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PRODUCTIVITY OF CORN HYBRIDS OF DIFFERENT FAO GROUPS DEPENDING ON MICROFERTILIZERS AND GROWTH STIMULANTS UNDER IRRIGATION IN THE SOUTH OF UKRAINE

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Aim. Identify efficient microfertilizers and growth stimulants considering biological features of new corn hybrids of different FAO groups under irrigation conditions in the South of Ukraine and trace their impact on grain productivity of the plants. **Methods.** The field method – to study the interaction of the research object with experimental factors of the natural environment, to register the yield and evaluate the biometrical indices; the laboratory method – to measure soil moisture, grain moisture content and grain quality indices; the statistical method – to evaluate the reliability of the obtained results; the calculation methods – for economic and energetic assessment of the growing techniques used. **Results.** The paper defines the impact of microfertilizers and growth stimulants on the yield and grain quality of the corn hybrids of different maturity groups and on the economic efficiency of growing them. **Conclusions.** Under irrigation conditions of the Southern Steppe of Ukraine it is recommended that the following hybrids should be grown in dark-chestnut soils: early maturity DN Pyvykha, medium-early Skadovskyi, medium maturity Kakhovskyi and medium-late Arabat, using the growth stimulants – treating the seeds with Sezam-Nano and fertilizing with Grainactive at the stage of 7–8 leaves.

Key words: corn hybrids, FAO groups, microfertilizers and growth stimulants, irrigation, grain yield, economic efficiency.

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INTRODUCTION

Corn is one of the most productive cereals of the universal purpose, the yield rate of which exceeds that of many crops in conditions of adequate moisture supply. At the same time it is characterized by rather high drought resistance and on condition of the optimization of the main agrotechnical measures it is capable of forming stable productivity even without any irrigation. The most efficient agents, influencing the rate of grain productivity of corn, are its hybrid content, the application of irrigation, mineral fertilizers, microfertilizers and growth stimulants [1–3].

Due to the necessity of improving technological ways of cultivating corn hybrids and determining the adaptiveness of certain genotypes to soil-ecological and technological conditions of cultivation in the south of Ukraine, the comparative studies with eight new corn hybrids were carried out both with and without irrigation. When hybrids were grown under irrigation conditions, the scheme of the experiment involved the application of microfertilizers and growth stimulants, as their application is known to be one of the most important ways of increasing the yield by 15–20 % and improving the quality of products [4–6].

The aim of the work was to determine efficient microfertilizers and growth stimulants taking into consideration biological specificities of new maize hybrids of different FAO groups under irrigation conditions in the south of Ukraine and to trace their impact on the formation of grain productivity of plants.

MATERIALS AND METHODS

The following methods were used: the field method – to analyze the interaction of the investigated object and both experimental and environmental factors with further registration of the yield volume and biometric measurements; the laboratory method – to determine soil humidity, humidity content in grain and quality indices of grain; the statistical method – to estimate the reliability of the results obtained; and the computational method – in economic and energetic estimation of the employed cultivation techniques.

The studies were carried out in 2013–2015 on the experimental field of the Institute of Irrigated Agriculture NAAS of Ukraine, located in the south of Ukraine in the zone of the Ingulets irrigated area. The soil of the experimental plot is dark-chestnut, medium loam, weakly alkaline, the water table is deep.

It was a double-factor experiment: factor A − corn hybrids, different by FAO groups (DN Pyvykha, Tendra, Baturyn 287 MB, Skadovskyi, Zbruch, Kakhovskyi, DN Hetera, Arabat); factor B − microfertilizers and growth stimulants (no treatment; Sezam-Nano – seed treatment; Sezam-Nano − seed treatment + foliage sprinkling of HUMIN PLUS in the phase of 7−8 leaves; Sezam-Nano − seed treatment + foliage sprinkling with Grainactive-C in the phase of 7−8 leaves; HUMIN PLUS − seed treatment + foliage sprinkling in the phase of 7−8 leaves; Nanomix − seed treatment + + foliage sprinkling in the phase of 7−8 leaves). The experiments were repeated four times with the location of variants by the method of randomized split plots. The area of the plot for sowing was 70 sq.m., the area for registration – 50 sq.m.

The abovementioned corn hybrids were grown for grain. The agrotechnology of cultivating corn, used in the experiments, was common for the southern zone of Ukraine, except for the investigated factors. Soy was the precursor plant. The irrigation was performed by the sprinkler method.

According to the scheme of the experiment, prior to sowing the seeds were treated with the solutions of preparations and sprinkled during the vegetation period in the phase of 7–8 leaves.

Mineral fertilizers were introduced in the estimated dose for pre-sowing cultivation. The dose was determined using the method of optimal parameters according to the difference between the yield removal and the actual content of nutrients in soil. Depending on the actual content of nutrients in soil it was $N_{220}P_0K_0$.

In optimal terms corn hybrids were sown in the first decade of May when the soil temperature at the depth of sowing the seeds was 12−14 °C.

The sowing, carrying out of the experiments, selection of soil and plant samples, their preparation for the analysis were conducted according to the methodological instructions for the experiment.

RESULTS AND DISCUSSION

Corn belongs to drought-resistant crops (mesophytes). However, the deficiency of moisture in the soil is a serious factor, limiting the obtaining of high yield of maize grain. The extreme weather conditions, frequently observed in the Southern Steppe of Ukraine (hot dry winds, high temperature, deficiency of productive moisture) have negative impact on the growth and development of these plants and decrease the efficiency of the fertilizers introduced.

In our experiments the plantings of corn were irrigated by vegetative watering, keeping the humidity at the level of 75 % from the least moisture-retention capacity in the soil layer of 0–70 cm.

The efficiency of introducing energy- and resource-keeping technologies in the sphere of agroindustrial complex is greatly dependent on such an important factor as microfertilizers and plant growth stimulants, containing relevant microelements, phytohormones and growth activators. Their application allows decreasing the application of chemical preparations, in particular, plant protectors, enhancing the efficiency of a number of technological operations, improving the resistance of plants to unfavorable environmental factors and the activity of pathogens, enhancing both quantity and quality characteristics of the products [8].

The application of microfertilizers and growth stimulants on the fields of corn in 2013–2015 had positive impact on the growth and development of plants and, as a result, on the yield formation. For instance, regardless of the terms of hybrid maturity during the years of studies the introduction of microfertilizers and growth stimulants increased the grain yield of corn hybrids by 0.38–1.26 t/ha on average with the performance gain of 3.8–10.04 % (Table 1, 2). This may be explained by complete or partial provision of plants with required microelements and growth-stimulating substances with their distribution during crop

vegetation, especially in the critical periods of plant development.

The data, presented in Tables 1 and 2, testify to the tendency of grain yield gain for all the groups of maturity of corn hybrids depending on the application of microfertilizers and growth stimulants.

The yield of corn grain under irrigation conditions without any treatment with preparations fluctuated in the range of 9.57–12.54 t/ha on average for all the groups of hybrid maturity in 2013–2015. The highest yield (13.8 t/ha) for the years of studies under irrigation conditions was demonstrated by medium-late Arabat hybrid with the complex application of growth stimulants – seed treatment with Sezam-Nano and fertilizing corn plants with Grainactive-C in the phase of 7–8 leaves which is exceeding the control by 1.26 t/ha. A similar regularity was found for other hybrids as well. Due to such treatment the yield gain of hybrids was 0.94–1.26 t/ha on average. It is noteworthy that the most evident response to the application of microfertilizers and growth stimulants under irrigation conditions was determined for medium maturity and medium-late hybrids.

The results of the studies in 2013–2015 demonstrate that higher yield stability (both actual and potential) under irrigation conditions was determined for hybrids of medium maturity and medium-late groups. The rate of yield drop depending on the biotype was found to be minimal for the investigated hybrids, FAO 310–430, which testifies to some advantages of the stability of high yield of medium maturity and medium-late hybrids compared to

Table 1. The yield of corn hybrid grain, FAO 180–290, depending on microfertilizers and growth stimulants, t/ha

Hybrid (A)	Treatment with the preparation (B)	2013	2014	2015	Average
DN Pyvykha (FAO 180)	1. No treatment	10.28	9.98	9.68	9.98
	2. Sezam-Nano	10.96	10.68	10.31	10.65
	3. Sezam-Nano +HUMIN PLUS	10.98	10.76	10.33	10.69
	4. Sezam-Nano + Grainactive-C	11.18	10.98	10.51	10.89
	5. HUMIN PLUS	10.82	10.74	10.27	10.61
	6. Nanomix	11.11	10.93	10.39	10.81
Tendra (FAO 190)	1. No treatment	9.91	9.57	9.23	9.57
	2. Sezam-Nano	10.52	10.22	9.71	10.15
	3. Sezam-Nano +HUMIN PLUS	10.59	10.27	9.77	10.21
	4. Sezam-Nano + Grainactive-C	10.89	10.47	9.96	10.44
	5. HUMIN PLUS	10.47	10.19	9.67	10.11
	6. Nanomix	10.81	10.47	9.86	10.38
Baturyn 287 MB (FAO 240)	1. No treatment	10.45	10.25	10.05	10.25
	2. Sezam-Nano	11.14	10.96	10.60	10.90
	3. Sezam-Nano +HUMIN PLUS	11.25	11.01	10.65	10.97
	4. Sezam-Nano + Grainactive-C	11.51	11.17	10.95	11.21
	5. HUMIN PLUS	11.15	10.81	10.50	10.82
	6. Nanomix	11.43	11.07	10.80	11.10
Skadovskyi (FAO 290)	1. No treatment	10.88	10.56	10.30	10.58
	2. Sezam-Nano	11.55	11.33	10.93	11.27
	3. Sezam-Nano + HUMIN PLUS	11.68	11.40	10.97	11.35
	4. Sezam-Nano + Grainactive-C	11.87	11.63	11.21	11.57
	5. HUMIN PLUS	11.59	11.35	10.90	11.28
	6. Nanomix	11.80	11.58	11.09	11.49
HIP_{05}, t/ha	A =	0.33	0.41	0.37	–
	B =	0.18	0.24	0.22	–

early-maturity corn hybrids under irrigation conditions.

The economic efficiency of the applied technology elements was determined with the purpose of objective substantiation of the most rational combination of measures in agriculture, namely hybrids of different maturity groups, microfertilizers and growth stimulants along with the use of scheduled cost of material and technical resources for the cultivation of corn for grain under irrigation conditions. The general norms of performance, prices for manual and automated labor were accepted pursuant to the recommended production standards [9]. Grain was used in the calculations as the main kind of products while determining the cost of gross production from 1 ha. It was determined that the cost of the products obtained while cultivating corn changes with the regularity, observed for the culture productivity (Table 3).

The estimation of economic efficiency revealed that in case of cultivating the investigated hybrids without growth stimulants and microfertilizers the production costs were 0.8–1.7 % less compared to the ones, incurred with the introduction of the mentioned factor to technological ways of corn cultivation. The maximal costs (21,575–21,741 hryvnia/ha) were determined for the application of HUMIN PLUS preparation to medium-maturity and medium-late hybrids.

The highest net profit in the experiment was provided by medium-late hybrid Arabat, regardless of growth stimulants and microfertilizers. It was maximal for hy-

Table 2. The yield of corn hybrid grain, FAO 310–430, depending on microfertilizers and growth stimulants, t/ha

Hybrid (A)	Processing with the preparation (B)	2013	2014	2015	Average
Zbruch (FAO 310)	1. No treatment	11.32	11.10	10.82	11.08
	2. Sezam-Nano	12.09	11.85	11.37	11.77
	3. Sezam-Nano + HUMIN PLUS	12.11	11.93	11.45	11.83
	4. Sezam-Nano + Grainactive-C	12.60	12.32	11.68	12.20
	5. HUMIN PLUS	12.03	11.77	11.36	11.72
	6. Nanomix	12.50	12.16	11.49	12.05
Kakhovskyi (FAO 380)	1. No treatment	11.61	11.29	11.06	11.32
	2. Sezam-Nano	12.36	12.12	11.61	12.03
	3. Sezam-Nano + HUMIN PLUS	12.40	12.16	11.68	12.08
	4. Sezam-Nano + Grainactive-C	12.86	12.60	11.95	12.47
	5. HUMIN PLUS	12.26	12.00	11.50	11.92
	6. Nanomix	12.78	12.42	11.79	12.33
DN Hetera (FAO 420)	1. No treatment	12.21	11.95	11.66	11.94
	2. Sezam-Nano	13.08	12.80	12.28	12.72
	3. Sezam-Nano + HUMIN PLUS	13.12	12.86	12.36	12.78
	4. Sezam-Nano + Grainactive-C	13.52	13.24	12.69	13.15
	5. HUMIN PLUS	12.98	12.72	12.07	12.59
	6. Nanomix	13.44	13.16	12.46	13.02
Arabat (FAO 430)	1. No treatment	12.74	12.52	12.36	12.54
	2. Sezam-Nano	13.67	13.41	13.06	13.38
	3. Sezam-Nano + HUMIN PLUS	13.69	13.49	13.11	13.43
	4. Sezam-Nano + Grainactive-C	14.17	13.83	13.40	13.80
	5. HUMIN PLUS	13.51	13.27	12.88	13.22
	6. Nanomix	14.10	13.72	13.31	13.71
HIP_{05}, t/ha	A =	0.33	0.41	0.37	–
	B =	0.18	0.24	0.22	–

Table 3. The economic efficiency of growing corn hybrids, FAO 180–430, depending on microfertilizers and growth stimulants in 2015

Hybrid maturity group (A)	Treatment with the preparation (B)	Yield, tons/ha	Cost of production, UAH/ha	Net profit, UAH/ha	Profitability, %
FAO 180−190	1. No treatment	9.23	27690	7042	34.1
	2. Sezam-Nano	9.71	29130	8297	39.8
	3. Sezam-Nano + HUMIN PLUS	9.77	29310	8415	40.3
	4. Sezam-Nano + Grainactive-C	9.96	29880	8961	42.8
	5. HUMIN PLUS	9.67	29010	8199	39.4
	6. Nanomix	9.86	29580	8692	41.6
FAO 240–290	1. No treatment	10.45	31350	10638	51.4
	2. Sezam-Nano	11.14	33420	12523	59.9
	3. Sezam-Nano + HUMIN PLUS	11.25	33750	12791	61.0
	4. Sezam-Nano + Grainactive-C	11.51	34530	13547	64.6
	5. HUMIN PLUS	11.15	33450	12575	60.2
	6. Nanomix	11.43	34290	13338	63.7
FAO 310–380	1. No treatment	11.32	33960	12548	58.6
	2. Sezam-Nano	12.09	36270	14673	67.9
	3. Sezam-Nano + HUMIN PLUS	12.11	36330	14671	67.7
	4. Sezam-Nano + Grainactive-C	12.60	37800	16017	73.5
	5. HUMIN PLUS	12.03	36090	14515	67.3
	6. Nanomix	12.50	37500	15848	73.2
FAO 400–430	1. No treatment	12.36	37080	15502	71.8
	2. Sezam-Nano	13.06	39180	17417	80.0
	3. Sezam-Nano + HUMIN PLUS	13.11	39330	17505	80.2
	4. Sezam-Nano + Grainactive-C	13.40	40200	18351	84.0
	5. HUMIN PLUS	12.88	38640	16899	77.7
	6. Nanomix	13.31	39930	18112	83.0

brids in case of using growth stimulants Sezam-Nano and Grainactive-C (Table 3).

Compared to the variants with no treatment, growth stimulants and microfertilizers increased the net profit for hybrids by 1.7–12.2 % on average.

In 2015 the highest profit level (18.351 UAH/ha) and the profitability of 84 % was obtained on the fields of hybrid Arabat on conditions of seed treatment with the growth stimulant Sezam-Nano and in the phase of 7–8 leaves – with Grainactive-C, which is 12.2 % higher than untreated variants. High profit was also provided by hybrids DN Hetera and Kakhovskyi.

Quite a different situation was observed while determining the profitability level of cultivating corn hybrids. In 2015 it was found to be in the range of 34.1–71.8 % for all the hybrids without the use of growth stimulants and microfertilizers. When treating with preparations, the profitability level increased and was 35.9–84.0 % on average by the variants of treatments. It should be noted that it was considerably higher when growing corn hybrids with longer vegetation period, and the cost of growing a unit of production was decreased.

CONCLUSIONS

To obtain corn grain yield at the level of 10–14 t/ha under irrigation conditions on dark-chestnut soil in the south of Ukraine the corn hybrids of medium maturity and medium-late groups Zbruch, Kakhovskyi, DN Hetera, Arabat are recommended to grow with application of innovation growth stimulants and microfertilizers.

Продуктивність гібридів кукурудзи різних груп ФАО залежно від мікродобрив та стимуляторів росту за умов зрошення на півдні України

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Мета. Встановити ефективні мікродобрива і стимулятори росту з урахуванням біологічних особливостей нових гібридів кукурудзи різних груп ФАО за умов зрошення півдня України та простежити їхній вплив на формування зернової продуктивності рослин. **Методи.** Для вивчення взаємодії об'єкта досліджень з експериментальними факторами і чинниками природного середовища використано польовий метод, який передбачає реєстрацію обсягу врожаю та вимірювання біометричних показників; для визначення вологості ґрунту, вмісту вологи в зерні та показників якості зерна застосовано лабораторний метод, а також статистичний – для оцінювання достовірності отриманих результатів і розрахунковий – для економічної та енергетичної оцінки застосованих прийомів вирощування. **Результати.** Встановлено вплив мікродобрив і стимуляторів росту на формування врожайності і якості зерна гібридів кукурудзи різних груп стиглості, а також на економічну ефективність їхнього вирощування. **Висновки.** За умов зрошення Південного Степу України на темно-каштанових ґрунтах для отримання врожайності 10−14 т/га і рентабельності виробництва 50−84 % рекомендується використовувати такі гібриди: ранньостиглий ДН Пивиха, середньоранній Скадовський, середньостиглий Каховський і середньопізній Арабат. Вирощування повинно супроводжуватися комплексним застосуванням стимуляторів росту (обробкою насіння «Сизам-Нано» та підживленням у фазі 7−8 листків кукурудзи «Грейнактив-С»).

Ключові слова: гібриди кукурудзи, групи ФАО, мікродобрива і стимулятори росту, зрошення, врожайність зерна, економічна ефективність.

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