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# *EFFECTS OF PLANT GROWTH REGULATORS ON SEED PRODUCTIVITY OF MAIZE LINES*

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Effects of plant growth regulators and methods of their application on morphometric parameters, duration of phenological phases, anthesis synchrony, pollen formation and viability of the parents of the 1st generation maize hybrids were studied. As to the biometric parameters in lines – sterility maintainers, plant growth regulators influenced the plant height in lines Kharkivska 155 ZM and Kharkivska 164 ZM. Anthesis was highly synchronic in lines Kharkivska 126 M and Kharkivska 126 ZM as well as in Appetizer-treated lines Kharkivska 215 M and Kharkivska 215 ZM (treatment 2). Plant growth regulators affected the seed productivity in lines – sterile counterparts in all the experiments. In all the lines - sterility maintainers (except for line Kharkivska 215 ZM), the effects of plant growth regulators on the seed productivity were noted in experiments 2 (Appetizer, spraying in the 5th leaf phase) and 3 (Nertus Plants Peg, pre-sowing seed treatment). It was found that lines with better anthesis synchrony had higher seed productivity. The best response to growth regulators was recorded in lines Kharkivska 126 M-ZM and Kharkivska 215 M. Treatment 2 (Appetizer) can be distinguished as the most effective growth regulator.

***Keywords:*** *maize, seed production, plant growth regulators, seed productivity*

Low seed productivity of maize hybrids' parents hinders the introduction of promising hybrids into production. Therefore, development of methods to apply growth regulators as a way to increase the seed productivity of hybrids' parents is important for maize seed production.

The widespread introduction of new high-yielding maize hybrids into production requires consistent seed production of starting parental forms – self-pollinated lines, which, until today, are characterized by relatively low productivity and significantly respond to changes in growing conditions [1]. Application of plant growth regulators (PGR), which, according to numerous scientific and industrial studies, affect the growth, development and performance of plants by stimulating important physiological processes, is a way to increase the seed productivity and yield of certified seeds from of maize hybrids' parents. Application of plant growth regulators or biostimulants is an important element of environmentally friendly and resource-saving technologies for growing agricultural different crops, which helps to increase their yields and quality of products manufactured [2, 3].

Results of studies and industrial trials indicate that application of growth regulators in cultivation technologies is one of the most affordable and highly profitable agro-measures to improve the preformance of basic crops and improve their quality [4-8].

For now, a large number of methods and systems for the use of growth regulators have been developed to improve the performance of commercial maize crops. However, the growth regulator effectiveness problem in improving the maize seed productivity in the primary seed production steps as well as in early stages of breeding is not sufficiently addressed.

Heterotic hybrids' parents are pure self-pollinated lines that are highly homozygous. Since maize is a cross-pollinated crop, forced self-pollination comes with a price of the inbreeding depression phenomenon, which is manifested as an integral decline in biological parameters such as growth, development, viability, and especially seed productivity [9]. Parents' low seed productivity hinders the introduction of promising hybrids into production. Therefore,

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development of methods of using growth regulators as a way to improve the seed productivity of hybrids' parents is important for maize seed production.

The amount of viable pollen produced by a plant is an indicator that largely determines the seed productivity of maize hybrids' parents. Hence, the pollen productivity of pollinators is an important factor in influencing the number of set seeds [10-13]. Because of this, the issue of the impact of growth regulators on the pollen-forming ability of maize sterility maintainers and fertility pollen restorers needs in-depth research.

Taking the above-said into account, studying effects of growth regulators on the seed productivity and sowing characteristics of seeds of female forms and on the pollen-forming ability of maize hybrids' parents as well as developing growth regulator application methods in the primary seed production steps are relevant and important scientific objectives for maize breeding and seed production.

In 2018-2019, the effects of different treatments on the morphometric parameters, duration of phenological phases, anthesis synchrony, pollen formation and viability of lines - maize hybrids' parents were determined.

## Materials and Methods

The effects of plant growth regulators on the sowing characteristics of seeds, seed productivity and pollen-forming ability of parents, as well as the effect of anthesis synchrony of tassels and stigmas on the productivity of maize hybrids were investigated.

The experiments were conducted in the crop rotation fields of the Plant Production Institute named after V.Ya. Yuriev of NAAS in 2018–2019. Seeds of maize lines were sown with manual planters in six-row plots of 29.4 $m^2$ (arrangement 4♀:2♂), in four replications. Phenological observations and biometric measurements were performed on 10 plants in each replication.

Eight maize lines – hybrids' parents were taken as the test material: 4 lines – sterile counterparts (Kharkivska 126 M, Kharkivska 215 M, Kharkivska 164 M, and Kharkivska 155 M) and 4 lines – sterility maintainers (Kharkivska 126 ZM, Kharkivska 215 ZM, Kharkivska 164 ZM, and Kharkiv 155 ZM).

There were 4 treatments: 1) no treatment (control); 2) Appetizer – spraying in the phase of 4-5 leaves; 3) Nertus Planta Peg – pre-sowing seed treatment; 4) Nertus Planta Peg – pre-sowing seed treatment + spraying in the phase of 4–5 leaves.

The stigma viability was determined by sequential removal of plastic bags [14, 15].

Phenological observations were performed visually, taking into account the condition of plants in a plot and recording the complete (75% of plants) onset of a developmental stage [16]. A system developed at Iowa State University of Science and Technology (Table 1) was used to identify and designate the stages of development [17].

The plant height and height of cob attachment for 10 plants in each of 4 replications were measured with a scale stick. The plant height was measured from the end of the lowest internode to the tassel apex; the height of cob attachment - from the lowest internode to the internode with the highest cob peduncle [18].

The plant condition during the leaf formation completion and tassel emergence onset was evaluated by Yu. I. Chirkov's method [14]. For this, the plant height and the largest diameter of the plant stem were measured on 10 plants during the leaf formation completion. Using these data, we estimated the plant weight according to the Table. From the plant weight, the plant condition was ranked with a five-point scale.

To evaluate the accession performance, the following parameters were recorded:

- The plant number per plot;
- The infertile plant number;
- The number of plants with undeveloped cobs;
- The number of plants with complete cobs.

One average quantitative sample of cobs (10 cobs) was taken and weighed for drying and analyzing the cob structure [19].

The water content at harvest and after drying was determined using an IVTs-2 hydrometer.

After drying, the samples of cobs were weighed, and the cob structure was analyzed. Then the cobs were threshed, and the 1000-kernel weight and the shaft diameter were determined [16].

The cob structure analysis included: the cob length, the diameter in the middle of the cob, the number of kernel rows and the kernel number per row. To determine the 1000-kernel weight, two samples of 250 kernels were taken and weighed [16].

Table 1.

**System of Identification and Designation of the Developmental Stages**

| Vegetative stages | | Reproductive stages | |
|---|---|---|---|
| designation | characteristic | designation | characteristic |
| VE | Emergence of shoots from soil | R1 | (silk) Emergence of 1 or more stigmas from the cob |
| V1 | The lowest leaf has a visible collar; this leaf has a rounded tip, unlike subsequent pointed leaves | R2 | (blister) Kernels look like small blisters with clear fluid (endosperm) |
| V2 | Two lowest leaves have visible collars | R3 | (milk) Kernels are yellow with milky white fluid |
| V(n) | “n” leaves have visible collars | R4 | (dough) Kernel contents are pasty as starch accumulates |
| VT | The lowest branch of the tassel is visible | R5 | (dent) Most kernels are dented due to the starch hardening at the top of the kernel. As maturity progresses, the starch hardens and the milk line moves toward the cob. |
| - | - | R6 | (black layer or physiological maturity) The milk line is no longer visible; a black layer forms at the kernel’s attachment, which signifies the end of dry matter accumulation. |

The suitability of accessions for seed production is determined not only by seed productivity, 1000-kernel weight and kernel variability, but also by pollen-forming ability. For this purpose, 10 tassels were taken in each experiment (in three replications), on which the type of tassel, the tassel length, the number of lateral branches, the number of spikelets and the number of flowers on the central axis and lateral branches were determined [16].

The viability of stigmas in sterile analogues was determined by T. Sundi’s technique, which was used to study the effect of simultaneous flowering on the quantity and quality of maize seeds at the Agricultural Research Institute of the Hungarian Academy of Sciences, Martonvashar. This technique includes the following: cobs of 25 plants of each sterile analogue were insulated under plastic bags until the stigma emergence (a typical non-insulated plant was taken as control); the plastic bags were removed five at a time every 3 days from the day when the first stigmas had appeared, and the fertilization percentage was calculated for the harvested cobs [20].

In the laboratory, the experiments were conducted to determine the pollen-forming ability, as described in [10] and the pollen viability by P.I. Diaconu’s method [19].

The pollen-forming ability of maize lines – sterility maintainers was determined using a Fuchs-Rosenthal chamber in three replications [10]. This technique consists in calculating pollen grains in a Fuchs-Rosenthal chamber. For this purpose, closed flowers were collected from the middle part of the main axis of the tassel from 5 typical plants one day prior to anthesis. To make a preparation, 10 anthers were removed from these flowers; they were placed in an Eppendorf tube; and then a few drops of concentrated sulfuric acid were added to dissolve all biological residues except pollen grains. For proper dissolution of the anther pieces, the solution was periodically stirred with a glass rod for 2-3 minutes. Afterwards distilled water was added to the tube until the total volume of the solution was exactly 1 ml. After thoroughly stirring the resulting solution, several drops were aspired with an automatic pipette and then placed on the Fuchs-Rosenthal chamber grid. The number of pollen grains in 5 squares of 1000 x1000 μm and a total volume of 0.2 $mm^3$ was calculated. Thus, the number of pollen grains in the chamber of a total volume of 1 $mm^3$ ($0.2 \times 5 = 1$) was obtained, and then the number of pollen grains per anther was calculated by the following formula:

$PG = n \times 1000/10$,

where PG is the number of pollen grains per anther;

n is the number of pollen grains in 1 $mm^3$ of solution, which is multiplied by 1000 to determine the number of pollen grains in 1 ml;

10 is the number of dissolved anthers in 1 ml of solution.

Having determined the number of pollen grains per anther and the total number of anthers per tassel, the pollen productivity per plant was calculated by the following formula:

$PP = PG \times A$,

where: PP is the pollen productivity;

PG is the number of pollen grains per anther;

A is the number of anthers per tassel.

The pollen viability was determined for 4 lines – sterility maintainers, 4 treatments in 3 replications by P.I. Diaconu's method (Z.P. Pausheva, 1980) [19, 21].

The pollen viability is confirmed by active dehydrogenase of the respiratory chain, in the presence of which a colorless solution of 2,3,5-triphenyltetrazolium chloride is reduced to bright red formazan. Dead pollen grains remain colorless. Pollen is placed in 1-2 drops of 0.5-0.1% solution of 2,3,5 triphenyltetrazolium chloride in 1/15 M Sorensen's phosphate buffer, pH 7.17, covered with a cover glass and put in a thermostat at 37°C for 20 - 30 minutes. Five viewing fields in each preparation are microscopically viewed. Red pollen grains are considered to be viable. For this experiment, 5 tassel fragments (middle part of the central axis of the tassel) were taken in a plot 1-2 days before flower opening. For each preparation 3 anthers were taken from each tassel fragment, from 2 flowers.

The laboratory germinability and germination energy of 4 lines – sterility maintainers and 4 sterile analogues were determined by germination method [22]. For this purpose, 4 samples of 50 seeds each were taken and placed in Petri dishes in a thermostat. To interrupt the dormancy of maize seeds, they were pre-cooled. For this purpose, the seeds sown on a moist substrate were kept at 5-10°C for 4 days and then returned to normal temperature. The germination energy was determined 2 days after pre-cooling, and the germinability – after 5 days. This method enabled determining the percentage of sprouted seeds, which are capable of giving good, proportionally developed, intact, and healthy (or with slight defects) sprouts under optimal conditions of germination. Seeds with high germination energy give early and even sprouts.

All mathematical and statistical calculations were performed in Microsoft Office Excel and Statistica 10 (serial number BXXR502C631824NET3). In addition to standard calculations of mean, maximum and minimum values, analysis of variance and correlation analysis of data were performed [10, 23, 24].

Agrotechnics in the experiments was aimed at ensuring optimal conditions for the plant growth and development and in accordance with conventional zonal recommendations [10, 22]. The crop care consisted of pre-sowing application of herbicide Hortus at a dose of 2 L/ha, 1 interrow cultivation and 2-3 pullings.

The experimental plots were in the crop rotation fields of the Plant Production Institute named after V.Ya. Yuriev of NAAS. Four separated six-row plots were seeded by manual semi-automatic planters on May 8, with a ratio of 4♀ to 2♂. The plot area for each treatment in 1 replication was 26.46 m$^2$, with a plant density of 60,000 plants/ha and an interrow spacing of 70 cm. The total area of the plots, including 4 treatments in 4 replications, plus 2 rows of headland was 573.3 m$^2$.

Before sowing, according to the experiment design, the seeds in all the 4 experiments were dressed with fungicide Insure at a dose of 0.5 L/t, and the seeds in experiments 3 and 4 were treated with Nertus Planta Peg at a dose of 0.4 L/t (Table 2).

Table 2.

**Experiment Design**

| Treatment | Agent and method of application | |
|---|---|---|
| | pre-sowing seed treatment | spraying in the phase of 5 leaves |
| 1 | Insure, 0.5 L/t (контроль) | - |
| 2 | Insure, 0.5 L/t | Appetizer, 0.5 L/ha |
| 3 | Insure, 0.5 L/t +<br>Nertus Planta Peg, 0.4 L/t | - |
| 4 | Insure, 0.5 L/t +<br>Nertus Planta Peg, 0.4 L/t | Nertus Planta Peg, 0.3 L/ha |

At the beginning of June, depending on the onset of the 5-leaf phase in the plot, spraying with Nertus Planta Peg and Appetizer was carried out at a dose of 0.3 L/ha and 0.5 L/ha, respectively.

Spraying was perfoemed with a sprayer at a flow rate of 300 L/ha.

**Weather conditions during the study period**. The experimental plots were seeded within the third 10 days of April in 2018 and 2019. The average temperature in April 2018 was 12.4$^o$C, which exceeded the multi-year average by 2.8$^o$C. The April was 12.9 mm (36.3% of the multi-year average). The May average air temperature was 19.9°C, which was by 3.8°C higher than the multi-year average, and the May precipitation was 15.9 mm (by 36.8% lower than the multi-year average). The maximum air temperature reached 26.0°C; the minimum temperasture dropped to 5.0$^o$C. In 2018, the weather during the spring-summer growing period was arid. Thus, the rainfall in April – August was 160.1 mm, or 61% lower than the multi-year average. The average daily temperature exceeded the multi-year average by 2.7°C.

Overall, in 2019 the growing period was characterized by high temperatures and low relative humidity of air. Thus, the average daily temperatures in April, May, June, August, and September exceeded the multi-year average by 1.9, 2.3, 4.6, 1.5, 2.8ºC, respectively. The average daily air temperature in July was close to the multi-year average of 21.4 ºC.

The rainfall in April exceeded the multi-year average by 9.0 mm, or 25%; in May it was similar to the multi-year average; and in June, July, August, and September it was significantly lower than the multi-year average by 48.1, 32.9, 33, 3, and 30.5 mm, respectively, or by 76, 46, 71, and 70%, respectively.

**Results and Discussion**

*Effects of growth regulators on the phenological phases and biometric parameters of maize hybrids' parents. Phenological observations.* The phenological phases of the plant development in the maize hybrids' parents in the 4 experimental plots during the vegetation periods of 2018–2019 were mostly equable. The phenological phases, which had certain time differences, are the phases of tassel and stigma flowering. For example, in lines Kharkivska 215 M, Kharkivska 155 M and Kharkivska 164 M, the "complete sprouts" phase was observed on days 14, 16 and 19 after sowing, respectively. In the control plots, Kharkivska 126 sprouted later: sprouts emerged 1-2 days later (on days 15–16) than in the plots with treatment 2, 3 and 4 (on days 14–15). The leaf formation phase was rather equable in all the lines under investigation, with the maximum difference of 1 day, depending on the treatment. No effects of growth regulators during this period were noted. Table 3 shows the duration of the interphase periods in maize lines – sterile counterparts.

Table 3.

**Duration of the Interphase Developmental Periods in Maize Lines – Sterile Counterparts (days), 2018–2019**

| Period | Kharkivska 126 M | Kharkivska 215 M | Kharkivska 155 M | Kharkivska 164 M |
|---|---|---|---|---|
| Sowing-sprouts | 15 | 12 | 14 | 18 |
| Sprouts-stigma flowering | 59 | 58 | 57 | 59 |
| Stigma flowering – dent stage | 37 | 40 | 38 | 38 |

The development stage lengths in maize plants somewhat differed between the lines (Fig. 1).

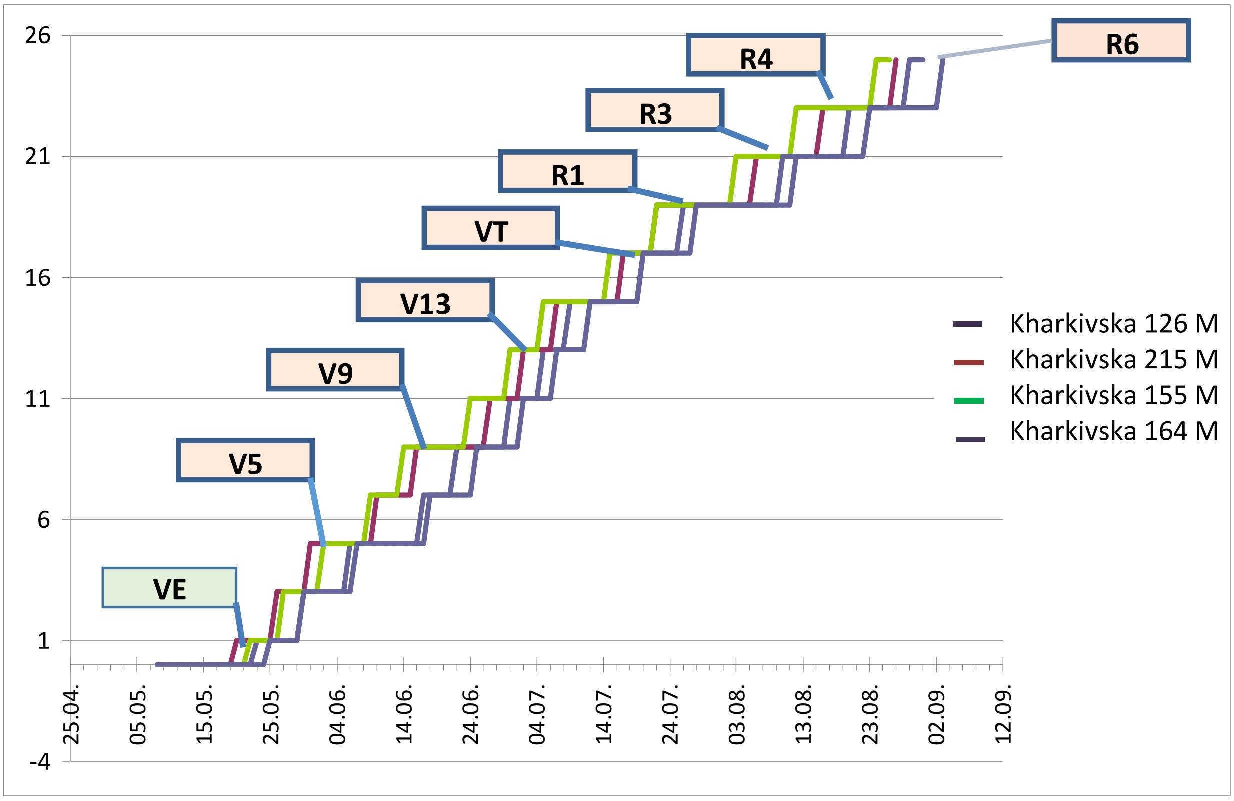

**Fig. 1**. Development Dynamics in Maize Lines – Sterile Counterparts, 2018.
* See the stage designations in Table 1.

The growing period was the shortest in lines Kharkivska 155 M and Kharkivska 215 M. In these lines, all vegetative stages passed almost simultaneously until R2, but they reached the stage of kernel physiological maturity with several day-difference (26/08/2018-27/08/2018). In lines Kharkivska 126 and Kharkivska 164 VE-V7 and VT were only simultaneous, the remaining stages in Kharkivska 164 were longer than those in the other lines, according to its ripeness group. As a result, line Kharkivska 164 was the last to reach the physiological maturity stage (R6) – 03/09/2018.

The growth regulators affected the anthesis length.

**Biometric parameters of maize hybrids parents**. To elucidate the plant growth regulator influence on the biometric parameters of the parental lines of maize hybrids, the plant height and cob attachment height were measured in all the lines, and for the lines – sterile counterparts, the diameter of the thickest part of the stem was additionally measured for further determination of the plant weight and overall condition at the tassel emergence end.

In the lines – sterile counterparts, a significant influence of the growth regulators on the plant weight and condition was observed before the tassel emergence onset (Table 4). Thus, the overall condition of Kharkivska 126 M plants in the control plot was 4 points by a five-point scale, while in the PGR-treated plots, this index was 5 points for treatments 2 (Appetizer) and 4 (Nertus +). It is also noteworthy that the plant weight was higher in the Nertus and Nertus + experiments. The plant height and cob attachment height were slightly bigger in the Appetizer experiment – the difference was 2–3 cm for the both parameters compared to the control.

In lines Kharkivska 215 M, Kharkivska 155 M and Kharkivska 164 M, the plant weight and overall condition were higher in all the PGR-treated plots than in the corresponding control ones. As to the plant height and cob attachment height, in these lines – sterile counterparts, the PGR-treated plots did not significantly exceed the corresponding control ones (on average by 2–3 cm higher than in the control).

Table 4.

**Plant Growth Regulator Effects on the Biometric Parameters of Maize Lines – Sterile Counterparts, 2018–2019**

| Treatment | Plant height, cm | | | Cob attachment height, cm | | | Estimated plant weight during the tassel emergence, g | Plant condition, points (1–5) |
|---|---|---|---|---|---|---|---|---|
| | mean | max | min | mean | max | min | | |
| Kharkivska 126 M | | | | | | | | |
| Control | 200 | 213 | 186 | 74 | 88 | 60 | 358 | 4 |
| Appetizer | 202 | 216 | 186 | 77 | 91 | 60 | 358 | 5 |
| Nertus | 200 | 211 | 190 | 75 | 91 | 60 | 362 | 4 |
| Nertus+ | 201 | 215 | 185 | 75 | 90 | 61 | 396 | 5 |
| Kharkivska 215 M | | | | | | | | |
| Control | 174 | 187 | 156 | 61 | 79 | 50 | 296 | 3 |
| Appetizer | 176 | 192 | 150 | 63 | 79 | 50 | 359 | 4 |
| Nertus | 175 | 196 | 156 | 60 | 72 | 47 | 343 | 4 |
| Nertus+ | 176 | 194 | 166 | 58 | 80 | 49 | 321 | 4 |
| Kharkivska 155 M | | | | | | | | |
| Control | 212 | 230 | 190 | 75 | 97 | 52 | 405 | 3 |
| Appetizer | 214 | 237 | 193 | 76 | 91 | 55 | 471 | 4 |
| Nertus | 214 | 230 | 190 | 78 | 97 | 62 | 461 | 4 |
| Nertus+ | 216 | 236 | 194 | 76 | 91 | 60 | 471 | 4 |
| Kharkivska 164 M | | | | | | | | |
| Control | 148 | 163 | 128 | 42 | 55 | 30 | 226 | 3 |
| Appetizer | 151 | 165 | 134 | 47 | 55 | 40 | 241 | 4 |
| Nertus | 151 | 163 | 140 | 44 | 55 | 32 | 229 | 4 |
| Nertus+ | 149 | 167 | 136 | 44 | 59 | 32 | 237 | 4 |

Treatment 4 of Kharkivska 155 M was distinguished, because the plant height exceeded the control on average by 4 cm. Treatment 2 of Kharkivska 164 M was also distinguished, because the cob attachment height exceeded the control by 5 cm.

The results of measuring the biometric parameters of the lines – sterile counterparts lead to the conclusion that plants in the PGR-treated plots had a greater vegetative mass, a larger leaf cover and a better condition than plants in the corresponding control plots. In general, in the lines – sterility maintainers, the plant height and cob attachment height were bigger by only 1–3 cm in the PGR-treated plots than in the corresponding control ones (Table 5).

Table 5.

**Plant Growth Regulator Effects on the Biometric Parameters of Maize Lines – Sterility Maintainers, 2018-2019**

| No | Treatment | Plant height, cm | | | Cob attachment height, cm | | |
|---|---|---|---|---|---|---|---|
| | | mean | max | min | mean | max | min |
| | | Kharkivska 126 ZM | | | | | |
| 1 | Control | 199 | 210 | 183 | 76 | 91 | 60 |
| 2 | Appetizer | 200 | 210 | 183 | 79 | 90 | 65 |
| 3 | Nertus | 200 | 212 | 192 | 78 | 90 | 65 |
| 4 | Nertus+ | 198 | 207 | 186 | 76 | 90 | 65 |
| | | Kharkivska 215 ZM | | | | | |
| 1 | Control | 178 | 190 | 170 | 65 | 75 | 50 |
| 2 | Appetizer | 182 | 191 | 169 | 64 | 75 | 46 |
| 3 | Nertus | 181 | 193 | 160 | 65 | 80 | 50 |
| 4 | Nertus+ | 178 | 189 | 166 | 65 | 75 | 50 |
| | | Kharkivska 155 ZM | | | | | |
| 1 | Control | 222 | 244 | 205 | 76 | 90 | 49 |
| 2 | Appetizer | 228 | 243 | 201 | 81 | 100 | 65 |
| 3 | Nertus | 229 | 248 | 209 | 77 | 90 | 55 |
| 4 | Nertus+ | 230 | 246 | 210 | 79 | 95 | 64 |
| | | Kharkivska 164 ZM | | | | | |
| 1 | Control | 155 | 165 | 145 | 49 | 60 | 37 |
| 2 | Appetizer | 158 | 169 | 146 | 50 | 60 | 40 |
| 3 | Nertus | 162 | 170 | 150 | 51 | 60 | 40 |

Line Kharkivska 155 ZM was singled out, since its plants were taller by 6–8 cm in all the 3 PGR experiments than in the control, and as to the cob attachment height, plants after treatment 2 were taller by 5 cm than control ones. Kharkivska 164 ZM was also noticeable for PGR effects, as plants after treatment 3 were taller by 7 cm than control ones.

Having investigated the biometric parameters in the lines – sterile counterparts and lines – sterility maintainers, we revealed the positive effects of the growth regulators on the vegetative mass and plant condition. The best response of plants to the PGRs was observed in lines Kharkivska 155 M and Kharkivska 155 ZM. After treatment 2 (Appetizer), we noted the greatest surplus in the biometric parameters in comparison with the corresponding control plots.

*Anthesis synchrony in the maize hybrids' parents and the anthesis length depending on the PGR and method of their application.* There were some differences in the anthesis synchrony between the control and PGR-treated plots during the stage of female inflorescence flowering in the lines – sterile counterparts and during the stage of male inflorescence flowering in the lines -– sterility maintainers. In the PGR-treated plots, the tassel flowering occurred later and stigmas appeared earlier, which reduced the gap in between the anthesis in the male and female lines.

Line Kharkivska 126 showed the best synchrony of anthesis in experiment 2 (Appetizer) – the anthesis time in the male and female forms almost coincided (♂ 27/07 - ♀ 28/07) (Fig. 2). In the treatment 3 (Nertus treatment of seeds) and 4 (Nertus treatment of seeds + spraying) plots, the anthesis peaks in the both forms coincided (♂ 27/07-♀ 27/07), however, the male forms stopped flowering much earlier than the female ones: there was an anthesis gap (as of 03/08 2% of ♂ forms and 43% of ♀ forms flowered).

Lines Kharkivska 215 M and Kharkivska 215 ZM were also positively influenced by the growth regulators in terms of the anthesis synchrony between female and male inflorescences. Like in line Kharkivska 126, the best synchrony in comparison with the control was shown in the treatment 2 plots (the anthesis peaks in ♂ and ♀ forms were on 23/07/2018 and 24/07/2018, respectively).

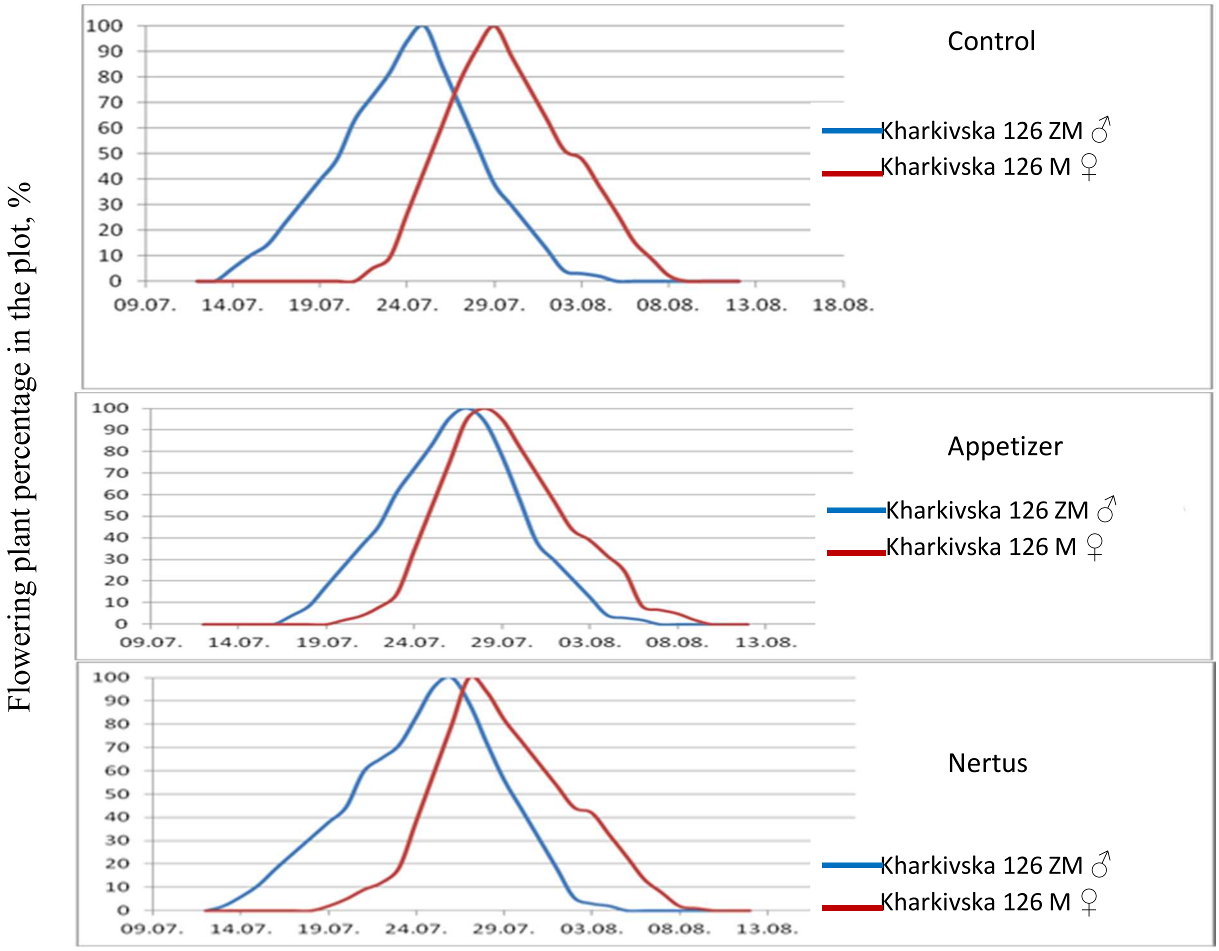

**Fig. 2**. Anthesis Synchrony in Lines Kharkivska 126 M and Kharkivska 126 ZM depending on the PGR application, 2018.

A similar synchrony was observed in the treatment 3 plots, with slight differences at the anthesis beginning and peak. Treatment 4 had no effect on the anthesis synchrony (Fig. 3).

There was also a noticeable influence of the growth regulators on the anthesis synchrony in lines Kharkivska 155 M and Kharkivska 155 ZM. The worst synchrony of anthesis was observed in the control, where ♀ forms flowered later than the others, resulting in a gap of 5 days between the anthesis peaks in the parents. (♂ 20/07/2018 - ♀ 26/07/2018). The shortest gap (3 days) in the anthesis was observed in the treatment 2 plots.

In lines Kharkivska 164 M and Kharkivska 164 ZM, insignificant effects of the growth regulators on the anthesis synchrony were only observed in the treatment 4 plots. The positive effect consisted in accelerating the flowering period of ♀ forms, which reduced the interval between the anthesis peaks by 3 days compared to the control (♂ 25/07 - ♀ 31/07 in the control) in experiment 4 (♂ 26/07/2018 - ♀ 29/07/2018). Other treatment options had no significant effects on the anthesis synchrony in lines Kharkivska 164 M and Kharkivska 164 ZM.

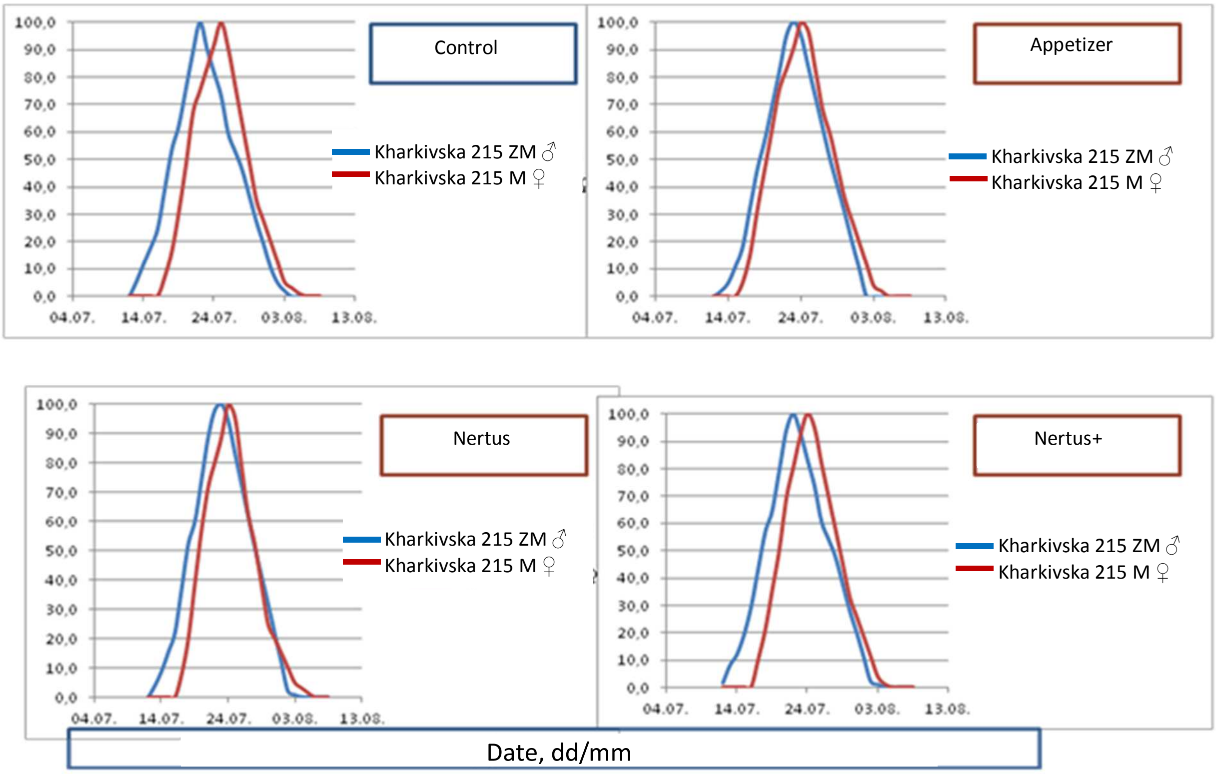

**Fig. 3**. Anthesis Synchrony in Lines Kharkivska 215 M and Kharkivska 215 ZM depending on the PGR application, 2018

*Influence of the plant growth regulators on the seed productivity of maize hybrids' female forms.* Having determined and analyzed the seed productivity of the lines – maize hybrids' parents, we noted significant differences in these parameters between the PGR-treated and control plots. We recorded a significant increase in the kernel weight of the sample, 1000-kernel weight, the total yield and other indices in the PGR-treated plots in comparison with the corresponding control ones (Tables 6 and 7).

Of the lines – sterile counterparts, the response to the growth regulators was the strongest in lines Kharkivska 126 M and Kharkivska 215 M (Table 6). The 3 growth regulator treatments were significantly superior to the control in terms of almost all parameters. The biological yields in the PGR-treated plots were higher by 0.6–0.7 t/ha and 0.5–0.6 t/ha than the control yields from Kharkivska 126 M and Kharkivska 215 M, respectively.

In lines Kharkivska 155 M and Kharkivska 164 M, there were fewer significant differences compared to the control, although insignificant surpluses could can be observed in all the parameters (Table 6). Thus, there were significant differences in the kernel weight of the sample and biological yield between the 3 treatments and control in line Kharkivska 155 M. As to the other parameters, there were noticeable differences related to the control, but they were not statistically significant.

After treatment 2 of line Kharkivska 164 M, we noted a significant influence of the growth regulators on the kernel weight of the sample and kernel weight per plant. As to treatment 3, a significant influence of the growth regulators on the kernel weight of the sample was only observed.

As a result of the study, treatment 2 (Appetizer) was singled out, as this agent had the greatest impact on the performance parameters in all the lines under investigation. In all the lines – sterility maintainers, except for Kharkivska 215 ZM, the performance parameters were significantly influenced by the growth regulators (Table 7).

Table 6.

**Plant Growth Regulator Effects on the Seed Productivity Indices in the Lines – Sterile Counterparts, 2018-2019**

| No | Treatment | Kernel weight per 10 cobs | | Kernel weight per plant, g | 1000-kernel weight, g | Biological yield, t/ha |
|---|---|---|---|---|---|---|
| | | kg | % | | | |
| Kharkivska 126 M | | | | | | |
| 1 | Control | 0.44 | 69.29 | 44.08 | 170.70 | 2.64 |
| 2 | Appetizer | 0.55 | 73.28 | 54.58 | 178.70 | 3.27 |
| 3 | Nertus | 0.54 | 73.20 | 53.69 | 177.79 | 3.22 |
| 4 | Nertus+ | 0.57 | 73.56 | 56.54 | 180.63 | 3.39 |
| | LSD$_{0.05}$ | 0.09 | 3.96 | 8.54 | 6.28 | 0.51 |
| Kharkivska 215 M | | | | | | |
| 1 | Control | 0.74 | 81.69 | 73.94 | 208.53 | 4.44 |
| 2 | Appetizer | 0.82 | 82.95 | 82.26 | 211.43 | 4.94 |
| 3 | Nertus | 0.85 | 84.12 | 82.57 | 211.93 | 5.10 |
| 4 | Nertus+ | 0.81 | 83.10 | 80.56 | 218.46 | 4.83 |
| | LSD$_{0.05}$ | 0.06 | 1.52 | 6.58 | 4.31 | 0.33 |
| Kharkivska 155 M | | | | | | |
| 1 | Control | 0.76 | 83.50 | 76.21 | 168.54 | 4.59 |
| 2 | Appetizer | 0.86 | 84.61 | 86.65 | 177.36 | 5.25 |
| 3 | Nertus | 0.81 | 82.88 | 80.92 | 177.14 | 4.86 |
| 4 | Nertus+ | 0.82 | 83.34 | 79.88 | 174.24 | 4.87 |
| | LSD$_{0.05}$ | 0.06 | 2.43 | 9.17 | 6.65 | 0.42 |
| Kharkivska 164 M | | | | | | |
| 1 | Control | 0.38 | 73.70 | 38.17 | 266.34 | 2.29 |
| 2 | Appetizer | 0.47 | 80.04 | 46.54 | 275.24 | 2.79 |
| 3 | Nertus | 0.46 | 79.07 | 46.42 | 268.76 | 2.79 |
| 4 | Nertus+ | 0.39 | 78.18 | 39.15 | 271.00 | 2.35 |
| | LSD$_{0.05}$ | 0.06 | 7.25 | 8.35 | 11.22 | 0.5 |

The best response of plants to the growth regulators was observed in line Kharkivska 126 ZM, since its PGR-treated plots were significantly superior to the control one by all the parameters.

In lines Kharkivska 155 ZM and Kharkivska 164 ZM, there were significant differences in the performance parameters between treatments 2 and 3 and the control. In the treatment 4 plots, there were noticeable, however statistically insignificant, differences in the performance parameters in comparison with the control. In line Kharkivska 215 ZM, a significant impact of only treatment 3 (Nertus) on the performance parameters was noted.

*Pollen-forming ability and pollen viability of the maize lines – sterility maintainers, depending on the plant growth regulator application.* The pollen productivity of a maize plant is determined by two parameters: the flower number per tassel and the number of pollen grains per anther. Analysis of the pollen-forming ability of the maize lines – sterility maintainers demonstrated the plant growth regulator effects on the both pollen productivity parameters (Table 8).

In lines Kharkivska 126 ZM, Kharkivska 155 ZM and Kharkivska 164 ZM, the flower number per tassel and the number of pollen grains per anther after the PGR treatments were higher than the corresponding control values. In the PGR-treated plots, the average number of flowers was greater by 100–200 flowers compared to the control. The number of pollen grains per anther the PGR-treated plots was greater by 100–200 grains than in the corresponding control plots in lines Kharkivska 126 MR and Kharkivska 155 MR and by 50 grains than in the control in line Kharkivska 164 MR.

Table 7.

**Seed Productivity of the Lines - Sterility Maintainers Depending on the Plant Growth Regulator Application, 2018–2019**

| No | Treatment | Kernel weight per 10 cobs | | Kernel weight per plant, g | 1000-kernel weight, g | Biological yield, t/ha |
|---|---|---|---|---|---|---|
| | | kg | % | | | |
| | Kharkivska 126 ZM | | | | | |
| 1 | Control | 0.41 | 67.17 | 41.14 | 175.10 | 2.47 |
| 2 | Appetizer | 0.47 | 66.18 | 46.72 | 181.04 | 2.80 |
| 3 | Nertus | 0.48 | 71.36 | 48.34 | 177.93 | 2.90 |
| 4 | Nertus+ | 0.44 | 70.30 | 44.40 | 178.56 | 2.66 |
| | LSD 0.05 | 0.09 | 3.96 | 8.54 | 6.28 | 0.51 |
| | Kharkivska 215 ZM | | | | | |
| 1 | Control | 0.74 | 84.94 | 74.05 | 208.96 | 4.44 |
| 2 | Appetizer | 0.79 | 84.05 | 79.16 | 212.22 | 4.75 |
| 3 | Nertus | 0.84 | 90.40 | 83.80 | 213.13 | 5.03 |
| 4 | Nertus+ | 0.72 | 82.96 | 72.43 | 211.19 | 4.35 |
| | LSD 0.05 | 0.08 | 8.85 | 8.29 | 10.56 | 0.5 |
| | Kharkivska 155 ZM | | | | | |
| 1 | Control | 0.63 | 79.02 | 63.20 | 171.54 | 3.79 |
| 2 | Appetizer | 0.76 | 81.97 | 75.80 | 173.56 | 4.55 |
| 3 | Nertus | 0.73 | 81.23 | 72.66 | 177.40 | 4.36 |
| 4 | Nertus+ | 0.70 | 81.64 | 70.20 | 180.33 | 4.21 |
| | LSD 0.05 | 0.07 | 2.17 | 7.10 | 6.86 | 0.43 |
| | Kharkivska 164 ZM | | | | | |
| 1 | Control | 0.33 | 74.55 | 33.45 | 260.32 | 2.01 |
| 2 | Appetizer | 0.40 | 76.18 | 40.28 | 268.35 | 2.42 |
| 3 | Nertus | 0.39 | 79.25 | 38.61 | 267.21 | 2.32 |
| 4 | Nertus+ | 0.36 | 77.69 | 36.00 | 258.05 | 2.16 |
| | LSD 0.05 | 0.04 | 4.26 | 4.05 | 9.27 | 0.24 |

The pollen productivity in line Kharkivska 215 MR was not significantly affected by the plant growth regulators. Treatment 2 became an exception, as the flower number per tassel (1.175 flowers in the control and 1.289 flowers after Appetizer treatment) and the overall pollen productivity (4.18 million grains in the control and 4.4 million grains after Appetizer treatment) exceeded the corresponding control values.

The failure of the plant growth regulators for the pollen productivity in line Kharkivska 215 ZM was acknowledged, since there were no significant differences in the seed productivity indices between the treatments and control.

Nevertheless, in the experiment the 3 treatments (Appetizer, Nertus, Nertus +) influenced the pollen productivity of the maize lines – sterility maintainers.

The plant growth regulators had no significant effect the pollen viability in the lines – sterility maintainers (Table 9). On average, in the PGR-treated plots the percentage of viable pollen was higher by 2–3% than in the corresponding control ones. Line Kharkivska 126 ZM was an exception, as the viability of its pollen in the PGR-treated plots was 93–94%, while it was 89–90% in the control plot.

Table 8.

**Pollen Productivity in Lines – Sterility Maintainers Depending on the PGR application, 2018-2019**

| № | Treatment | Length, cm | | Number per tassel | | | Number of pollen grains | |
|---|---|---|---|---|---|---|---|---|
| | | tassel | central axis | lateral branches | flowers | anthers | per anther | per tassel, mln |
| | Kharkivska 126 ZM | | | | | | | |
| 1 | Control | 32.1 | 23.4 | 16 | 2.056 | 6.167 | 1.188 | 7.36 |
| 2 | Appetizer, 0.5 L/ha | 34.7 | 26.1 | 16 | 2.229 | 6.687 | 1.275 | 8.53 |
| 3 | Nertus, 0.4 L/t | 33.3 | 24.9 | 16 | 2.124 | 6.373 | 1.337 | 8.50 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 34.7 | 25.7 | 17 | 2.186 | 6.559 | 1.324 | 8.69 |
| | Kharkivska 215 ZM | | | | | | | |
| 1 | Control | 29.7 | 21.3 | 17 | 1.175 | 3.526 | 1.182 | 4.18 |
| 2 | Appetizer, 0.5 L/ha | 30.6 | 22.6 | 16 | 1.289 | 3.867 | 1.136 | 4.40 |
| 3 | Nertus, 0.4 L/t | 30.4 | 22.2 | 16 | 1.205 | 3.615 | 1.034 | 3.74 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 29.4 | 21.4 | 16 | 1.145 | 3.435 | 1.248 | 4.29 |
| | Kharkivska 155 ZM | | | | | | | |
| 1 | Control | 32.6 | 24.7 | 9 | 1.257 | 3.770 | 1.089 | 4.12 |
| 2 | Appetizer, 0.5 L/ha | 35.3 | 27.2 | 10 | 1.534 | 4603 | 1.263 | 5.82 |
| 3 | Nertus, 0.4 L/t | 35.3 | 26.4 | 9 | 1.444 | 4.332 | 1.202 | 5.21 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 36.8 | 27.2 | 11 | 1.539 | 4.618 | 1.160 | 5.40 |
| | Kharkivska 164 ZM | | | | | | | |
| 1 | Control | 28.3 | 19.4 | 15 | 1.312 | 3.937 | 388 | 1.52 |
| 2 | Appetizer, 0.5 L/ha | 31.6 | 22.8 | 15 | 1.508 | 4.525 | 443 | 2.01 |
| 3 | Nertus, 0.4 L/t | 29.8 | 20.7 | 16 | 1.508 | 4.525 | 446 | 2.02 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 31.7 | 22.2 | 17 | 1.596 | 4.788 | 398 | 1.91 |

*Duration and viability of stigmas in the maize lines – steryle counterparts, depending on the PGR application.* Before considering the growth regulator effects on the stigma viability, it should be noted that this experiment, as required by the method, begins from the moment of the emergence of stigmas on the first 5 insulated cobs, followed by counting days and subsequent removal of plastic bags. It was noted that stigmas emerged later on insulated cobs than on non-insulated ones. Because of this, the experiment partially took place when, according to the general data for the plot, the flowering of cobs actually ended. Despite these obstacles, the data obtained were sufficient to record differences in the stigma viability between the treatments in the lines – steryle counterparts. The stigma viability in line Kharkivska 126 M was very low after all the treatments (Fig. 4). As early as for the second 5 cobs, which were collected on August 1 (01/08/18), the stigma viability was below 1%. However, in the first 5 cobs, which were collected on July 29 (29/07/18), higher percentages of set seeds (4% and 9.3%) were recorded after treatments 2 and 4, respectively. The viability percentage in the control plot was 2.8%. The cobs, from which the bags were removed in the following days, showed near-zero percentages of setting after all the treatments.

Table 9.

**Influence of the Growth Regulators on the Viability of Pollen Grains in the Lines – Sterility Maintainers, 2018-2019**

| No | Treatment | Viability of pollen grains, % |
|---|---|---|
| | Kharkivska 126 ZM | |
| 1 | Control | 89.1 |
| 2 | Appetizer, 0.5 L/ha | 93.2 |
| 3 | Nertus, 0.4 L/t | 93.8 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 94.2 |
| | Kharkivska 215ZM | |
| 1 | Control | 89.8 |
| 2 | Appetizer, 0.5 L/ha | 92.9 |
| 3 | Nertus, 0.4 L/t | 93.2 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 92.0 |
| | Kharkivska 155 ZM | |
| 1 | Control | 90.2 |
| 2 | Appetizer, 0.5 L/ha | 91.6 |
| 3 | Nertus, 0.4 L/t | 92.2 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 91.3 |
| | Kharkivska 164 ZM | |
| 1 | Control | 91.1 |
| 2 | Appetizer, 0.5 L/ha | 91.3 |
| 3 | Nertus, 0.4 L/t | 90.5 |
| 4 | Nertus, 0.4 L/t + Nertus, 0.3 L/ha | 93.4 |

The influence of the growth regulators on the stigma viability was somewhat more noticeable in line Kharkivska 215 M. Thus, it is seen for the cobs of the first and second samples (from which the bags were removed on 23/07/18 and 26/07/18, respectively) that the control percentage of set seeds was lower compared to the three treatments. The treatment 2 plots showed the highest viability of stigmas of the first 3 samples (Fig. 5).

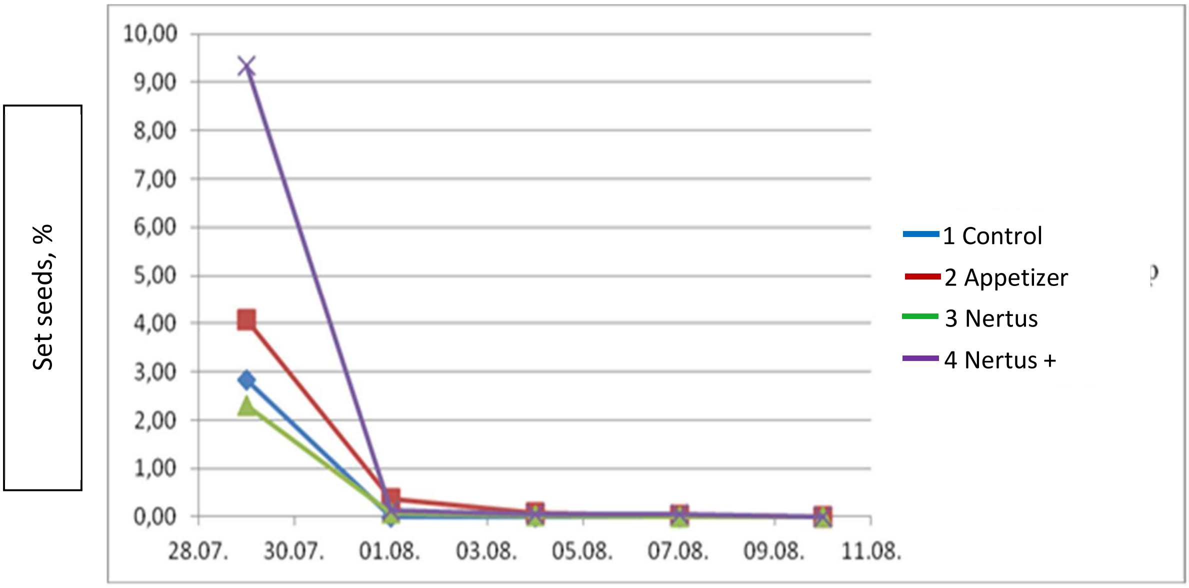

**Fig. 4.** The Stigma Viability in Line Kharkivska 126 M, depending on the PGR application, 2018

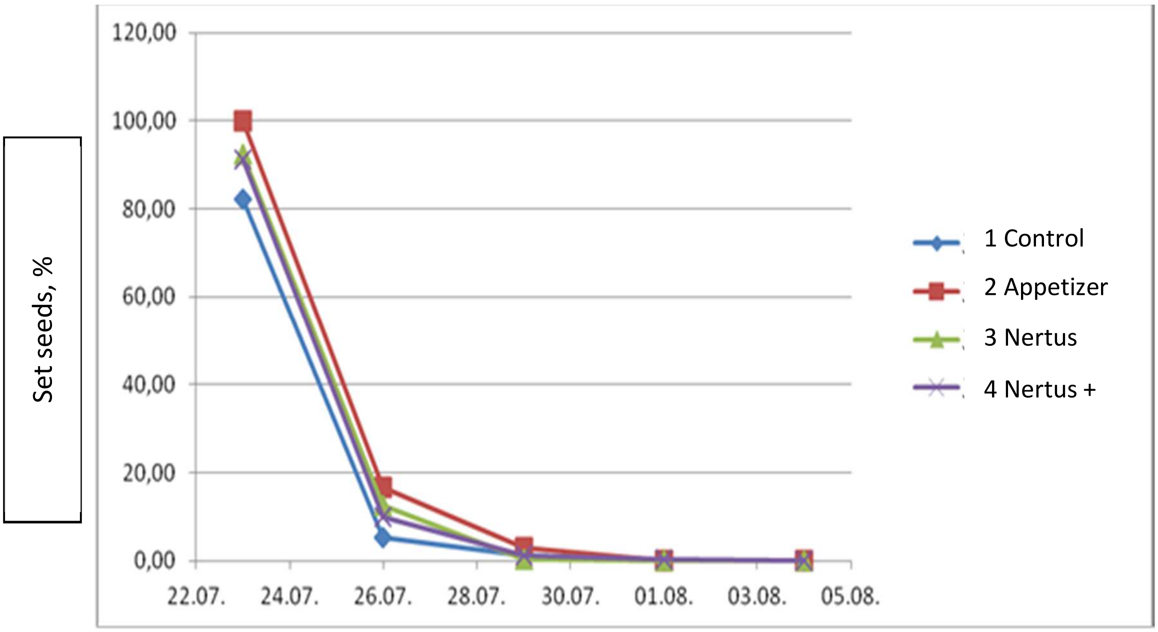

**Fig. 5.** The Stigma Viability in Line Kharkivska 215 M, depending on the PGR application, 2018

In line Kharkivska M 155, the stigma viability was the same after treatments 2 and 4, but not after treatment 3 (Nertus Planta Peg), where higher percentages of set seeds were obtained for the first 4 samples (Table 10).

Line Kharkivska 164 M had a rather low viability of stigmas in all the experiments (Fig. 6). However, the treatment 2 and 3 plots showed almost 3-fold percentage of set seeds compared to the control (33.1% after treatment 2 and 27.6% after treatment 3 vs. 10% in the control) in the first sample. As to the cobs of the second sample, the percentages of set seeds after treatments 2 and 3 were more than twice as low as the control value (0.41% after treatment 2 and 0.96% after treatment 3 vs. 2.65% in the control).

Table 10.

**The Stigma Viability in Line Kharkivska 155 M, depending on the PGR application, 2018**

| No | Treatment | Date of estimation | | | | |
|---|---|---|---|---|---|---|
| | | 23/07 | 26/07 | 29/07 | 01/08 | 04/08 |
| 1 | Control | 99.28 | 50.55 | 1.09 | 0.23 | 0.02 |
| 2 | Appetizer | 100 | 38.72 | 1.37 | 0.17 | 0.05 |
| 3 | Nertus | 101.36 | 64.55 | 1.14 | 0.85 | 0.01 |
| 4 | Nertus + | 92.62 | 51.45 | 1.08 | 0.09 | 0.04 |

Therefore, it can be concluded that, the cobs of the first sample from the treatment 2 and 3 plots had high percentages of set seeds compared to the corresponding controls. For the cobs of the second sample, it was shown that stigmas in the control plots remained viable longer than stigmas in the PGR-treated plots.

Thus, it was found that the PGRs exerted no influence on the phenological phases of the lines – sterile counterparts of the parents. The plant growth regulators affected the plant weight and condition during the tassel emergence. Of the lines – sterility maintainers, the PGRs affected the plant height in lines Kharkivska 155 ZM and Kharkivska 164 ZM .

The anthesis synchronicity was shown to be high in lines Kharkivska 126 M and Kharkivska 126 ZM as well as in lines Kharkivska 215 M and Kharkivska 215 ZM treated with Appetizer (treatment 2).

In the lines – sterile counterparts, the PGR influence on the seed productivity was noted for all the treatments: to a greater extent in lines Kharkivska 126 M and Kharkivska 215 M after treatment 2 and to a lesser extent (neverthells, the difference was significant) in lines Kharkivska 155 M and Kharkivska 164 M.

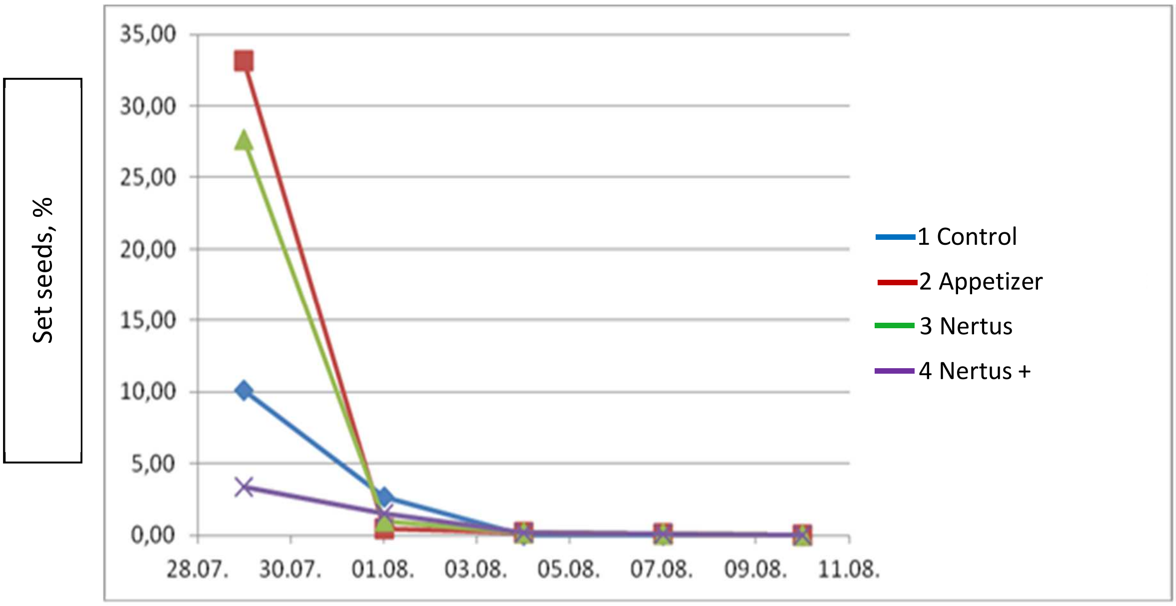

**Fig. 6.** The Stigma Viability in Line Kharkivska 164 M, depending on the PGR application, 2018

The PGR effect on the seed productivity was noted in all the lines – sterility maintainers, except for line Kharkivska 215 ZM after treatments 2 and 3.

It was found that the lines with the best synchrony of anthesis had a higher seed productivity. These lines include Kharkivska 126 M, Kharkivska 126 ZM Kharkivska 215 M, and Appetizer-treated Kharkivska 215 ZM.

The PGR effect on the pollen productivity in the sterility maintainers was noted on lines Kharkivska 126 ZM, Kharkivska 155 ZM and Kharkivska 164 ZM. Of the PGR-treated lines, the pollen viability differed significantly only in Kharkivska 126 ZM.

Of the sterile analogues, the PGR effect on the stigma viability was noted for lines Kharkivska 126 M and Kharkivska 215 M. It was less noticeable in the other lines.

The best response to the growth regulators was recorded in lines Kharkivska 126 M-ZM and Kharkivska 215 M. We recognize treatment 2 (Appetizer) as the most effective growth regulator.

## Conclusions

1. The effects of the plant growth regulator on the morphometric parameters, phenological phase lengths, anthesis synchrony, pollen-forming ability and viability as well as methods of their application on the maize lines – hybrids' parents were determined. The best response to the growth regulators was observed in lines Kharkivska 126 M-ZM and Kharkivska 215 M. We can distinguish treatment (Appetizer) as the most effective growth regulator.

2. There was no influence of the plant growth regulators (PGR) on the phenological phase lengths in the lines – sterile counterparts of the parents. The plant growth regulators affected the plant weight and condition during the tassel emergence. Of the lines – sterility maintainers, the PGRs affected the plant height in lines Kharkivska 155 ZM and Kharkivska 164 ZM. The high synchrony of anthesis was shown for lines Kharkivska 126 M and Kharkivska 126 ZM as well as for Appetizer-treated lines Kharkivska 215 M and Kharkivska 215 ZM.

3. The PGR influence on the seed productivity was observed in the lines – sterile counterparts after all the treatments: to a greater extent in lines Kharkivska 126 M and Kharkivska 215 M after treatment 2; to a lesser extent (however, the difference was significant) in lines Kharkivska 155 M and Kharkivska 164 M. The seed productivity was affected by the PGRs in all the lines – sterility maintainers, except for Kharkivska 215 ZM after treatments 2 and 3.

4. It was revealed that the lines with the best synchrony of anthesis had a higher seed productivity. Theses lines include Kharkivska 126 M, Kharkivska 126 ZM and Kharkivska 215 M as well as Appetizer-treated Kharkivska 215 ZM.

5. As to the sterility maintainers, the PGR influence on the pollen productivity was noted in lines Kharkivska 126 MR, Kharkivska 155 MR and Kharkivska 164 MR. Of the PGR-treated lines, the pollen viability differed significantly only in Kharkivska 126 ZM. As to the sterile counterparts, the PGR impact on the stigma viability was observed in lines Kharkivska 126 M and Kharkivska 215 M. It was less noticeable in the other lines.

6. The results on the growth regulator effectiveness allow us to recommend Appetizer and Nertus Planta Peg as improvers of the seed productivity of the 1st generation maize hybrids' parents.

**It is tragic that young researcher S. Buriak passed away, and we offer our condolences to his relatives and friends**.

## *Список використаних джерел*

1. Маслак О. Ринок кукурудзи врожаю 2016 року. Агробізнес сьогодні: електронне видання. 2016. № 21(340). URL: http://www.agro-business.com.ua/ekonomichnyi-gektar/6636-rynok-kukurudzy-vrozhaiu-2016-roku.html (дата звернення: 16.10.2016).
2. Гуляев, Г.В., Гужев Ю.Л. Селекция и семеноводствополевых культур. Москва: Агропромизд, 1987. С. 340–343.
3. Кириченко В.В. та ін Основи управління продукційним процесом польових культур: монографія. Х.: ФОП Бровін О.В., 2016. 537 с.
4. Стан і перспективи розвитку селекції та насінництва кукурудзи в умовах зміни клімату: матеріали міжнародної науково-практичної конференції (Харків, 7–9 лип., 2015 р.). НААН, ін-т рослинництва ім. В.Я. Юр'єва. Х. 2015. 15 с.
5. Берников Н. И. Влияние регуляторов роста на семенную продуктивность и качество семян капусты белокочанной в условиях Южного региона России: диссертация кандидата с/г наук: 06.01.05. Москва, 2007. 160 с.
6. Dunand R.T., Saichuk J.K. Plant Growth Regulators. In: 2007 Rice Varieties and Management Tips. La. Coop. Extn. Serv. Pub. 2270. 2007. 24 p.
7. Basuchaudhuri P. Influences of plant growth regulators on yield of soybean // Indian Journal of Plant Sciences ISSN: 2319–3824(Online) An Open Access 2016. Vol.5 (4). P. 25–38. URL: http://www.cibtech.org/jps.htm.
8. Пономаренко С.П. Регулятори росту рослин – вагомий резерв урожаю. Аграрний тиждень [Електронний ресурс] 2009. URL: http://a7d.com.ua/1231-reguljatori-rostu-roslin-vagomijj-rezerv-urozhaju.html.
9. Буряк Ю.І., Чернобаб О.В. Регулятори росту рослин – важливий елемент сучасних технологій вирощування насіння зернових колосових культур: стан та перспективи розвитку насінництва в Україні. Збірник НАУ. К., 2008. С. 196–200.
10. Доспехов Б.А. Методика полевого опыта (с основами статистической обработки результатов исследований): учебное пособие. М.: Агропромиздат, 1985. С. 351.
11. Молоцький М.Я., Васильківський С.П., Власенко В.І., Князюк В.А. Селекція і насінництво сільськогосподарських рослин: підручник. К.: Вища освіта, 2006. С. 200–201.
12. Лобанов Г.А. Влияние различного количества пыльцы на оплодотворение. Агробиология. 1950. № 3. С. 78–86.
13. Егикян А.А. О жизнеспособности пыльцы кукурузы. Изв. АН Арм. ССР. 1956. № 9. С.3.
14. Информационный бюллетень по кукурузе №5. Мартонвашар. НИИ сельского хозяйства Венгерской Академии Наук. 1986. 184с.

15. Techniques for Pollination Biologists. Kearns Carol Ann Inouye David William. University Press of Colorado, Niwot, 1993. 583 p.
16. Методика Державного випробування сортів рослин на придатність до поширення в Україні. Загальна частина. Офіційний бюлетень, №1. 2003. Ч. 3. 105 с.
17. Чирков Ю.И. Агрометеорологические условия и продуктивность кукурузы. Ленинград: Агрометеорологическое издание, 1969. 245 с.
18. Mueller D., Sisson A. Corn field guide: 2 nd edition. Iowa State University of Science and Technology. 2013. 93 c.
19. Кириченко В.В., Гур'єва І.А., Рябчун В.К., Кузимишина Н.В., Вакуленко С.М., Степанова В.П. Класифікатор-довідник виду Zea mays L. Харків. ІР ім.. В.Я. Юр'єва УААН, 2009. 84 с..
20. Паушева З.П. Практикум по цитологии растений. Колос, 1980. 303 с.
21. ДСТУ 4136–2002 Насіння сільськогосподарських культур. Метод визначання якості. – Чинний від 01.01.2004. К.: Держспоживстандарт України, 2003. 173 с.
22. Wolfe M., Barrett C.H. Patterns of pollen removal and deposition in tristylous Pontederia cordata. Biological Journal of the Linnean Society. 1989. № 36. C. 317–329.
23. Костромітін В. М., Магомедов Р.Д., Циганко В.А., Музафаров Н.М. Особливості реакції сучасних гібридів кукурудзи на агрофони живлення в залежності від погодних умов року: вісник ХНАУ ім. В. В. Докучаєва, Серія «Рослинництво, селекція і насінництво, овочівництво». 2006. Вип. Х. № 4. С. 3–6.
24. Вольф В.Г., Литун П.П. и др. Методические рекомендации по применению математических методов для анализа экспериментальных данных по изучению комбинационной способности. Харьков. 1980. 75 с.

## References

1. Maslak O. Corn market of the 2016 harvest. Ahrobiznes Siohodni: electronic edition. 2016; 21(340). URL: http://www.agro-business.com.ua/ekonomichnyi-gektar/6636-rynok-kukurudzy-vrozhaiu-2016-roku.html (дата звернення: 16.10.2016).
2. Gulyaev, G.V., Guzhev Yu.L. Breeding and seed production of field crops. Moscow: Agropromizd, 1987: 340–343.
3. Kyrychenko V.V. et al. Fundamentals of the field crop production management: monograph. Kh.: Private enterpriser Brovin O.V., 2016. 537 p.
4. Status and prospects of the development of corn breeding and seed production under climatic changes: Abstracts of the International Scientific-Practical Conference (Kharkiv, July 7-9, 2015). NAAS, Plant Production Institute nd. a V.Ya. Yuriev. Kh., 2015. 15 p.
5. Bernikov N.I. The influence of growth regulators on the seed productivity and quality of white cabbage in the conditions of the Southern region of Russia: thesis for the Academic Degree of Candidate of Agricultural Sciences: 06.01.05. Moscow, 2007. 160 p.
6. Dunand R.T., Saichuk J.K. Plant Growth Regulators. In: 2007 Rice Varieties and Management Tips. La. Coop. Extn. Serv. Pub. 2270, 2007. 24 p.
7. Basuchaudhuri P. Influences of plant growth regulators on yield of soybean. Indian Journal of Plant Sciences ISSN: 2319–3824(Online) An Open Access. 2016; 5 (4): 25–38. URL: http://www.cibtech.org/jps.htm
8. Ponomarenko S.P. Plant growth regulators - a significant reserve of yields. Ahrarnyi Tyzhden [Electronic resource] 2009. URL: http://a7d.com.ua/1231-reguljatori-rostu-roslin-vagomijj-rezerv-urozhaju.html.
9. Buriak Yu.I., Chernobab O.V. Plant growth regulators - an important element of modern technologies of cultivation of spiked cereals: Status and Prospects for Seed Production Development in Ukraine: Zbirnyk NAU. K., 2008: 196–200.
10. Dospekhov B.A. Methods of field experimentation (with basics of statistical processing of research data): manual. M.: Agropromizdat. 1985. 351 p.

11. Molotskyi M.Ya., Vasylkivskyi S.P., Vlasenko V.I., Kniaziuk V.A. Breeding and seed production of agricultural plants: guidebook. K.: Vyshcha Osvita, 2006: 200–201.
12. Lobanov G.A. The effect of varying amounts of pollen on fertilization: Agrobiologiya. 1950; 3: 78–86.
13. Egikyan A.A. On the viability of corn pollen. Izv. AN Arm. SSR. 1956; 9: 3.
14. Informatsionnyy Byulleten po Kukuruze No. 5. Martonwashar. Research Institute of Agriculture of the Hungarian Academy of Sciences. 1986. 184 p.
15. Techniques for Pollination Biologists. Kearns Carol Ann Inouye David William. University Press of Colorado, Niwot, 1993. 583 p.
16. Methods of the State trials of plant varieties for suitability for dissemination in Ukraine. The general part. Ofitsiinyi Biuleten, No. 1. 2003. Part 3. 105 p.
17. Chirkov Yu.I. Agrometeorological conditions and corn performance. Leningrad: Agrometeorologicheskoye Izdaniye. 1969. 245.
18. Mueller D., Sisson A. Corn field guide: 2nd edition. Iowa State University of Science and Technology. 2013. 93 p.
19. Kyrychenko V.V., Hurieva I.A., Riabchun V.K., Kuzmyshyna N.V., Vakulenko S.M., Stepanova V.P. Classifier-guide for the species *Zea mays* L. Kharkiv. PPI nd.a V.Ya. Yuriev UAAS,. 2009. 84 p.
20. Pausheva Z.P. The laboratory manual on plant cytology. Kolos, 1980. 303 p.
21. State Standard of Ukraine Agricultural crop seeds. Method for quality evaluation. - Valid from 01/01/2004. K.: Derzhspozhyvstandart Ukrainy, 2003. 173 p.
22. Wolfe M., Barrett C.H. Patterns of pollen removal and deposition in tristylous Pontederia cordata // Biological Journal of the Linnean Society. 1989; 36: 317–329.
23. Kostromitin V.M., Mahomedov R.D., Tsyhanko V.A., Muzafarov N.M. Peculiarities of the response of modern maize hybrids to nutrition depending on weather conditions of the year: Visnyk KhNAU im. V.V. Dokuchaieva, Series "Roslynnytstvo, selektsiia i nasinnytstvo, ovochivnytstvo". Kh. 2006; 4: 3–6.
24. Volf V.G., Litun P.P. et al. Guidelines for the use of mathematical methods for analysis of experimental data on the combining ability. Kharkov. 1980. 75 p.

## *ВПЛИВ РЕГУЛЯТОРІВ РОСТУ РОСЛИН НА НАСІННЄВУ ПРОДУКТИВНІСТЬ ЛІНІЙ КУКУРУДЗИ*

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**Мета та завдання досліджень.** Вивчити вплив регуляторів росту на насіннєву продуктивність і посівні якості насіння материнських форм, та пилкоутворюючу здатність батьківських форм гібридів кукурудзи, а також розробити способи застосування регуляторів росту у первинних ланках насінництва

**Матеріал і методи.** Досліди проведено у 2018-2019 роках на полі насінницької сівозміни Інституту рослинництва ім. В. Я. Юр'єва НААН. Насіння ліній кукурудзи було висіяне ручними саджалками на шестирядкових ділянках площею 29,4 м$^2$ (за схемою 4♀:2♂), в чотирьох повтореннях. Фенологічні спостереження та біометричні вимірювання були виконані на 10 рослинах кожного повторення. Матеріалом для досліджень було використано 8 ліній – батьківських компонентів гібридів кукурудзи: чотири лінії стерильні аналоги (Харківська 126 М, Харківська 215 М, Харківська 164 М, Харківська 155 М), 4 лінії закріплювачі стерильності (Харківська 126 ЗМ, Харківська 215 ЗМ, Харківська 164 ЗМ, Харківська 155 ЗМ). Дослід включає чотири варіанти обробітку: 1). Без обробітку (контроль); 2). «Аппетайзер» – обприскування у фазі 4-5 листків; 3). «Нертус Планта Пег» – передпосівна обробка насіння; 4). «Нертус Планта Пег» – передпосівна обробка насіння + обприскування у фазі 4-5 листків. Проведено дослід з визначення життєздатності приймочок шляхом послідовного зняття ізоляторів. Для оцінки продуктивності зразків було проведено облік: - рослин на ділянці; - безплідних рослин; - рослин з нерозвиненими качанами; - повноцінних качанів. Було відібрано і зважено одну середню кількісну пробу качанів (10 качанів) для висушування та аналізу структури качанів.

**Результати та обговорення.** На лініях стерильних аналогах, відмічено істотний вплив регуляторів росту на показники маси рослини, та її стан у період перед початком виходу волоті. Найкращу реакцію рослин на застосування РРР було виявлено на лініях Харківська 155 М та Харківська 155 ЗМ. На варіанті обробітку № 2 Аппетайзер було відмічено найбільше перевищення біометричних показників у порівнянні з контрольними ділянками. На ділянках з обробітком РРР, було відмічено більш пізнє цвітіння волотей та більш ранній вихід приймочок, що зменшувало розрив у цвітінні батьківських та материнських ліній. У дослідах на лінії Харківська 126 найкращі показники синхронності цвітіння показали ділянки з варіантом обробітку № 2 (Аппетайзер) – строки цвітіння батьківських та материнських форм на них майже співпадали (♂ 27.07 - ♀ 28.07). На ділянках з варіантами обробітку № 3 (Нертус обробка насіння) та № 4 (Нертус обробка насіння + обприскування) співпали піки цвітіння обох форм (♂ 27.07-♀ 27.07), проте після цього батьківські форми припиняли цвітіння значно раніше ніж материнські – відбувся розрив у цвітінні (станом на 03.08 цвіло 2% ♂ форм та 43% ♀ форм). На ділянках з обробітком РРР, було відмічено суттєве збільшення маси зерна з проби, маси 1000 зерен, загальної врожайності та інших показників у порівнянні з контрольними ділянками. Було відмічено вплив усіх трьох варіантів обробітку (Аппетайзер, Нертус, Нертус +) на показники пилкової продуктивності ліній закріплювачів стерильності кукурудзи. Вивчення життєздатності пилку ліній закріплювачів стерильності показало, що застосування регуляторів росту рослин не має суттєвого впливу на цей показник. Вплив РРР на життєздатність приймочок стерильних аналогів, відмічено на лініях Харківська 126 М та Харківська 215 М. На інших лініях він був менш помітним.

**Висновки.** Отримані результати по ефективності застосування регуляторів росту дозволяють рекомендувати Аппетайзер та Нертус Планта Пег в якості поліпшувачів насіннєвої продуктивності батьківських компонентів гібридів першого покоління кукурудзи.

***Ключові слова**: кукурудза, насінництво, регулятори росту рослин, насіннєва продуктивність*

## *EFFECTS OF PLANT GROWTH REGULATORS ON SEED PRODUCTIVITY OF MAIZE LINES*

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**Purpose and objectives.** To study the influence of growth regulators on seed productivity and seeding quality of the development of maternal forms, and the pollen-forming ability of parental forms of corn hybrids, as well as to develop ways of using growth regulators in the primary stages of seed production.

**Material and methods.** The experiments were conducted in the crop rotation fields of the Plant Production Institute named after V.Ya. Yuriev of NAAS in 2018-2019. The experiments were conducted in the crop rotation fields of the Plant Production Institute named after V.Ya. Yuriev of NAAS in 2018-2019. Seeds of maize lines were sown with manual planters in six-row plots of 29.4 m$^2$ (arrangement 4♀:2♂), in four replications. Phenological observations and biometric measurements were performed on 10 plants in each replication. Eight maize lines – hybrids' parents were taken as the test material: 4 lines – steryl counterparts (Kharkivska 126 M, Kharkivska 215 M, Kharkivska 164 M, and Kharkivska 155 M) and 4 lines – sterility maintainers (Kharkivska 126 ZM, Kharkivska 215 ZM, Kharkivska 164 ZM, and Kharkiv 155 ZM). There were 4 treatments: 1) no treatment (control); 2) Appetizer - spraying in the phase of 4-5 leaves; 3) Nertus Planta Peg – pre-sowing seed treatment; 4) Nertus Planta Peg - pre-sowing seed treatment + spraying in the phase of 4-5 leaves. The stigma viability was determined by sequential removal of plastic bags. To evaluate the accession performance, the following parameters were recorded: - The plant number per plot; - The infertile plant number; - The number of plants with undeveloped cobs; - The number of plants with complete cobs. One average quantitative sample of cobs (10 cobs) was taken and weighed for drying and analyzing the cob structure.

**Results and discussion.** In the lines - steryl counterparts, a significant influence of the growth regulators on the plant weight and condition was observed before the tassel emergence onset. The best response of plants to the PGRs was observed in lines Kharkivska 155 M and Kharkivska 155 ZM. After treatment 2 (Appetizer), we noted the greatest surplus in the biometric parameters in comparison with the corresponding control plots. In the PGR-treated plots, the tassel flowering occurred later and stigmas appeared earlier, which reduced the gap in between the anthesis in the male and female lines. Line Kharkivska 126 showed the best synchrony of anthesis in experiment 2 (Appetizer) - the anthesis time in the male and female forms almost coincided (♂ 27/07 - ♀ 28/07). In the treatment 3 (Nertus treatment of seeds) and 4 (Nertus treatment of seeds + spraying) plots, the anthesis peaks in the both forms coincided (♂ 27/07-♀ 27/07), however, the male forms stopped flowering much earlier than the female ones: there was an anthesis gap (as of 03/08 2% of ♂ forms and 43% of ♀ forms flowered). We recorded a significant increase in the kernel weight of the sample, 1000-kernel weight, the total yield and other indices in the PGR-treated plots in comparison with the corresponding control ones. Nevertheless, in the experiment the 3 treatments (Appetizer, Nertus, Nertus +) influenced the pollen productivity of the maize lines - sterility maintainers. The plant growth regulators had no significant effect the pollen viability in the lines - sterility maintainers. Of the sterile analogues, the PGR effect on the stigma viability was noted for lines Kharkivska 126 M and Kharkivska 215 M. It was less noticeable in the other lines.

**Conclusions.** The results on the growth regulator effectiveness allow us to recommend Appetizer and Nertus Planta Peg as improvers of the seed productivity of the 1st generation maize hybrids' parents.

***Key words:*** *maize, seed production, plant growth regulators, seed productivity*