the study, maize height varied, with minimum sizes ranging from  $Min = 235.00$  cm to  $Min = 263.00$  cm in the third and second years, respectively. The same trend of change was observed in terms of its maximum height, which had values between  $Max = 257.00$  cm for 2022 to  $Max = 285.00$  cm for 2021. The difference between the indicated values was the lowest  $D=16.00$  cm in 2020. For 2021 and

2022, the indicator was equal to  $D=22.00$  cm. From the data in the Table, it can be seen that the coefficient of variation changed within the limit from  $CV=2.58\%$  for the first year to  $CV=4.15\%$  for the third experimental year.

Increasing the density from 5500 p/da to 6000 p/da did not result in a significant change in plant height. The measured average height ranged from  $\bar{x} = 250.33$  cm for 2022 to  $\bar{x} = 275.33$  cm for 2021. This result exceeded by 14.00 cm the average height obtained from the three years of the experiment. The calculated standard deviation was the lowest  $S=6.65$  cm for the first year and the highest  $S=10.88$  cm for the third year. The standard error followed the same direction of variation. Its values were  $S\bar{x} = 3.84$  cm and  $S\bar{x} = 6.29$  cm, respectively. Expressed

as a percentage, the specified value varied between  $S\bar{x} \% = 1.49$  and  $S\bar{x} \% = 2.51$ . The measured minimum height varied by year from  $Min = 235.00$  cm to  $Min = 261.00$  cm, for 2022 and 2021 respectively. The same variation trend was observed for the maximum height of maize, whose dimensions were  $Max = 259, 00$  cm and  $Max = 284.00$  cm. The range of the investigated values was the largest  $D=24.00$  cm for the third and the smallest  $D=15.00$  cm for the first year. Its average value was  $D=20.67$  cm over the three years of the study. From the data in the Table, it can be seen that the coefficient of variation changed from  $CV=2.57\%$  for 2020 to  $CV=4.35\%$  for 2022 and  $CV=3.54\%$  averaged over the three years of the experiment.

**Table 3.** Statistical analysis of plant height of maize hybrids Kn-613 for the period 2020-2022

Statistical magnitudes	density – 5200 p/da				density – 5700 p/da			
	2020	2021	2022	Average	2020	2021	2022	Average
$\bar{x}$	270.00	285.67	258.00	271.22	268.67	286.00	258.33	271.00
S	9.20	10.50	6.53	8.74	9.67	9.63	7.36	8.89
$S\bar{x}$	5.32	6.07	3.77	5.05	5.59	5.57	4.25	5.14
$S\bar{x} \%$	1.97	2.12	1.46	1.85	2.08	1.95	1.64	1.89
Min	257.00	271.00	250.00	259.33	255.00	273.00	249.00	259.00
Max	277.00	295.00	266.00	279.33	276.00	296.00	267.00	279.67
D	20.00	24.00	16.00	20.00	21.00	23.00	18.00	20.00
CV%	3.41	3.67	2.53	3.20	3.60	3.37	2.85	3.27

When growing hybrid Kn-613 with 5200 p/da and an average of the variants ( $T_0$ ,  $T_1$  and  $T_2$ ), the measured average height was the lowest  $\bar{x} = 258.00$  cm in 2022 (**Table 3**). The most favorable year for corn was 2021, during which the average height had the highest value  $\bar{x} = 285.67$  cm. It exceeded by 14.45 cm the average height obtained from the three experimental years. The standard deviation followed the same variation as that of the mean height. It ranged from  $S = 6.53$  cm to  $S = 10.50$  cm. The average error was the lowest score  $S\bar{x} = 3.77$  cm for the third year and the highest  $S\bar{x} = 6.07$  cm for the second. Its relative value was  $S\bar{x} \% = 1.46$  and  $S\bar{x} \% = 2.12$ , respectively. Both for the specified values and for the measured minimum and maximum height, the second year of the

experiment was the most favorable. The numerical values of this indicator were: -  $Min = 271.00$  cm and  $Max = 295.00$  cm. The difference between them was the highest  $D=24.00$  cm. The range of the indicated values had the lowest value  $D=16.00$  cm in 2022. The results are also analytical with regard to the coefficient of variation. It varied in a range from  $CV=2.53\%$  for the third year to  $CV=3.67\%$  for the second year.

When growing hybrid Kn-613 with 5700 p/da, the average measured plant height of the three variants ( $T_0$ ,  $T_1$  and  $T_2$ ) was the smallest  $\bar{x} = 258.33$  cm for 2022. This result was smaller by 12.67 cm compared to the study period average. In 2021, the same indicator had the highest value  $\bar{x} = 286.00$  cm. It exceeded by

15.00 cm the average obtained for the three years of the experiment. The standard deviation ranged from  $S = 7.36$  cm to  $S = 9.67$  cm, for the third and first years, respectively. The same trend of change was observed in terms of the standard error and its relative magnitude. Their obtained results were in the range of  $S\bar{x} \% = 4.25$  cm to  $S\bar{x} \% = 5.59$  cm and from  $S\bar{x} = 1.64$  to  $S\bar{x} = 2.08$ . For the minimum and maximum height of maize, the best results were obtained in 2021, respectively  $\text{Min} = 273.00$  cm and  $\text{Max} = 296.00$  cm. The difference between them had the highest value  $D=23.00$  cm. It exceeded by 3.00 cm the average obtained for the study period. By year, the coefficient of variation ranged from  $CV=2.85\%$  to  $CV=3.60\%$ , for the third and first year, respectively. On average for the period 2020-2022, this indicator had a value of  $CV=3.27\%$ .

### CONCLUSION

Average for the period 2020-2022 year for hybrid Kn-517, the greatest average height  $\bar{x} = 268.33$  cm was measured at a density of 6000 p/da and fertilization with  $N_{17}P_{10.8}K_{12.8}$ . By years, the specified magnitude had the best result  $\bar{x} = 276.00$  cm in 2021 and a density of 5500 p/da. In the same year, seeding density and fertilization with  $N_{17}P_{10.8}K_{12.8}$ , the maximum height of the maize was measured  $\text{Max} = 285.00$  cm. The coefficient of variation was the lowest  $CV=3.61\%$  for fertilization with  $N_{8.5}P_{5.4}K_{6.4}$  and the highest  $CV=4.77\%$  for fertilizer rate  $N_{17}P_{10.8}K_{12.8}$  and a density 5500 p/da. By years, this value changed from  $CV=2.57\%$  for 2020 to  $CV=4.35\%$  for 2022 and 6000 p/da.

Average for the period 2020-2022 year for hybrid Kn-613 and for both densities 5200 p/da and 5700 p/da the greatest average height  $\bar{x} = 279.33$  cm and  $\bar{x} = 279.67$  cm was measured when fertilized with  $N_{17}P_{10.8}K_{12.8}$ . The studied indicator had the best result  $\bar{x} = 286.00$  cm in 2021. In the same year, the maximum height  $\text{Max} = 296.00$  cm was measured at 5700 p/da and the fertilizer rate

$N_{17}P_{10.8}K_{12.8}$ . The coefficient of variation changed from  $CV=3.37\%$  for  $N_0P_0K_0$  to  $CV=4.90\%$  for  $N_{8.5}P_{5.4}K_{6.4}$  and a density of 5200 p/da. By year, this height ranged from  $CV=2.53\%$  for 2022 to  $CV=3.67\%$  for 2021 and 5200 p/da.

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