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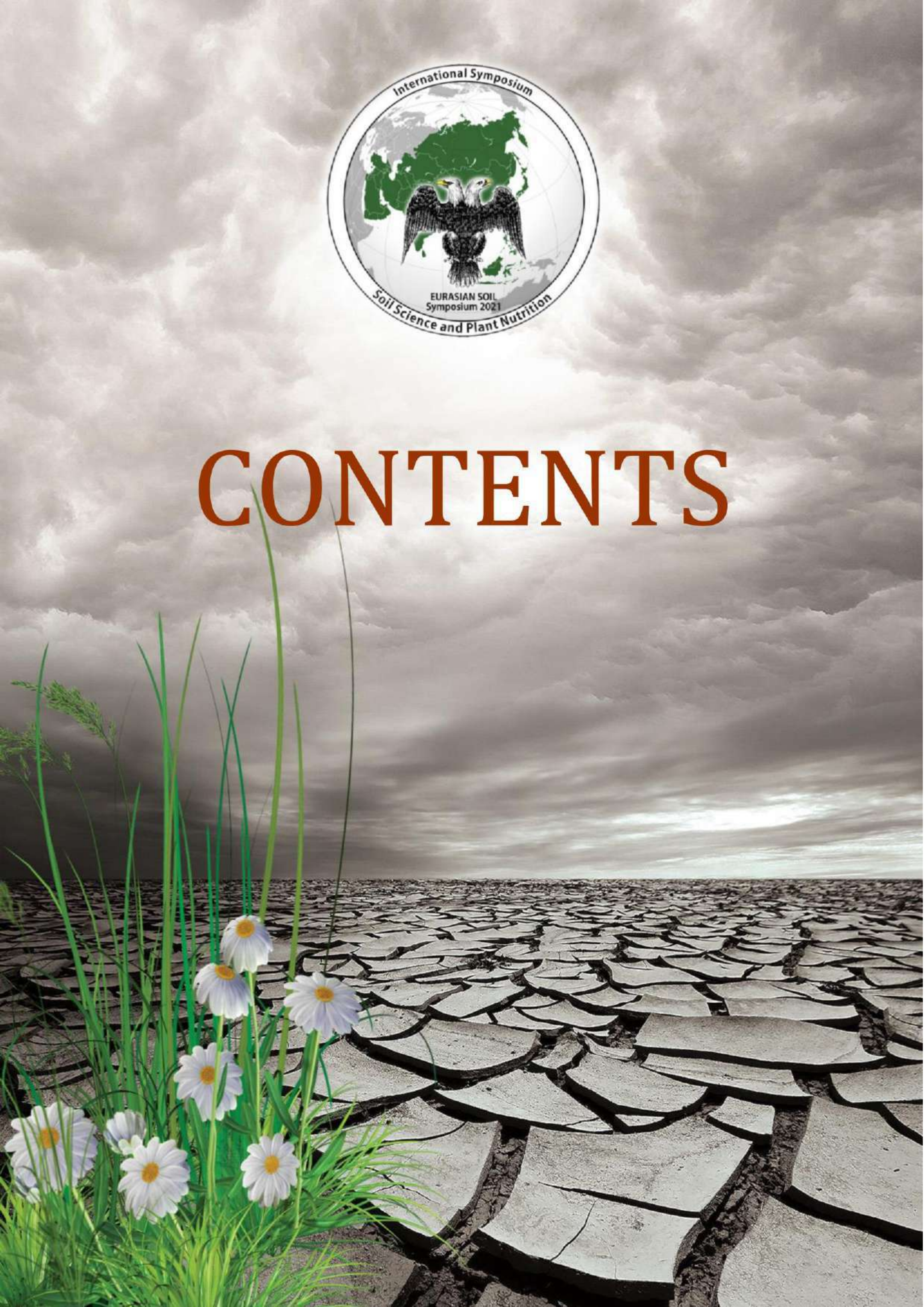

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Uptake of biogenic elements by corn plants depending on the effect of trial factors

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Abstract

For the growth, development and formation of grain corn requires a significant availability of basic nutrients in the soil. Thus, the maximum accumulation of nitrogen occurs within 2-3 weeks before the initiation of panicles, that of phosphorus - in the phase of 4-6 leaves (setting of future inflorescences) and in the phase of grain formation and ripening. Corn plants absorb up to 90% of potassium before the beginning of panicle initiation, the absorption of this element ceases after flowering.

It was found out that a vegetative part of corn plants accumulated 95.8 kg/ha of nitrogen, 29.1 kg/ha of phosphorus, but the amount of these elements in grain was much higher - 151.3 kg/ha, 58.4 kg/ha, respectively. The research results indicate that the vegetative part of corn plants accumulated 197.2 kg/ha of potassium, but in grain potassium amount was much less - 41.5 kg/ha. The studies of the hybrids of different maturity groups show that despite the formation of different conditions for the nutrient uptake and a significant accumulation of dry matter by plants per unit area, the uptake of these elements increases accordingly. Therefore, the determination of the optimal parameters of corn fertilizer systems should be approached carefully, taking into account its biological needs, the availability of nutrients in the soil and the capabilities of different fertilizer systems.

Keywords: biogenic elements, corn, fertilizer system, hybrids, plants density, uptake.

Introduction

Corn requires a sufficient amount of the main nutrition elements in the soil for its growth, development and grain formation. The highest accumulation of nitrogen occurs within 2-3 weeks before panicle initiation, that of phosphorus takes place in the phase of 4-6 leaves (the setting of future inflorescences) and in the phase of grain formation and maturation. Corn plants absorb 90 % of potassium before panicle initiation, the absorption of this element ceases after flowering [1-5].

It has been found out that to form the grain yield equal to 8.0-10.0 t/ha, corn plants uptake the following amount from the soil: nitrogen – 190-220, phosphorus - 80-100 and potassium 200-230 kg/ha [6].

Accordingly, if there is a deficit of at least one nutrition element, the growth rates, the formation of vegetative and regenerative plant organs worsen, grain underdevelopment is recorded [7-11].

When estimating the effect of nutrition elements separately, it turns out that due to the lack of nitrogen the corn yield capacity decreases by 25-35 % [12]. The lack of phosphorus worsens the development of reproductive organs [13], the lack of potassium slows down the plant photo-synthetic processes [12]. The research carried out in the USA showed the efficiency of the application of $N_{120-150}$ in the following pattern: before sowing N_{50-60} and N_{70-90} top dressing. But the increase of the rate up to N_{180} appeared to be undesirable for the plants [14-15]. Besides, the works of other researchers contain much higher application rates of fertilizers as optimal ones: $N_{170-280}P_{50-135}K_{35-135}$[16] and $N_{45-200}P_{0-170}K_{0-170}$ with a mandatory diagnostics of the deficit of the main nutrition elements [17]. In the conditions of India, the application of fertilizers at rate N_{240} provided the best result, in Pakistan the top dressing at rate $N_{300}P_{150}$ was a success [18]. In Turkey the application rate N_{320} facilitates the yield increase of corn ears by 59.4 %, as compared with the control – N_{120} [19].

In the conditions of Poland, the best results were received when 30 t/ha of manure were applied as well as a summary application of mineral fertilizer at rate $N_{100-150}P_{70-90}K_{150-200}$. And in the conditions of northern Germany N_{80-110} and P_{60-90} were the best application rates [20].

The role of balanced organic-mineral plant nutrition should be mentioned. It has been established that such method of the fertilizer application makes it possible to considerably increase plant resistance to diseases and pests, to decrease yield losses caused by damages.

It has been identified that in the conditions of the Southern Steppe-zone of Ukraine it is advisable to apply not less than N_{20-150} та P_{60-120} [12]. And in the southern chornozem soils the yield increase of corn grain was 37.0-57.0 % at a combined nitrogen and phosphorus application [13].

To study the peculiarities of the application of organic fertilizers is a very significant fertilization issue. For instance, provided the application of mineral top dressing $N_{60}P_{60}$ and 20 t/ha of manure was studied, the yield capacity amounted to 9.23 t/ha when organic fertilizers were applied, as compared with the control – 6.70 t/ha [13].

The research conducted in the conditions of the Right-bank Forest-steppe zone of Ukraine proved that due to a mineral fertilization system the corn yield capacity increased by 21-42 %, due to an organic fertilization system the indicator was 20-34 %, and due to an organic-mineral system it increased by 24-46 % [10].

And in the conditions of Bilhorod region, during the two years under study the highest corn yield capacity – 7.03 t/ha was recorded in the treatment when poultry manure/compost 20 t/ha + N_{60} were applied. [10].

Therefore, the results of the research carried out by other scientists confirm both a high demand of corn for nutrition elements and the necessity to work out complex treatments of the application of fertilization systems. After all, the use of mineral fertilization alone is expensive and unreasonable in the conditions of soil droughts. Also, it is not easy to find classical organic fertilizers in the recommended application rates which can be applied in the industrial scales.

Material and Methods

In 2017-2019 field trials were carried out in the experimental field of SPC of Bila Tserkva NAU, situated in the Right-bank Forest-steppe zone – in Bug-Middle Dnipro area. The relief of the experimental field is a slightly-wavy plain with a small slope of the surface from the south to the south-west. Recommended corn hybrids and elements of their cultivation technology were the objects of the research. The effect of the plant density and the fertilization system on the formation of yield capacity of corn hybrids was studied: DN PYVYKHA, FAO 180 (early-ripening), DN ORLYK, FAO 280 (medium-ripening), DN SARMAT, FAO 380 (medium-ripening). The fertilization system implied the following application: 1. $N_{240}P_{120}K_{40}$, 2. $N_{120}P_{60}K_{20}$+ 3.5 t Organic compost 3. Organic compost, 7 t/ha, 4. Manure 40 t/ha.

In the years when the research was conducted (2017-2019) weather conditions differed from long-term indicators. However, generally they were favorable for the growth and development of corn.

To reach the goal the following techniques were used: a field method – to identify the correlation of the plant with biotic and abiotic factors; a calculation method – to keep records of plant density by vegetation on replication plots I and III with the length of 14.3 m; a weighing method – to keep records of corn yield capacity, in the phase of total maturation from each plot; a statistical analysis of the research results was made with help of variation, disperse, correlation and regression methods using applied computer software Statistica.

Results and Discussion

The uptake and assimilation of the main biogenic nutrition elements are the important indicators which are used to determine the efficiency of the application of fertilization systems of corn.

According to our researches and the works of other scientists, in the first two months corn plants grow very slowly. During this period it is necessary to maintain a sufficient concentration of nutrient substances in the upper soil layers where the main mass of the root system of young plants is situated. As the corn plant grows and develops, its roots penetrate into deeper soil layers, and the plant can use nutrients from the soil layers at the depth of 1.01.6 m [21].

There are two kinds of the uptake: a biological one – general costs for the formation of a vegetative mass and grain, an economic uptake of nutrition elements – costs for the formation of corn grain only. However, as the practical experience proves, nutrition elements which are in by-products not always return to the soil. They are lost completely from the circulation of nutrition elements when plant residues are processed into bio-fuel.

For instance, plants require large amounts of nitrogen and they assimilate more than 200 kg/ha to form such yield capacity of corn as 7 t/ha. Plants assimilate nitrogen unevenly and before the 6th leaf appears they require 5 % of it from the required amount. And from the phase of the 6th leaf to panicle initiation (within a month) corn plants assimilate about 60 % of the required nitrogen, i.e., 100-120 kg/ha. They keep assimilating the rest of nitrogen almost till the beginning of corn ear maturation [22-23]. The peculiarities of nitrogen uptake by corn hybrids depending on the effect of trial factors are presented in Table 1.

Table1. Nitrogen uptake by corn hybrids depending on the effect of trial factors, average in 2017-2019, kg/ha

Hybrid	Density at harvesting, th. pcs.	Fertilization system	Vegetative mass	Grain	Total
DN PYVYKHA, FAO 180 (early-ripening)	55	$N_{240}P_{120}K_{40}$	68.68	109.92	178.60
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	83.27	133.16	216.43
		Organic compost, 7 t/ha	81.25	128.61	209.86
		Manure 40 t/ha	77.10	121.92	199.02
	65	$N_{240}P_{120}K_{40}$	81.38	129.43	210.82
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	99.47	158.13	257.60
		Organic compost, 7 t/ha	96.75	151.08	247.83
		Manure 40 t/ha	90.64	143.78	234.42
	75	$N_{240}P_{120}K_{40}$	88.61	139.76	228.37
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	106.89	170.40	277.30
		Organic compost, 7 t/ha	103.14	161.73	264.88
		Manure 40 t/ha	97.62	154.46	252.08
DN ORLYK, FAO 280 (medium early-ripening)	55	$N_{240}P_{120}K_{40}$	71.66	113.55	185.22
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	88.28	136.92	225.20
		Organic compost, 7 t/ha	83.99	132.79	216.78
		Manure 40 t/ha	79.01	125.54	204.55
	65	$N_{240}P_{120}K_{40}$	83.71	133.79	217.50
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	102.86	163.83	266.69
		Organic compost, 7 t/ha	99.88	157.11	257.00
		Manure 40 t/ha	93.97	148.30	242.27
	75	$N_{240}P_{120}K_{40}$	90.96	144.30	235.26
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	112.66	175.63	288.29
		Organic compost, 7 t/ha	107.61	169.19	276.80
		Manure 40 t/ha	102.07	160.26	262.32
DN SARMAT, FAO 380 (medium early-ripening)	55	$N_{240}P_{120}K_{40}$	81.59	129.02	210.61
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	100.18	159.68	259.86
		Organic compost, 7 t/ha	96.07	153.33	249.40
		Manure 40 t/ha	92.12	144.12	236.24
	65	$N_{240}P_{120}K_{40}$	98.67	155.35	254.02
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	119.44	188.84	308.27
		Organic compost, 7 t/ha	115.82	183.15	298.97
		Manure 40 t/ha	111.38	173.29	284.67
	75	$N_{240}P_{120}K_{40}$	97.39	154.87	252.26
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	119.73	187.45	307.18
		Organic compost, 7 t/ha	114.70	181.10	295.80
		Manure 40 t/ha	108.59	171.91	280.50
$HIP_{0.05}$			4.3	7.0	9.8

The research proved that on the average in the trial a vegetative part of corn accumulated 95.8 kg/ha of nitrogen, its amount in corn grain was much higher – 151.3 kg/ha.

The highest nitrogen uptake was recorded in the treatment when the organic-mineral fertilization system was applied; the plant density was 75 th. pcs./ha in hybrids DN PYVYKHA and DN ORLYK, the plant density was 65 th. pcs./ha in hybrid DN SARMAT.

The average data concerning nitrogen uptake depending on a corn hybrid is shown in Figure 1.

Among all the studied hybrids, late-ripening ones accumulated nitrogen the most as they formed a larger vegetative and grain mass: DN ORLYK and DN SARMAT.

Biogenic phosphorus ensures a good growth of a root system and facilitates a fast formation of shoots and leaves. In the first 4-10 weeks of growth corn has a high demand for easily accessible phosphorus forms. Phosphorus uptake by corn hybrids depending on the effect of the trial factors is presented in Table 2.

Table 2. Phosphorus uptake by corn hybrids depending on the effect of trial factors, average in 2017-2019, kg/ha

Hybrid	Density at harvesting, th. pcs.	Fertilization system	Vegetative mass	Grain	Total
DN PYVYKHA, FAO 180 (early-ripening)	55	$N_{240}P_{120}K_{40}$	21.02	42.39	63.41
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	25.54	51.26	76.80
		Organic compost, 7 t/ha	24.79	49.39	74.18
		Manure 40 t/ha	23.33	47.03	70.36
	65	$N_{240}P_{120}K_{40}$	24.77	49.62	74.39
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	30.42	60.88	91.30
		Organic compost, 7 t/ha	29.13	58.77	87.90
		Manure 40 t/ha	27.61	55.49	83.11
	75	$N_{240}P_{120}K_{40}$	26.70	54.01	80.72
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	32.57	65.21	97.78
		Organic compost, 7 t/ha	31.31	62.99	94.30
		Manure 40 t/ha	29.70	59.56	89.26
DN ORLYK, FAO 280 (medium early)	55	$N_{240}P_{120}K_{40}$	22.03	43.31	65.35
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	26.98	53.25	80.24
		Organic compost, 7 t/ha	25.44	51.06	76.50
		Manure 40 t/ha	24.09	48.30	72.39
	65	$N_{240}P_{120}K_{40}$	25.52	51.91	77.43
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	31.53	63.06	94.59
		Organic compost, 7 t/ha	30.35	61.17	91.52
		Manure 40 t/ha	28.82	57.30	86.12
	75	$N_{240}P_{120}K_{40}$	27.69	55.66	83.35
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	33.93	67.75	101.68
		Organic compost, 7 t/ha	32.75	64.59	97.34
		Manure 40 t/ha	31.15	61.86	93.01
DN SARMAT, FAO 380 (medium-ripening)	55	$N_{240}P_{120}K_{40}$	24.69	49.58	74.27
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	30.46	60.96	91.42
		Organic compost, 7 t/ha	29.15	58.92	88.07
		Manure 40 t/ha	27.87	55.81	83.69
	65	$N_{240}P_{120}K_{40}$	29.74	60.57	90.31
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	36.04	72.75	108.79
		Organic compost, 7 t/ha	35.22	71.12	106.34
		Manure 40 t/ha	33.70	67.02	100.72
	75	$N_{240}P_{120}K_{40}$	29.75	59.52	89.27
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	35.91	72.78	108.68
		Organic compost, 7 t/ha	34.92	70.20	105.12
		Manure 40 t/ha	32.88	67.19	100.07
$HIP_{0.05}$			1.8	2.7	3.3

It was found out that on the average in the trial a vegetative part of the corn plant accumulated 29.1 kg/ha of phosphorus, and its amount in grain was much higher – 58.4 kg/ha.

The highest phosphorus uptake was recorded in the treatment when the organic-mineral fertilization system was applied; the plant density was 75 th. pcs./ha in hybrids DN PYVYKHA and DN ORLYK, the plant density was 65 th. pcs./ha in hybrid DN SARMAT.

Similar results confirmed that, among all the studied hybrids, late-ripening ones accumulated phosphorus the most as they formed a larger vegetative and grain mass: DN ORLYK and DN SARMAT.

Corn plants need potassium in large amounts, leaves and stems absorb its greater part; it is required the most when stems grow and absorb it faster than any other element [24-25]. The peculiarities of potassium uptake by corn hybrids depending on the effect of trial factors are presented in Table 3.

Table 3. Potassium uptake by corn hybrids depending on the effect of the trial factors, average in 2017-2019, kg/ha

Hybrid	Density at harvesting, th. pcs.	Fertilization system	Vegetative mass	Grain	Total
DN PYVYKHA, FAO 180 (early-ripening)	55	$N_{240}P_{120}K_{40}$	141.86	30.15	172.01
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	172.32	36.88	209.20
		Organic compost, 7 t/ha	166.07	35.15	201.22
		Manure 40 t/ha	158.47	33.54	192.01
	65	$N_{240}P_{120}K_{40}$	169.22	35.58	204.80
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	205.53	43.05	248.57
		Organic compost, 7 t/ha	197.32	40.87	238.19
		Manure 40 t/ha	184.90	39.39	224.28
	75	$N_{240}P_{120}K_{40}$	181.56	38.16	219.73
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	220.65	46.35	267.01
		Organic compost, 7 t/ha	212.49	44.67	257.16
		Manure 40 t/ha	202.26	42.37	244.63
DN ORLYK, FAO 280 (medium-early)	55	$N_{240}P_{120}K_{40}$	146.86	30.80	177.66
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	182.54	38.03	220.57
		Organic compost, 7 t/ha	171.71	36.26	207.97
		Manure 40 t/ha	163.61	34.38	197.99
	65	$N_{240}P_{120}K_{40}$	172.53	36.49	209.02
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	212.70	44.20	256.90
		Organic compost, 7 t/ha	207.11	43.00	250.11
		Manure 40 t/ha	193.69	40.81	234.50
	75	$N_{240}P_{120}K_{40}$	188.45	39.73	228.18
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	231.09	48.35	279.45
		Organic compost, 7 t/ha	220.57	46.29	266.86
		Manure 40 t/ha	212.34	43.24	255.58
DN SARMAT, FAO 380 (dedium-ripening)	55	$N_{240}P_{120}K_{40}$	166.88	35.33	202.22
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	205.70	43.47	249.17
		Organic compost, 7 t/ha	197.25	42.26	239.50
		Manure 40 t/ha	187.08	39.95	227.02
	65	$N_{240}P_{120}K_{40}$	202.25	43.05	245.29
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	246.08	52.47	298.55
		Organic compost, 7 t/ha	238.89	50.13	289.02
		Manure 40 t/ha	227.44	47.55	274.99
	75	$N_{240}P_{120}K_{40}$	200.64	41.81	242.44
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	245.90	51.83	297.73
		Organic compost, 7 t/ha	238.11	49.76	287.87
		Manure 40 t/ha	225.73	47.68	273.41
$HIP_{0.05}$			10.1	1.7	16.0

The research results proved that on the average in the trial a vegetative part of corn plants accumulated 197.2 kg/ha of potassium, its amount in corn grain was much less – 41.5 kg/ha.

As to the total potassium uptake, its highest parameters were recorded in the treatment when an organic-mineral fertilization system ($N_{120}P_{60}K_{20}$+ 3.5 t Organic compost) was applied; the pre-harvesting plant density was 75 th. pcs./ha in DN PYVYKHA (267.01 kg/ha) and DN ORLYK (279.45), the plant density was 65 th. pcs./ha in hybrid DN SARMAT, the rest of the trial indicators were similar – 298.55 kg/ha.

When analyzing the average data of potassium accumulation in the corn plants by hybrids, one could see that its smallest amount was in grain (38.85 kg/ha) and in vegetative mass (184.4 kg/ha) in hybrid DN PYVYKHA, hybrid DN ORLYK took the second place – 40.13 and 191.9 kg/ha, hybrid DN SARMAT was the leader/had the highest potassium amount in grain and vegetative mass – 45.44 and 215.2 kg/ha. All this corresponds to the peculiarities of the dry matter accumulation by the corn plants of the hybrids of various maturation groups

Conclusion

The research conducted on the hybrids of various maturation groups show that despite the creation of different conditions for the uptake of biogenic nutrition elements and a considerable plant accumulation of dry matter per area unit, the uptake of these elements increases accordingly. Hence, there should be a reasonably careful approach to the determination of the optimal parameters of the fertilization systems of corn taking into consideration its biological needs, the availability of nutrition elements in the soil and the feasibility of various fertilization systems.

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