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Productivity of maize hybrids of different FAO groups depending on conditions of irrigation and dosage of fertilizers in the southern steppe of Ukraine

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Aim. *To determine optimal doses of mineral fertilizers taking into consideration biological specificities of new maize hybrids of different FAO groups in irrigation conditions of the southern Ukraine and to trace their impact on the formation of grain productivity of plants.* ***Methods****. The field method was used to study the interaction of the investigated object and both experimental and environmental factors via the registration of the yield volume and biometric measurements; the laboratory method was used to determine soil humidity, humidity content in grain and quality indices of grain; the statistical method was used to estimate the reliability of the results obtained; and the computational method was used in economic and energetic estimation of the employed cultivation techniques.* ***Results.*** *The yield of maize grain of 13–15.42 t per ha on condition of irrigation and introduction of the estimated amount of mineral fertilizer $N_{240}P_0K_0$ is registered for hybrids of mid-ripening and middle-late groups – Azov, Krasyliv 357 MB, Sokolov 407 MB, Bystrytsia 400 MB. Without irrigation, the highest yield is remarkable for the hybrids of early-ripening and middle-early groups – Tendra, April 187 MB, Syvash, Orzhytsia 237 MB (grain yield of 3.15–3.39 t per ha).* ***Conclusions.*** *The following hybrids are recommended for cultivation on condition of irrigation of dark-chestnut soils of the southern steppe of Ukraine: early-ripening Tendra, middle-early – Orzhytsia 237 MB, mid-ripening – Krasyliv 357 MB, and middle-late – Bystrytsia 400 MB, with the introduction of the estimated dose of the mineral fertilizers, defined by the difference between the amount of nutritious elements, required for the formation of productivity of the desired level and their content in the soil of a specific plot.*

Keywords: *maize hybrids, FAO groups, profitability, irrigation, yield and quality of grain, economic efficiency.*

INTRODUCTION

According to the level of potential productivity, maize exceeds all the grain crops, if provided with moisture in the soil. 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 main factors of yield formation while cultivating maize on lands with and without irrigation are the nutritious background and the selection of hybrid composition [1–3].

Due to the necessity of improving technological ways of cultivating maize 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 maize hybrids were carried out both with and without irrigation. While cultivating hybrids with irrigation, the scheme of experiments included the introduction of mineral fertilizers, as it is known that the latter and the optimization of moisture regime promote the increase in the productivity of crops 2−5 times [4−8].

The aim of the work was to determine optimal doses of mineral fertilizers taking into consideration biological specificities of new maize hybrids of different FAO groups in irrigation conditions of the southern Ukraine and to trace their impact on the formation of grain productivity of plants.

MATERIALS AND METHODS

The field method was used to study the interaction of the investigated object and both experimental and

environmental factors using the registration of the yield volume and biometric measurements; the laboratory method was used to determine soil humidity, humidity content in grain and quality indices of grain; the statistical method was used to estimate the reliability of the results obtained; and the computational method was used in economic and energetic estimation of the employed cultivation techniques.

The studies were carried out in 2011–2013 on the experimental field of the Institute of Irrigated Agriculture NAAS, located in the south of Ukraine in the zone of the Ingulets irrigated area. The soil of the experimental plot was dark-chestnut, medium loam, weakly alkaline, the water table was deep.

The following factors were used in the experiments: A − maize hybrids, differing by FAO groups – Tendra, April 187 MB, Syvash, Orzhytsia 237 MB, Azov, Krasyliv 357 MB, Sokolov 407 MB, Bystrytsia 400 MB; B − irrigation and no irrigation; C – fertilizers and no fertilizers (recommended dose of mineral fertilizers for the zone of experiments − $N_{150}P_{90}$ and the estimated dose − $N_{240}P_0$). 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 – 84.0 sq.m., the area for registration – 51.2 sq.m.

The agrotechnology of cultivating maize, used in the experiments, was common for the southern zone of Ukraine. The predecessor crop was soybean. The watering was carried out according to the scheme of the experiment by the raining method.

The mineral fertilizers (factor C) were introduced as follows: ammonia nitrate (N – 34 %) – during presowing harrowing; granular superphosphate (P – 20 %) – during autumn plowing, performed at the depth of 27–30 cm. The estimated dose of fertilizers $N_{240}P_0K_0$ was determined by the optimum parameters method as the difference between the yield carry-over and the actual content of nutritive elements in the soil [9].

Maize 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 methodological instructions and standards.

RESULTS AND DISCUSSION

Maize belongs to drought-resistant crops (mesophytes). However, the deficiency of moisture in the soil is a serious factor, limiting the yield of maize grain. The extreme weather conditions, frequently observed in the southern steppe of Ukraine (dry hot 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 maize 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.

Noteworthy is the index of the recoupment of the irrigation water by additionally obtained yield of grain due to irrigation (Table 1).

Table 1. The recoupment of the irrigation water due to the grain yield surplus, kg/m^3 (average for 2011–2013)

Hybrid	FAO	Recoupment of irrigation water		
		Due to irrigation	Due to irrigation and recommended dose of fertilizers N150P90	Due to irrigation and estimated dose of fertilizers N240P0
Tendra	190	1.91	3.54	3.80
April 187MB	190	1.66	3.32	3.54
Syvash	250	1.99	3.10	4.11
Orzhytsia 237 MB	280	2.39	3.80	4.31
Azov	350	3.57	4.47	4.89
Krasyliv 357 MB	352	2.46	5.24	5.65
Sokolov 407 MB	420	2.91	5.05	5.67
Bystrytsia 400 MB	420	3.31	5.08	5.63

Table 2. Grain yield of maize hybrids depending on doses of mineral fertilizers and irrigation, t/ha

Hybrid B	No irrigation (A)				Irrigation (A)											
	No fertilizers (C)				No fertilizers (C)				$N_{150}P_{90}$ (C)				Caculated dose (C)			
	2011	2012	2013	Average	2011	2012	2013	Average	2011	2012	2013	Average	2011	2012	2013	Average
Early-ripening																
Tendra	5.42	1.42	2.96	3.27	6.39	7.83	7.03	7.08	9.48	11.02	10.52	10.34	10.14	11.51	10.96	10.87
April 187 MB	5.39	1.38	2.83	3.20	6.02	6.91	6.62	6.52	9.13	10.57	10.09	9.93	9.46	10.93	10.41	10.27
Mid-ripening																
Syvash	4.05	1.47	3.94	3.15	6.47	7.67	7.23	7.12	8.48	10.08	9.50	9.35	10.34	12.16	11.58	11.36
Orzhytsia 237 MB	5.12	1.4	3.64	3.39	7.54	8.70	8.26	8.17	10.18	11.60	11.16	10.98	11.34	12.64	12.04	12.01
Mid-ripening																
Azov	5.43	1.87	2.08	3.13	9.83	10.72	10.26	10.27	10.87	12.96	12.39	12.07	11.98	13.84	12.90	12.91
Krasyliv 357 MB	6.21	1.98	2.83	3.67	7.88	9.20	8.68	8.59	13.50	14.76	14.16	14.14	14.53	15.42	14.97	14.97
Middle-late																
Sokolov	6.87	1.23	2.35	3.48	8.85	9.75	9.29	9.3	12.92	14.23	13.57	13.57	14.01	15.53	14.93	14.82
Bystrytsia 400 MB	6.56	1.11	2.02	3.23	9.26	10.34	9.91	9.84	12.73	14.06	13.39	13.39	13.84	15.16	14.44	14.48

Note. LED_{05}, t/ha A – 0.72; AB – 0.77; ABC – 0.85; B – 0.38; AC – 0.81; C − 0.54; BC – 0.49.

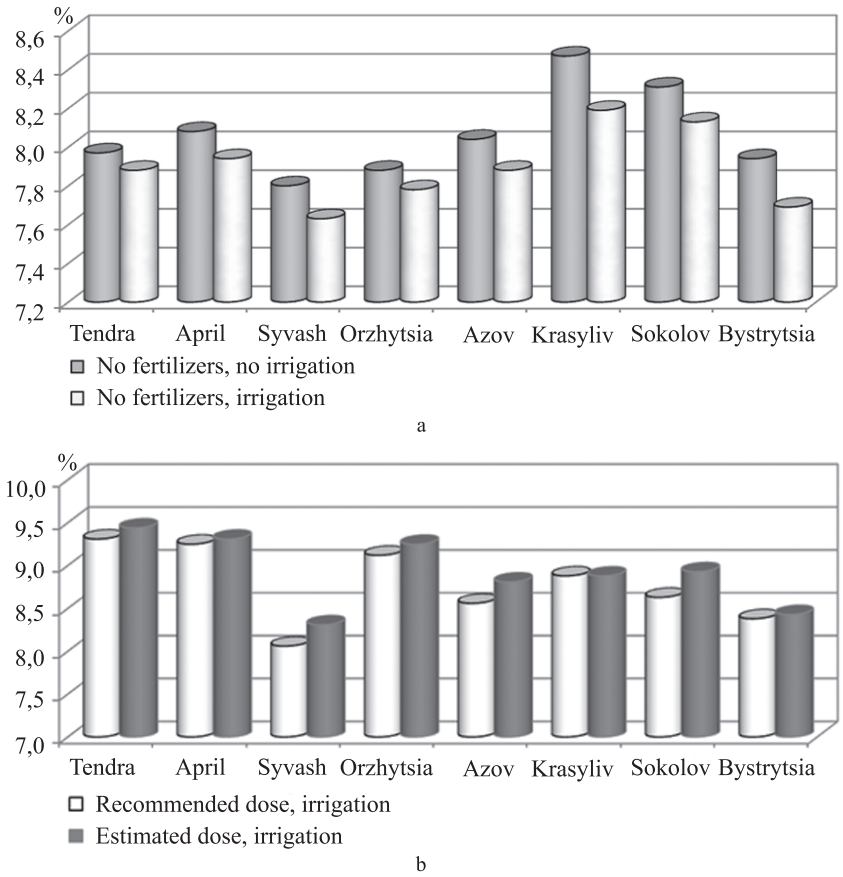

Fig. 1. The impact of investigated factors on the protein content (%) in the maize grain of hybrids of different ripening groups (average for 2011–2013): a – no fertilizers, no irrigation (1) and with irrigation (2); b – recommended (1) and estimated (2) doses of introducing fertilizers on condition of irrigation

During three years of studies of all the hybrids with vegetative watering without fertilizers, on average this index was 2.65 kg/m^3; on the background of using the recommended dose of the mineral fertilizer – $N_{150}P_{90}$ – it increased up to 4.37 kg/m^3, and using the estimated dose – $N_{240}P_0$ – up to 4.83 kg of grain per 1 m^3 of water. The abovementioned testifies to the reasonability of introducing mineral fertilizers while cultivating crops, maize in particular, on irrigated lands.

The results of the registration demonstrated that on condition of irrigation the mineral fertilizers induced the productivity of the investigated hybrids on average from 40.3 to 74.3 % during 2011–2013 (Table 2). This increase was in direct proportion to the dose of the introduced nitrogen fertilizers.

The data of Table 2 confirm the tendency of grain yield surplus in all the groups of hybrid ripening depending on the irrigation and mineral dose of fertilizers (both recommended and estimated doses).

The maximal yield of maize grain was observed on the background of irrigation and introduction of the estimated dose of mineral fertilizers – on average during the years of studies of all the hybrids it is 12.71 t/ha, and in 2013 the yield of grain was 12.78 t/ha. In case of introducing the recommended dose of fertilizer $N_{150}P_{90}$ the yield was somewhat lower, amounting to 11.72 and 11.85 t/ha, respectively, which is 8.4 and 7.9 % less. The irrigation with no fertilizers had different effect on the yield level of maize grain – the surplus for hybrids of early-ripening group was rather considerable, during three years of studies it amounted to 210 % on average.

Generally, the yield surplus of maize grain after the irrigation increased from 38.2 % in favorable 2011 to 600.7 % in dry 2012. The highest index was demonstrated while cultivating mid-ripening hybrid Azov, the productivity of which due to irrigation for three years was on average 3.3 times higher than the absolute control with no irrigation.

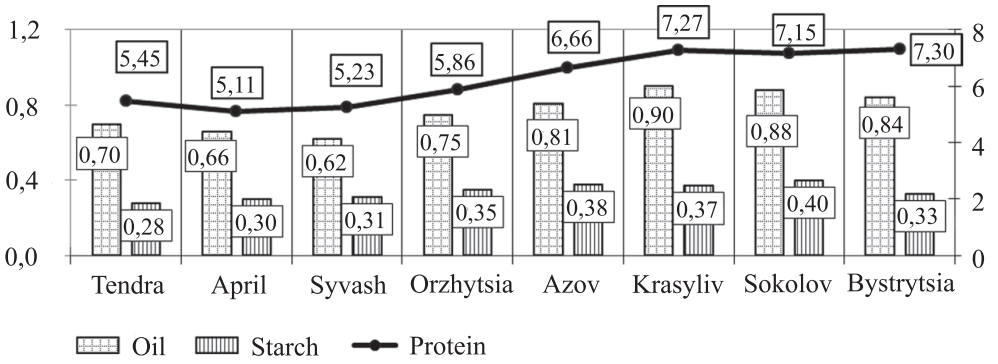

Fig. 2. The conditional yield (t/ha) of protein, oil and starch from the unit of area (average values for the investigated maize hybrids for 2011–2013)

Table 3. Economic efficiency of cultivating maize hybrids of different ripening groups depending on the conditions of irrigation and the nutritious background in 2013

Factor			Yield, tons/ha	Cost of products, UAH/ha	Net profit, UAH/ha	Profit-ability, %
A	B	C				
Tendra	No irrigation	No fertilizers	2.96	38480	1201	45.4
April 187 MB			2.83	36790	1036	39.2
Syvash			3.94	5122	2488	94.5
Orzhytsia 237 MB			3.64	4732	2082	78.6
Azov			2.08	2704	77	2.9
Krasyliv 357 MB			2.83	3679	1016	38.1
Sokolov 407 MB			2.35	3055	410	15.5
Bystrytsia 400 MB			2.02	2626	–3	–0.1
Tendra	Irrigation	No fertilizers	7.03	9139	141	1.6
		N150P90	10.52	13676	1010	8.0
		N240P0	10.96	14248	1973	16.1
April 187 MB		No fertilizers	6.62	8606	–299	–3.4
		N150P90	10.09	13117	544	4.3
		N240P0	10.41	13533	1298	10.6
Syvash		No fertilizers	7.23	9399	403	4.5
		N150P90	9.50	12350	–179	–1.4
		N240P0	11.58	15054	2688	21.7
Orzhytsia 237 MB		No fertilizers	8.26	10738	1623	17.8
		N150P90	11.16	14508	1871	14.8
		N240P0	12.04	15652	3243	26.1
Azov		No fertilizers	10.26	13338	3957	42.2
		N150P90	12.39	16107	3273	25.5
		N240P0	12.90	16770	4306	34.5
Krasyliv 357 MB		No fertilizers	8.68	11284	2146	23.5
		N150P90	14.16	18408	5436	41.9
		N240P0	14.97	19461	6859	54.4
Sokolov 407 MB		No fertilizers	9.29	12077	2831	30.6
		N150P90	13.57	17641	4712	36.4
		N240P0	14.93	19409	6823	54.2
Bystrytsia 400 MB		No fertilizers	9.91	12883	3601	38.8
		N150P90	13.39	17407	4490	34.8
		N240P0	14.44	18772	6208	49.4

The protein content in maize grain changes under the impact of fertilizers, irrigation and biological specificities of hybrids (Fig. 1). Compared to the cultivation with neither fertilizers nor irrigation, the protein content is somewhat decreased under the impact of irrigation, fluctuating in the range of 7.63–8.19 and 7.80–8.47 %. During three years of cultivation the amount of protein in grain for all the hybrids (with neither fertilizers nor irrigation) was 8.06 % on average, and with irrigation – 7.89 %.

In case of irrigation the mineral fertilizers increased the protein content in the maize grain considerably. While during the years of studies the protein content in grain was 7.89 % on average when cultivating maize hybrids with no fertilizers, in case of introducing the recommended dose of fertilizers its concentration was 8.77 %, and with the estimated dose – 8.92 %.

The determination of conditional yield of protein, starch and oil from the unit of area revealed its changes depending on the ripening groups of maize hybrids (Fig. 2) and its considerable increase under the influence of mineral nutrition.

The economic efficiency of the applied technology elements was determined with the purpose of objective grounding of the most rational combination of measures in agriculture. The general norms of performance, prices for manual and automated labor were accepted pursuant to the recommended production standards. 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 maize 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 with neither irrigation nor fertilizers the production costs were 2.0–2.8 times less compared to the ones, incurred with the introduction of the mentioned factors to technological ways of maize cultivation. The maximal expenses (12,528–12,972 UAH/ha) were incurred in case of irrigation and introduction of the recommended dose of the mineral fertilizer. With the introduction of the estimated dose the expenses were reduced, which is related to the reduction in expenses for phosphoric fertilizers.

The highest net profit in the experiment regardless of irrigation was demonstrated by mid-ripening hybrid Krasyliv 357 MB. It had the maximal values among all the hybrids in case of the estimated dose of fertilizers. Compared to the variants with neither fertilizers nor irrigation, the vegetative watering induced 1.7-fold increase in the net profit for hybrids on average. On the background of irrigation, due to fertilizers it increased by 52.5 % with the recommended dose of fertilizers, and by 88.9 % – with the estimated dose.

In 2013 due to the low purchase value of maize grain the net profit index for all the variants of the experiment was lower than the average indices for many years.

For instance, the highest profit – 6,859.2 UAH/ha – was obtained from Krasyliv hybrid 357 MB and the introduction of the estimated dose of fertilizers which was 2.2 times lower than the average value for three years. High profit was also obtained from hybrids Bystrytsia 400 MB and Sokolov 407 MB.

Quite a different situation was observed while determining the profitability level of cultivating maize hybrids. On average for the years of studies with neither fertilizers nor irrigation it was 132.1 % for all the hybrids, and in 2013 – 39.2 %. With vegetative watering this index decreased to 69.0 and 24.5 % respectively, which is related to the cost of the irrigation water and expenses for vegetative watering. In case of using the recommended dose of fertilizer $N_{150}P_{90}$ the profitability level increased up to 69.7 % compared to the plots with no fertilizers, and in case of introducing the estimated dose of the mineral fertilizer – up to 88.8 %.

It is noteworthy that while cultivating maize hybrids with longer vegetation period the profitability was at a considerably higher level, and the cost of production per one production unit was reduced.

CONCLUSIONS

To obtain maize grain yield at the level of 11–14 t/ha with the irrigation of dark-chestnut soil of the southern Ukraine, it is reasonable to introduce the estimated dose of the mineral fertilizer, which is defined by the difference between the required amount of nutritious elements for the formation of productivity of the desired level and their content in the soil of a particular plot. It is also reasonable to use maize hybrids of mid-ripening and middle-late groups – Azov, Krasyliv 357 MB, Sokolov 407 MB, Bystrytsia 400 MB.

The hybrids of early-ripening and mid-ripening groups – Tendra, April 187 MB, Syvash, Orzhytsia 237 MB, capable of better utilization of the moisture of soil resources and forming higher yield, –

should be used when cultivating maize with no irrigation.

Продуктивность гибридов кукурузы различных групп ФАО в зависимости от увлажнения и доз удобрений в условиях южной степи Украины

Р. А. Вожегова, Ю. А. Лавриненко, Т. В. Глушко

Цель. Установить оптимальные дозы минеральных удобрений с учетом биологических особенностей новых гибридов кукурузы различных групп ФАО в орошаемых условиях юга Украины и проследить их влияние на формирование зерновой продуктивности растений. **Методы.** Полевой – с целью изучения взаимодействия объекта с исследуемыми факторами и природной средой путем учета урожая и биометрических измерений; лабораторный – определение влаги почвы, содержания влаги в зерне, показателей качества зерна; статистический – для оценки достоверности полученных результатов; расчетный – для экономической и энергетической оценки изучаемых приемов выращивания. **Результаты.** Урожайность зерна кукурузы 13–15.42 т/га формируется при орошении и внесении расчетной дозы минеральных удобрений N240P0K0 у гибридов среднеспелой и среднепоздней групп – Азов, Красилов 357 МВ, Соколов 407 МВ, Быстрица 400 МВ. При выращивании кукурузы без орошения большую урожайность формируют гибриды раннеспелой и среднеранней групп – Тендра, Квитневый 187 МВ, Сиваш, Оржица 237 МВ (урожайность зерна 3.15–3.39) **Выводы.** В условиях орошения южной степи Украины на темно-каштановых почвах рекомендуется использовать раннеспелый гибрид Тендра, среднеранний – Оржица 237 МВ, среднеспелый – Красилов 357 МВ и среднепоздний – Быстрица 400 МВ, и вносить расчетную дозу минерального удобрения, которую определяют по разности между необходимым количеством элементов питания для формирования урожайности заданного уровня и их содержанием в почве конкретного поля.

Ключевые слова: гибриды кукурузы, группы спелости, окупаемость, орошение, урожайность и качество зерна, экономическая эффективность.

Продуктивність гібридів кукурудзи різних груп ФАО залежно від умов зволоження та доз добрив у південному степу України

Р. А. Вожегова, Ю. О. Лавриненко, Т. В. Глушко

Мета. Встановити оптимальні дози мінеральних добрив з урахуванням біологічних особливостей нових гібридів кукурудзи різних груп ФАО в умовах зрошення півдня України та простежити їхній вплив на формування зернової продуктивності рослин. **Методи.** Польовий – для вивчення взаємодії об'єкта досліджень з експериментальними факторами та чинниками природного середовища, реєструючи обсяг врожаю та здійснюючи біометричні виміри; лабораторний – для визначення вологи ґрунту, вмісту вологи в зерні та показників якості зерна; статистичний – для оцінювання достовірності отриманих результатів; розрахунковий – для економічної та енергетичної оцінки застосованих прийомів вирощування. **Результати.** Урожайність зерна кукурудзи 13–15.42 т/га формується за умов зрошення та внесення розрахункової дози мінеральних добрив N240P0K0 у гібридів середньостиглої та середньопізньої груп – Азов, Красилів 357 МВ, Соколов 407 МВ, Бистриця 400 МВ. При вирощуванні кукурудзи без зрошення більшу урожайність формують гібриди ранньостиглої та середньоранньої груп – Тендра, Квітневий 187 МВ, Сиваш, Оржиця 237 МВ (урожайність зерна 3.15–3.39 т/га). **Висновки.** За умов зрошення південного степу України на темно-каштанових ґрунтах рекомендується використовувати наступні гібриди: ранньостиглий Тендра, середньоранній – Оржиця 237 МВ, середньостиглий – Красилів 357 МВ і середньопізній − Бистрицю 400 МВ та вносити розрахункову дозу мінерального добрива, яку визначають за різницею між необхідною кількістю елементів живлення для формування врожайності заданого рівня та їхнім вмістом у ґрунті конкретного поля.

Ключові слова: гібриди кукурудзи, групи ФАО, окупність, зрошення, врожайність і якість зерна, економічна ефективність.

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