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APPLICATION OF PLANT GROWTH REGULATORS ON CORN CROPS IN THE SOUTHERN STEPPE OF UKRAINE

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Abstract. *The aim of the research was to determine the productivity of the Ingulsky corn hybrid of the medium-ripening group of maturity depending on seed and plant treatment during the growing season when applying Regoplant and Vermystym biostimulants, as well as the effect of a plant density in different moisture conditions. Methods. The field laboratory and mathematical and statistical methods were used in the course of the research. Results. Irrigation provided an increase in the yield of silage mass by 1,4–2,2 times. Thus, on average, over three years, the highest productivity of corn for silage was observed when having a plant density of 90 thousand/ha without applying biostimulants – 48,6 t/ha and with applying biostimulants – 59,3–64,7 t/ha. The highest dry matter yield of 17,3–18,5 t/ha, feed unit yield of 16,1–17,4 t/ha and digestible protein content of 0,75–0,82 t/ha was obtained when biostimulants were applied when having a plant density of 90 thousand/ha. It was found that in non-irrigated conditions, the highest grain yield was 3,1–4,7 t/ha on the variant with a plant density of 30 thousand/ha. Applying Regoplant biostimulant provided an increase in grain yield by 1,6 t/ha, while applying Vermystym biostimulant provided an increase in grain yield by 1,2 t/ha, respectively. Conclusions. In non-irrigated conditions, it is necessary to apply Vermystym biostimulant with a sowing rate of 70 thousand/ha to obtain the highest yield of fodder units of 9,6 t/ha and 0,42 t/ha of digestible protein content from corn green mass. In irrigated conditions, the seeding rate should be increased to 90 thousand/ha and Regoplant biostimulant should be used to obtain the highest yield of feed units of 17,4 t/ha and 0,87 t/ha of digestible protein content. The cultivation of the Ingulsky hybrid corn for grain in non-irrigated conditions provided the highest yield of 4,7 t/ha with a plant density of 30 thousand/ha and applying Regoplant biostimulant. In irrigated conditions increasing a plant density to 70 thousand/ha and applying Regoplant biostimulant provided the maximum yield of 11,2 t/ha.*

Key words: *corn, biostimulants, plant density, irrigation, fertilization, productivity*

Relevance of the research.. Corn is one of the most valuable fodder crops, which provides livestock with juicy fodder (green mass, silage) and valuable fodder grain. The highest quality silage is obtained when it is mowed for vegetative mass in the phase of milk-wax and waxy grain ripeness. The nutritional value of 1 kg of green mass during these periods is 0,22–0,26 and 0,27–0,32 feed units, respectively. One kilogram of corn grain is equivalent to 1,34 feed units, while 1 kilogram of barley is equivalent to 1,26 feed units, rye – to 1,18, and oats – to 1.0 feed units. It contains 65–70 % carbohydrates, 9–12 % protein, 4–8 % fat and a small amount of fiber [1, 3, 10].

The average grain yield reaches 6-7 t/ha, although the potential productivity is much higher. When using high-yielding hybrids, moisture supply and modern growing technologies, grain yield can reach 10–12 t/ha [4, 8, 10, 24, 25].

An insufficient yield of this crop is also observed in the southern region of the country. In this regard, it is important to realize the genetic potential of modern corn hybrids through the use of irrigation, fertilizers and plant growth bioregulators in improved cultivation technologies, which create more optimal conditions for their growth and development, increase resistance to adverse environmental

factors, increase yield and improve the quality of the grown products.

However, the effect of growth bioregulators on the forage productivity of new hybrids of grain-forage corn in the modern conditions of the southern region has not been sufficiently studied yet, which proves the relevance of research.

Analysis of recent research and publications. An important condition for obtaining high productivity of corn is the use of a set of optimal agrotechnical measures in view of the characteristics of the soil and climatic cultivation zone, where the sowing density plays an important role. Researchers point to its lower effect on the formation of aboveground mass under irrigation compared to the effect of mineral fertilizers [2, 5]. With insufficient moisture supply, the advantages of thickened crops decrease [7].

Treatment with growth bioregulators leads to an increase in plant height, leaf surface area of crops, accumulation of fresh mass and dry matter. With improved moisture supply under irrigation, the effectiveness of the use of growth bioregulators increases due to synergy and optimization of plant production processes [2, 12, 14].

In the conditions of Polissya, when using Biogran and Polymyxobacterin preparations for corn, an increase in crop yield of up to 20 % was recorded over a ten-year period. The effective action of biological preparations on crop productivity without deterioration of product quality in field conditions is 85–90 % [1].

In the conditions of the northern Steppe of Ukraine, the treatment of corn seeds with chelate-based biological preparations contributed to the enhanced growth intensity in the initial stage and increased grain yield. The highest effectiveness was obtained when using the complex microbial preparation Biogran, the complexes of trace elements Reastim-humus, and Reakom-S corn. The effectiveness of the preparations was determined by the background of mineral nutrition [17].

The study the effectiveness of the use of Biogran biopreparations for corn (green mass) in the system of biological and organo-mineral farming in the conditions of the Volyn RS of the Institute of Western Polissya Agriculture of NAAS on drained sod-podzolic soils, revealed that using Biogran biopreparations increases the content of nitrogen compounds in the soil by 4–14 % under the organo-mineral fertilization system. The use of Biogran and Microhumin preparations against the background of different fertilization systems increased in the yield of grain-forage crops: corn for green mass by 6,3 t/ha and spring barley – by 0,4 t/ha, compared to the control [13].

Treatment of seeds and plants in the 3–5 or 7–9 leaf phase with the microbial Polimilxo-bacterin preparation increases crop yield by 2.4 t/ha, protein content in grain by 0,6–1,4 % and starch by 7,9–8,9 %. With the combined use of seed bacterization and plant treatment during the growing season, the number of grains, corn cob length and thousand-grain weight significantly increase by 11 % [19, 20].

Plant growth bioregulators reveal the genetic potential of new morphobiotypes, increasing the efficiency of irrigation, which in turn contributes to increasing the profitability of their use [9, 15]. The use of growth bioregulators is especially important in crops of self-pollinated corn lines, which are characterized by low germination energy, weak initial growth, and sensitivity to damage by pests and phytoinfections [3, 8, 9].

It was established that the use of plant growth bioregulators and micronutrients improves nutrient absorption, enhances photosynthesis processes, increases plant resistance to high and low temperatures, lack of moisture, phytotoxic effects of pesticides, and damage by diseases and pests, increases yield, and contributes to the maximum use of plants' potential [6, 15, 16, 18, 23].

In the southern region of the country, the use of plant growth bioregulators "Grainactiv-S" and "Sizam-Nano" reduced the use of chemicals and increased plant resistance to adverse environmental factors under irrigation. Growing mid-season and mid-late-season corn hybrids such as Zbruch, Kakhovsky, DN Getera, Arabat when using innovative growth stimulants and micronutrients allowed obtaining grain yields of 11,1–13,4 t/ha on irrigated dark chestnut soils of southern Ukraine [3].

Thus, scientists confirm that plant growth bioregulators and micronutrients can take an important place in the system of improving corn grain production technology. However, the impact of new plant growth bioregulators on the feed productivity of high-yielding hybrids of grain-feed corn in modern conditions of southern Ukraine has not been sufficiently studied yet.

Research objectives and methodology. The purpose of the research was to substantiate theoretical provisions and improve existing technologies for growing corn by increasing its productivity under irrigation and non-irrigation conditions when using a complex of agro-technical measures. To achieve these goals, it was necessary to investigate the productivity of a mid-ripening corn hybrid when treating seeds and plants during vegetation with plant growth

bioregulators, as well as the effect of stand density under different moisture supply conditions. Field and laboratory studies were conducted according to the research methods in 2016-2018 on irrigated lands of the Institute of Climate-Oriented Agriculture of the NAAS of Ukraine [11, 21, 22].

Soils are dark chestnut, slightly saline, medium loamy with a humus layer of 45–50 cm. The humus content in the arable soil layer (0-30 cm) is 2,8–3,4 %, hydrolyzed nitrogen content is 4,5–5,5 %, mobile phosphorus content is 4,0–6,0 mg per 100 g of soil, exchangeable potassium content is 40 mg per 100 g of soil. The minimum moisture-holding capacity in the 0-50 cm of soil layer is 23,2 %, 0–100 cm – 21,5 %, 0–150 cm – 21,3 %. The withering point is 11,4; 11,6; 11,9 % to an over-dry weight, respectively. To determine the feed value of grain, a certified analytical laboratory of the institute was used.

The agricultural technology of crop growing was generally accepted for the zone. Sowing was performed in the third decade of April. Ingulsky (FAO-350) corn hybrid was sown, on irrigated and non-irrigated areas with a seeding rate of 30, 50, 70 and 90 thousand seeds/ha. The sown area was 50 m^2, the accounting area was 20 m^2.

Crops were sown when applying mineral fertilizer N_{90} in the form of ammonium nitrate applied in the period of pre-sowing cultivation. Regoplant (seed treatment rate is 250 ml/t and plant treatment rate is 50 ml/ha) and Vermistim (seed treatment rate is 10 l/t and plant treatment rate is 8 l/ha) regulators were used. The active substance of the Regoplant regulator is a complex of biologically active compounds (polysaccharides, 15 amino acids, analogues of phytohormones of cytokinin and auxin nature), biogenic trace elements, potassium salt of alpha-naphthylacetic acid and aversectin C. The active substance of the Vermistim regulator includes such biocomponents as humates, fulvic acids, amino acids, vitamins and natural phytohormones.

Plant growth bioregulators were applied for the first time in the 5–7 leaf phase, and for the second time in the 8–10 leaf phase. On average, the total irrigation rate over three years was 3000 m^3. Irrigation was performed with a DDA-100MA sprinkler.

Weather conditions during the years of research were characterized by high temperatures and droughts in the summer. In 2016 the precipitation was 87 % for June-August period, in 2017 – 22 % and in 2018 – 101 % of the norm.

Research results. One of the tasks of optimizing the production process is to form the optimal density of corn crops. Thus, on average for 2016-2018, under non-irrigated conditions, the highest productivity of corn per silage mass was when having a plant density of 70 thousand/ha with a yield of 29,2–36,3 t/ha, dry matter content of 7,7–10,8 t/ha, yield of feed units of 7,0–9,6 t/ha, digestible protein content of 0,29–0,42 t/ha and metabolic energy of 74–104 GJ (Table 1). Under these conditions, when having a plant density of 30 thousand/ha, the yield of feed units decreased by 48–50 %, digestible protein content by 48–55 %. When having a density of 50 thousand/ha, there was a decrease in feed units by 14–22 % and in digestible protein content by 17–22 %. When having a plant stand density of 90 thousand/ha, there was a decrease in the yield of feed units by 6–21 % and in digestible protein content by 10–21 %.

Biostimulant treatment of corn seeds before sowing and plants during vegetation, under non-irrigated conditions, provided an increase in dry matter yield on average by 18–27 % depending on plant density variants, and feed units by 18–28 %.

When having a plant density of 70 thousand/ha and applying Vermystym biostimulant, the feed unit yield was 9,6 t/ha, digestible protein content – 0,42 t/ha, and metabolizable energy – 104 GJ. Regoplant biostimulant was worse by these indicators by 16 %, 7 %, and 17 %, respectively.

Irrigation provided an increase in silage yield by 1,4–2,2 times. Thus, on average over three years, the highest productivity of corn for silage under irrigation was observed when having a plant density of 90 thousand/ha without applying biostimulants was 48,6 t/ha and when applying biostimulants it was 59,3–64,7 t/ha. The highest dry matter yield of 17,3–18,5 t/ha, the feed units yield of 16,1–17,4 t/ha and digestible protein content of 0,75–0,82 t/ha were obtained when applying biostimulants having a plant density of 90 thousand/ha. Applying Regoplant biostimulant provided the highest increase in silage yield by 25 % and dry matter yield by 32 %.

The effect of different factors on the formation of corn productivity showed that moisture conditions had the most significant effect on the grain and dry matter yield (82,5 % and 44,6 %, respectively). The effect of bioregulators on grain and dry matter yield was 6,1 %, 7,0 % respectively.

Thus, the main factor affecting corn productivity, both for grain and green mass, in the conditions of the southern Steppe of Ukraine is the factor of crop water supply. The use of plant growth regulators can be considered only as an additional means of increasing crop productivity.

1. Corn productivity depending on applying bioregulators under different moisture supply conditions (average for 2016–2018)

Water supply conditions (A)	Plant density, thousand/ha (C)	Yield, t/ha		dry matter yield, t/ha	Yield		
		grain	silage mass		feed units, t/ha	digestible protein content, t/ha	metaboli-zable energy, GJ
Non-irrigated area	Ground fertilization N_{90} (B)						
	30	3,1	14,1	4,0	3,6	0,13	39
	50	2,9	24,3	6,6	6,0	0,24	64
	70	2,6	29,2	7,7	7,0	0,29	75
	90	2,0	24,6	6,2	5,5	0,23	60
	Ground fertilization + Regoplant (B)						
	30	4,7	16,8	4,7	4,2	0,19	45
	50	4,4	26,1	7,6	6,9	0,30	73
	70	3,4	32,6	9,0	8,1	0,39	87
	90	2,5	29,9	8,1	7,6	0,35	79
	Ground fertilization + Vermystym (B)						
	30	4,4	18,5	5,4	4,8	0,22	52
	50	4,0	27,8	8,1	7,4	0,31	78
	70	3,0	36,3	10,8	9,6	0,42	104
	90	2,4	33,7	9,2	8,3	0,39	88
Irrigated area	Ground fertilization N_{90} (B)						
	30	6,1	28,7	9,0	8,4	0,33	88
	50	8,0	40,8	10,8	9,8	0,47	104
	70	9,0	46,0	12,4	11,4	0,52	121
	90	8,5	48,6	12,6	11,4	0,54	122
	Ground fertilization + Regoplant (B)						
	30	7.2	37,4	12,7	11,3	0,55	122
	50	8.6	44,1	12,3	11,6	0,54	121
	70	11.2	57,6	16,6	15,5	0,74	164
	90	10.3	64,7	18,5	17,4	0,82	182
	Ground fertilization + Vermystym (B)						
	30	6,7	33,9	11,7	10,5	0,45	112
	50	8,4	41,9	12,9	12,1	0,55	127
	70	10,7	51,6	15,3	14,4	0,66	151
	90	9,6	59,3	17,3	16,1	0,75	170
LSD_{05}:	A	0,83	0,56	0,23			
	B	0,10	0,30	0,09			
	C	0,12	0,23	0,06			

At the time of full grain maturity, in non-irrigated conditions, the highest height of corn plants was 191–205 cm when applying Vermystym biostimulant. When having a plant density of 30 thousand pcs./ha, both the highest plant height and other economically valuable characteristics of corn grain yield are recorded (Table 2).

Thus, in non-irrigated conditions, when applying Vermystym bioregulator the increase in the grain weight per cob was 16.6–44.7 % compared to the control area. However, under irrigation, treatment of plants with Regoplant bioregulator increased economically valuable characteristics more than Vermystym (Table 3). Under these conditions, the highest plant height (248–249 cm) when treating with biostimulants was when having a plant density of 30 thousand pcs./ha. Under irrigation, economically valuable characteristics also tended to decrease with increasing a plant density of corn.

When studying the effect of growth bioregulators and plant density on the grain yield of the Ingulsky corn hybrid, it was found that in non-irrigated conditions, the variant with a plant density of 30 thousand/ha was the most productive (3,1–4,7 t/ha) (Table 1). The application of Regoplant growth bioregulator provided an increase in grain yield by1,6 t/ha (52 %), and Vermystym preparation provided an increase in grain yield by 1,2 t/ha (38 %).

2. Main economically valuable characteristics of corn hybrids for grain depending on applying bioregulators in non-irrigated conditions

Plant density, thousand pcs./ha	Plant height, cm	Corn cob length, cm	Number of grains per cob, pcs	Grain weight of 1 cob, g	Weight of 1000 grains, g
Ground fertilization N_{90}					
30	200	16,0	536	123	230.0
50	200	16,0	490	105	215.0
70	187	15,6	428	94	219.2
90	180	11,7	373	78	210.0
Ground fertilization + Regoplant					
30	203	19,0	582	166	284.7
50	198	17,4	570	149	262.0
70	191	16,2	435	96	220.0
90	185	14,4	358	76	212.0
Ground fertilization + Vermystym					
30	205	19,6	633	158	239.2
50	201	17,4	598	152	264.3
70	194	17,0	588	135	230.7
90	191	14,5	412	91	220.0
$\overline{X} \pm S_{\overline{X}}$	194 ± 5	16,2 ± 1,3	500 ± 61	119 ± 21	234 ± 15

3. Main economically valuable characteristics of corn hybrids for grain depending on applying bioregulators in irrigated conditions

Plant density, thousand pcs./ha	Plant height, cm	Corn cob length, cm	Number of grains per cob, pcs	Grain weight of 1 cob, g	Weight of 1000 grains, g
1	2	3	4	5	6
Ground fertilization N_{90}					
30	247	20,5	622	218	350.5
50	243	20,0	584	201	345.0
70	238	20,5	553	189	342.3
90	231	19,8	523	146	280.0
Ground fertilization + Regoplant					
30	249	20,5	671	250	372.3
50	247	20,0	632	230	364.5
70	245	21,4	601	204	339.0
90	241	18,9	584	172	295.0

Continuation of Table 3

1	2	3	4	5	6
Ground fertilization + Vermystym					
30	248	19,8	647	230	355.0
50	246	19,8	622	211	340.0
70	242	19,6	605	193	318.8
90	240	17,9	526	152	288.0
$\overline{X} \pm S_{\overline{X}}$	243±3,2	19,9±0,5	597,5±2,2	200±20	332±19

Improving the soil fertility for corn cultivation for grain when applying plant growth bioregulators also provided a positive impact on the water consumption coefficient (Fig. 1).

Thus, in non-irrigated conditions, the lowest water consumption coefficient of 304 m^3/t was recorded when applying Regoplant growth bioregulator with a plant density of 30 thousand pcs/ha, which increased economical use of moisture by 34,2 % compared to the control; when applying Vermystym it was by 28,0 % respectively. In irrigated conditions, the greatest moisture saving was also provided by Regoplant growth bioregulator with a water consumption coefficient of 414 m^3/t when having a plant density of 70 thousand pcs/ha (by 17,0 % less compared to the control and by 6,2 % less compared to the option when applying Vermystym growth bioregulator).

On irrigated land, the Regoplant plant growth regulator provided the largest yield increase of 1,9 t (by 21 %) with a yield of 11,2 t/ha and a plant density of 70 thousand/ha. Vermystym plant growth regulator was by 6 % less effective than Regoplant and provided the highest yield of 10,4 t/ha having the same plant density of 70 thousand/ha.

Conclusions. Thus, in non-irrigated conditions, Vermystym plant growth regulator can be used to obtain the highest yield of feed units of the corn green mass of 8,3 t/ha and 0,32 t/ha of digestible protein with a seeding rate of 70 thousand/ha. In irrigated conditions, the seeding rate should be increased to 90 thousand/ha and Regoplant plant growth regulator can be used to obtain the highest yield of feed units of 14,4 t/ha and 0,67 t/ha of digestible protein.

Growing the Ingulsky corn hybrid for grain in non-irrigated conditions provided the highest yield of 4,7 t/ha when having a plant density of 30 thousand/ha and applying Regoplant plant growth regulator. In irrigated conditions increasing the plant density to 70 thousand/ha and applying Regoplant plant growth regulator provided the maximum yield of 11,1 t/ha.

In non-irrigated conditions, the lowest water consumption coefficient of 304 m^3/t was recorded when applying Regoplant plant growth regulator when having a plant density of 30 thousand/ha. In irrigated conditions, the largest moisture saving was also provided due to applying this plant growth regulator having a water consumption coefficient of 414 m^3/t and a plant density of 70 thousand/ha.

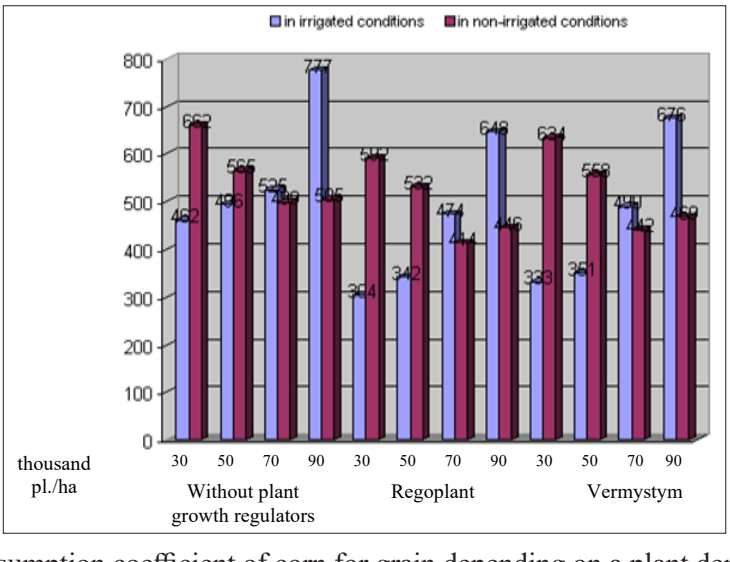

Fig. 1. Water consumption coefficient of corn for grain depending on a plant density and effect of bioregulators in different moisture supply conditions

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ВПЛИВ РІСТ-РЕГУЛЮЮЧИХ ПРЕПАРАТІВ НА КОРМОВУ ПРОДУКТИВНІСТЬ КУКУРУДЗИ В УМОВАХ ПІВДНЯ УКРАЇНИ

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Анотація. *Метою досліджень було визначити продуктивність гібриду кукурудзи Інгульський середньостиглої групи стиглості залежно від обробки насіння й рослин по вегетації біостимуляторами Регоплант та Вермистим, а також впливу густоти стояння за різних умов зволоження. Методи. У процесі виконання досліджень використовували польовий метод, лабораторний та математично-статистичний методи. Результати. Зрошення забезпечило збільшення врожайності силосної маси до 1,4–2,2 рази. Так, в середньому за три роки, на зрошенні найбільша продуктивність кукурудзи на силосну масу відмічалась за густоти 90 тис./га без підживлення біостимуляторами – 48,6 т/га та з підживленням біостимуляторами – 59,3–64,7 т/га. Найбільший збір сухої речовини 17,3–18,5 т/га, виходу кормових одиниць 16,1–17,4 т/га та перетравного протеїну 0,75–0,82 т/га отримано при внесенні біостимуляторів за густоти 90 тис./га. Встановлено, що за неполивних умов найбільша урожайність зерна становила 3,1–4,7 т/га на варіанті з густотою 30 тис./га. Застосування біостимулятора Регоплант забезпечило прибавку врожаю зерна на 1,6 т/га, а препарату Вермистим відповідно на 1,2 т/га. Висновки. За неполивних умов, для найбільшого виходу з зеленої маси кукурудзи кормових одиниць 9,6 т/га й 0,42 т/га перетравного протеїну необхідно застосовувати біостимулятор Вермистим з нормою висіву 70 тис./га. На зрошенні варто збільшувати норму висіву до 90 тис./га й використовувати біопрепарат Регоплант з отриманням найбільшого виходу кормових одиниць 17,4 т/га й 0,87 т/га перетравного протеїну. Вирощування гібриду кукурудзи Інгульський на зерно за неполивних умов забезпечило найбільшу врожайність 4,7 т/га із густотою стояння 30 тис./га та застосування препарату Регоплант. На зрошенні збільшення густоти стояння рослин до 70 тис./га й застосування цього ж препарату, забезпечує максимальну врожайність 11,2 т/га.*

Ключові слова: *кукурудза, біостимулятори, густота стояння, зрошення, удобрення, продуктивність*