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Effect of micronutrients on the peculiarities of growth and development of maize plants

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Abstract

At the present stage of development of agriculture in Azerbaijan, when small farms are created everywhere in the country, differentiated approach to solving many problems of farming is of special importance. In the republic, natural fodder lands are unproductive, and in many farms pastures and hayfields are absent at all, so the main share of fodder is produced through field fodder production. Here a special role is given to high-yielding promising crops, such as corn. In grain and fodder production, corn in Azerbaijan occupies one of the first places among spring grain, leguminous and fodder crops. In increasing the production of grain and green mass of corn, as well as improving the quality of the harvest, mineral nutrition is of great importance. In the physiology of mineral nutrition an important role belongs to trace elements. For conditions of Mugani soils characterized by low content of mobile forms of microelements, it is of special interest to determine the influence of optimal norms, combinations and methods of using microfertilizers on maize productivity. For normal growth, development and formation of high yield of green mass and corn grain, a vital condition is a sufficient supply of plants with nutrients on ameliorated soils. In soils usually gross content of nutrient elements exceeds the needs of plants, but only a small part of them is soluble in soil moisture and available to cultivated crops in a certain period of their development. Therefore, it is necessary to know the content of macro- and microelements in the soils of the experimental plot. Soil analysis plays a major role in determining the level of plant nutrient availability.

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Introduction

The doctrine of trace elements stands as one of the remarkable achievements of natural science in the 20th and 21st centuries. Today, it occupies a vital place in both fundamental and applied sciences, including plant physiology, agronomy, medicine, and animal husbandry. This growing interest is due to the essential role of trace elements in metabolism—the central process of all living systems (Abdallah and Mejnun, 2013; Aslanova and Asadova, 2023; Dunyamaliev *et al.*, 2021).

Numerous studies have established that optimal levels of trace elements such as manganese, zinc, copper, boron, cobalt, iodine, molybdenum, and other ultramicroelements are necessary for the normal physiological functioning of plants, animals, and humans. These elements are critical in the synthesis of biologically active compounds and are integral components of enzymes, hormones, vitamins, and regulatory molecules involved in various metabolic pathways.

Among these, manganese (Mn) and zinc (Zn) have received considerable scientific attention due to their versatile biochemical roles. Manganese is particularly known for its variable valence and its activation of oxidative enzymes such as polyphenol oxidase and peroxidase. It is also indispensable in photosynthesis, phosphorylation, and carbohydrate metabolism. Manganese deficiency leads to severe physiological symptoms in plants, including chlorosis, necrosis, and growth retardation.

Zinc, on the other hand, ranks second only to iron in abundance in living organisms and is essential for numerous enzymatic and genetic functions. It plays a key role in protein synthesis, membrane stabilization, transcription processes, and nitrogen metabolism. Zinc deficiency manifests in plants through chlorosis, rosetting, and stunted growth—physiological conditions that severely affect crop productivity.

In light of these roles, understanding the function of manganese and zinc in plant growth is critical, particularly for high-yield crops such as maize (*Zea mays* L.), which is known for its high productivity and versatile usage. Maize is not only an essential source of grain and silage but also a crucial component of crop rotations and green fodder systems. However, due to its high biomass production, maize requires a well-balanced and readily available supply of nutrients, especially micronutrients like Mn and Zn. Deficiencies in these elements often result in yield losses and reduced crop quality (Aslanova and Asadova, 2023; Eyubov, 1980; Gurbanov and Aslanova, 2023; Viswanath *et al.*, 2020).

Therefore, comprehensive studies on the physiological impact of manganese and zinc on maize growth and metabolism are of both theoretical and practical significance. This research aims to contribute to a deeper understanding of how these trace elements influence maize productivity and to offer insights that can support more effective crop nutrition strategies under varying agro-ecological conditions.

Materials and methods

To eliminate micronutrient deficiencies in maize (*Zea mays* L.) crops, the influence of manganese (Mn) and zinc (Zn) on plant growth and development was investigated. Micronutrients were applied using two methods:

1. Soil application, and
2. Pre-sowing seed treatment (coating of seeds before planting).

Experimental plots were established under uniform agro-technical conditions using selected maize varieties. Different doses and application methods of manganese and zinc were tested. Each treatment was arranged in three replicates using a randomized block design to ensure statistical validity.

During the experiment, the growth and developmental characteristics of the maize plants were systematically observed. The following parameters were recorded and analyzed:

1. Number of leaves per plant,
2. Number and formation of cobs,
3. Plant height and biomass weight,
4. Duration of the vegetation period.

The collected data were used to determine the relationship between the dose and method of micronutrient application and the morphological and developmental traits of the plants. This allowed for the assessment of the physiological effects of manganese and zinc on different growth stages of maize.

Results and discussion

The data of phenological observations (Table 1) show that the period from sowing seeds and until the onset of the flush phase in all almost variants corn plants passed for the same number of days. Plants that received neither NRC nor microfertilizers, although they reached the hatching phase 2 days earlier than the others, but were very weak and lagged behind in growth from plants fertilized with macro- and microelements. In many plants of the control variant, development stopped at this phase and later they did not form cobs. All experimental corn plants that received microfertilizers had better development indicators than the control. Application of microfertilizers into the soil promoted more intensive development of corn and compared to the plants of the background variant by 1-4 days. The effect of zinc sulfate in doses of 2 and 3 kg/ha d.o.w. was more effective than the effect of manganese. The combined effect of zinc and manganese had a positive effect and accelerated corn ripening. Grain ripeness came 3 days earlier than in the background variant.

Table 1. Effect of microfertilizers on maize development rate

Variant	Number of days				
	from sowing (10.IV-15.IV) to emergence	Sweeping out - flowering	Sweeping out - mol.v. sp.z.	Sweeping - full ripeness of grain	Growing season length
1. Used control	74	13	30	39	113
2. phen. obr+$N_{120}P_{90}K_{60}$	76	13	29	38	114
3. phen. obr +Zп 1 кг/га	76	13	28	36	113
4. phen. obr +Zn 2 кг/га	76	10	26	34	110
5. phen. obr +Zn 3 кг/га	76	10	26	34	110
6. phen. obr +Mn 2 кг/га	76	11	27	35	111
7. phen. obr +Mn 4 кг/га	76	12	28	36	112
8. phen. obr +Mn 6 кг/га	76	12	27	35	112
9. phen. obr +Zn 1+Mп 2	76	12	27	35	112
10. phen. obr +Zn 1+Mn 4	76	12	27	35	112
11. phen. obr +Zn 2+Mn 2	76	10	26	34	110
12. phen. obr +Zn 2+Mn 4	76	12	28	36	112

Table 2. Effect of pre-sowing seed treatment with microelements on the rate of development of maize plants

Option	Number of days				
	Sowing seedlings	Shoots-sweeping	Shoots - flowering	Shoots - supposedly to ripeness	Shoots - full ripeness
1. Used control	11	68	80	96	112
2. phen. obr + $N_{120}P_{90}K_{60}$	11	69	80	96	110
3. phen. obr +Zп 0,2%	9	68	78	95	110
4. phen. obr +Mn 0,1%	9	68	78	95	110
5. phen. obr +Zn0,2+Mn+0,1	8	68	77	94	108

Variants with the application of (4-6) kg/ha of manganese into the soil were less effective: the experimental plants here are 1-2 days ahead of the background variant.

Pre-sowing treatment of seeds with microelements allows to multiply their content in the seeds themselves. Micronutrients in the seeds in the process of soaking contribute to their better growth, providing at the first stages of development need of corn plants in manganese and zinc. Therefore, immediately after the emergence of seedlings the positive effect of trace elements on experimental plants is felt (Table 2). In variants with zinc application, sprouts were obtained 1-3 days earlier than in control and background variants. And further these plants grew and developed faster and reached the phase of milk-wax ripeness of grain 2-4 days earlier than in the control variant.

Growth rate of plants in height is an important morphological trait, which can be used to judge the reaction of plants to changes in growing conditions.

Table 3 shows data on the dynamics of corn stalk growth under the influence of microfertilizers applied to the soil.

Observations on growth and development of maize showed that when NRC was applied to the soil only, experimental plants were formed better than in the variant without fertilizers. However, under the influence of microfertilizers on the background of NRC plants were characterized by better development. Especially obvious was the advantage of plants receiving zinc sulfate separately and in combination with manganese sulfate. So, if by the time of cutting for silage, plants of the control variant had a height of 130.8 cm, background - 173.6 cm, then in the variant of zinc fertilizers (in doses of 2 and 3 kg / ha d.w.) - 210.0 and 210.6 cm.

Under the influence of manganese salt, corn also exceeds background and control plants in stem length, but with a smaller difference. The height of corn in these variants varies within 180.6-189.6 cm. In variants of joint application of manganese and zinc fertilizers the height by the time of mowing was 183.4 - 208.5 cm.

Table 3 shows the results of the experiment with treatment of corn seeds with solutions of zinc and manganese salts. When microfertilizers are applied to the soil, their influence is felt after a certain period of time. In case of pre-sowing treatment of seeds, the effect of microfertilizers is manifested immediately after sprouting.

Table 3. Effect of root fertilization with microfertilizers on corn growth dynamics

Experience options	Average height of experimental plants, cm			
	Sweeping out	Cob thread yield	Flowering	Milky-wax
1. Used control	118,4	128,7	130,6	130,8
2. phen. obr + $N_{120}P_{90}K_{60}$	154,8	170,3	171,9	173,6
3. phen. obr + Zп 1 kg/ha	167,3	179,6	192,6	194,8
4. phen. obr + Zп 2 kg/ha	184,3	201,4	210,3	210,0
5. phen. obr + Zп 3 kg/ha	186,6	198,1	210,0	210,6
6. phen. obr + Mп 2 kg/ha	162,1	179,8	186,3	189,6
7. phen. obr + Mn 4 kg/ha	163,5	174,6	180,1	180,8
8. phen. obr + Mп 6 kg/ha	154,2	177,8	180,3	180,6
9. phen. obr + Zn 1 + Mn 2	163,4	182,8	187,8	188,8
10. phen. obr + Zn 1 + Mп 4	166,8	188,9	183,5	183,4
11. phen. obr + Zn 2 + Mп 4	180,7	193,4	208,0	208,5
12. phen. obr + Zп 2 + Mп 2	188,9	206,7	206,7	205,8

In variants where seeds were treated with microelements corn grew and developed better than in control and background variants. At the last measurement, shortly before mowing, the plants of the control variant had a stem height of 131.2 cm, in the background variant - 163.3 cm, and in variants with seed treatment with zinc - 193.8; manganese - 179.1 cm; combined solution of microelement salts - 192.5. The most effective was the variant of seed treatment with zinc sulfate - plants in this case are 30.3 cm higher than background ones.

When comparing the data of Table 3 and 4 we see that the application of microfertilizers in the soil was more effective than seed treatment before sowing, and of the tested 3 doses when applying microfertilizers in the soil, the best effect on the growth and development of experimental plants had a medium dose of Zn (2 kg / ha) and a smaller dose of Mn (2 kg / ha), increasing the dose of Zn did not lead to changes, and increasing the dose of Mn had a slightly depressing effect.

In both experiments in the first 15 days after the emergence of seedlings average daily growth ranged from 0.9 to 2.2 cm, in the following week it slightly decreases, and further growth of plants in height gradually increases and reaches a maximum at the time of flapping. By the end of this period, the average daily growth sharply decreases. The highest average daily growth in each of the stages of corn development is observed in variants of microfertilizer application.

Table 4. Effect of pre-sowing seed treatment with microelements on growth dynamics of maize plants

Experience options	Average height of experimental plants, cm					
	15 days after germination	5-6 leaves	Sweeping out	Yield of nutritious cobs	Bloom	Milky-waxy ripeness
1. Used control	16,8	24,2	122,3	131,3	135,0	131,2
2. phen. obr + $N_{120}P_{90}K_{60}$	23,5	31,6	148,3	158,1	159,9	163,3
3. phen. obr + Zп 0,2%	28,1	39,4	178,6	187,8	191,3	193,8
4. phen. obr + Mn 0,1%	25,3	34,4	161,8	175,8	177,1	179,1
5. phen. obr + Zn0,2+Mn0,1	28,0	36,5	180,5	190,1	191,5	192,5

Table 5. The influence of root feeding with micronutrients on the morphological and structural parameters of corn

Experience options	Plant height, cm	Weight of 1 plant, g	Quantity per plant, pcs.		Weight of 1 ear
			leaves	cobs	
Used control	130.8	405,4	9.5	1,0	90,5
phen. obr + $N_{120}P_{90}K_{60}$	173,6	520,4	13,2	1,5	151,0
phen. obr + Zn 1 kg/ha .	194,8	731,5	14.6	2,0	208,1
phen. obr + Zn 2 kg/ha	210,0	951,4	16,0	2,3	220,0
phen. obr + Zn 3 kg/ha	210,6	954,2	16,2	2,3	220,5
phen. obr + Mn 2 kg/ha	189,6	781,4	14,2	2,0	200,0
phen. obr + Mn 4 kg/ha	180,8	781,5	14,3	2,0	206,0
phen. obr + Mn 6 kg/ha	180,6	634,4	13,5	1,6	200,0
phen. obr + Zn1 + Mп 2 kg/ha	188,8	718,9	14.2	2,0	195,0
phen. obr + Zn2 + Mn 4 kg/ha	208,5	905,3	15,5	2,1	245,2
phen. obr + Zn1 + Mп 4 kg/ha	183,4	689,2	13,0	2,0	190,0
phen. obr + Zn2 + Mn 2 kg/ha ---	205,8	994,0	16,0	2,4	240,0

Structural analysis of corn plants more clearly showed the influence of individual microelements and their mixture on the formation of leaf apparatus and cobs (Table 5).

The best results were obtained in variants of 2 kg zinc application to the soil. In that variant the largest cobs were obtained and there were often 3 or even 4 cobs on the plant. Also very good results were obtained in variants of joint application of 2 microelements. Here the results even exceed the variants with zinc. Thus, the average weight of one corn plant in these variants is almost twice as much as the plants in the background variant. Thus, microelements had a positive effect on the growth and development of experimental plants both when applied to the soil and at pre-sowing seed treatment.

In the variants of using zinc sulfate at a dose of 2 kg/ha d.o.w. and at joint application, the number of leaves on one plant on average more by 3 leaves, and the weight of 1 cob by 50-90 g compared to the plants of the background variant.

Significant increase in the weight of one plant and the number of cobs on one plant was obtained when zinc was applied to the soil in doses of 2-4 kg/ha, as well as in those variants where this element was applied to the soil together with manganese. The average weight of 1 corn plant increased from 520.4 g in the background variant to 951.4-994.0 g under the influence of microfertilizers, and the number of cobs, respectively, from 1.5 to 2.3-2.4.

The obtained data indicate a positive effect of zinc and manganese on the morphological and structural parameters of corn. Thus, the results of observations indicate a stable efficiency of using microfertilizers against the background of NPK in the conditions of sierozem-meadow soils of Mugan. Microfertilizer fertilization contributed to a noticeable acceleration of the growth and development process, an increase in the leaf-stem mass of experimental corn plants.

Conclusion

The conducted research allowed to improve the generally accepted system of corn fertilization in the region, as a result of which the yield of exchange energy per hectare of arable land increases from 50.1-97.5 to 59.6-126.0 thousand MJ, digestible protein - from 4.8-8.6 to 6.1-12.6 centners.

Effective doses of zinc microfertilizers (2 and 3 kg/ ha active ingredient) and manganese (2 and 4 kg/ ha active ingredient), as well as their combinations (2 kg/ha active ingredient) have been identified, allowing to increase the collection of dry matter per hectare by 10.2-28.9% in relation to the yield against the background of NPK 102.1 centners/ha.

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