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EFFECT OF FERTILIZATION ON UPTAKE OF MACROELEMENTS WITH SUNFLOWER BIOMASS IN A POT EXPERIMENT WITH HAPLIC VERTISOL

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ABSTRACT

The study was conducted in the conditions of pot experiment with Haplic Vertisol soil. The aim was to evaluate the effect of different norms and combinations of nitrogen, phosphorus, potassium and silicon fertilizers in the soil and their impact on the content and uptake of some main macro elements with sunflower biomass. The test culture was an early to medium-early hybrid Sunflower (*Helianthus annuus L.*) - Sumiko HTS. The experiment includes 16 variants of fertilization with 3 repetitions. Data are obtained on the yield of fresh and absolutely dry biomass from the above-ground part and the content of N, P, K, Si, Ca and Mg in the resulting dry biomass from plants. According to the experimental data obtained, the content and uptake of the examined macro elements with the sunflower biomass are significantly influenced by the imported norms and combinations of fertilizers. The highest is the uptake of nitrogen in the variants with the following norms: N_{200}, N_{300} and N_{400}.N uptake is the highest also in comparison with all other values of the examined elements.It is established that the changes in the macroelements uptake significantly follow changes in the quantities of the relevant elements in dry biomass in the variants of the experiment. With an increase in fertilization norms, not only the content of N, P, and Si is increased, but also the uptakes with sunflower biomass.This trend is expressed to a lesser extent with potassium.

Key words*: fertilizers, rates, export by sunflower biomass. “Helianthus annuus, L.” and “macro elements uptake.*

INTRODUCTION

Sunflower is a major oilseed crop in Bulgaria. The nutrient requirements for yield formation depend both on the specific soil and climatic conditions of the area and on several other factors. Sunflower responds well to nitrogen fertilization, excess nitrogen lowers oil content and lowers plant resistance to disease. Appropriately balanced phosphorus and potassium fertilization increase yield and oil content. The potassium requirements of sunflower are high - 7-11 kg per 100 kg of seed, and increases the absolute weight and fat content of the seeds. Experiments conducted in our country show an increase in fat yield under the influence of potassium fertilization(Nikolova, 2010).Determining the optimal nutrient regime for crops requires establishing the export and consumption of nutrients to form a unit of production, and their balance in the soil for different soil conditions (Nenova, Mitova,2018; Mitova, Dinev 2012). Establishing nutrient balance is an effective method for assessing nutrient use by crops.In this way, the negative consequences of improper fertilization could be avoided. Furthermore, balanced nutrition plays a key role in obtaining stable yields of high quality. This crop is also distinguished by its exceptional micronutrient requirements. Very important is also the growth of the stem, which must be resistant to lodging and provide a continuous transfer of metabolites to the growing seeds, and here is mainly the role of Si. In our country, the use of silicon fertilizers is poorly developed. Silicon (Si) is not classified as an essential element for plants, but numerous studies have described its beneficial effects under various soil and climatic conditions, including low levels of plant-available forms of silicon. The application of Si shows the potential to increase the availability of nutrients in the rhizosphere and their uptake by plants (Pavlovic et al., 2021). Plant species vary greatly in their ability to accumulate Si, with values ranging from 0.1% to 10% Si (Epstein, Bloom, 2008). Consequently, some plant species are minimally affected by the introduction of Si compared to others (Coskun et al., 2019).

The main objective of the study was to determine the content and export of macronutrients (N, P, K, Si, Ca, and Mg) with biomass of sunflower (*Helianthus annuus* L.), under the influence of increasing levels of fertilization with nitrogen, phosphorus, potassium, and silicon under the conditions of a growing experiment on haplicvertisol.

MATERIALS AND METHODS

A vegetation fertilizer trial with a test crop of an early hybrid of sunflower (Helianthus annuus L.) - Sumiko HTS of Sinjenta was set up and established. The initial soil is leached smolnitza supplied by the experimental field in Bozhurishte, Sofia region.According to the classification of soils in Bulgaria (Koinov, 1987), it is defined as haplicvertisol(FAO, 2015). It is characterized by a close to neutral soil reaction in the plowing horizon (pH_{H2O}- 6,4,pH_{KCl} - 5.6), with a high content of total (0,217%) and mineral nitrogen (40,32 mg N/kgsoil). The soil has a low supply of mobile phosphorus (1,92 мg P_2O_5/100 gsoil) and better available potassium content (30,86mg K_2O /100 g soil).Before sowing the seeds, fertilizers with different amounts of active substances in mg/plant were added to the experimental pots of 3 kg capacity, as presented in Table 1. Five sunflower seeds were sown, leaving 3 plants in each pot at a later stage. On the 67th day of vegetation in the budding phase, the plants were harvested, weighed, and prepared for chemical analysis. The content (% a. b.w.) of macronutrients N, P, K, Si, Ca, and Mg in sunflower plant biomass was determined by acid digestion and ICP readings (5800 ICP - OES system - Agilent). The export of the tested elements with the plant production was determined.The experiment included 16 fertilization treatments in 3 replications. It is a multifactorial scheme with four factors varied at 5 levels (Sadovski, 2020). Table 1 shows the experimental design and the imported amounts of the active substance of the macroelements used in mg/pot.

Table 1. Scheme of a pot experiment and quantities of active substance in mg/pot:

1.$N_0P_0K_0Si_0$ -Control	9. $N_{200}P_{160}K_{140}Si_{2000}$
2.$N_0P_{160}K_{140}Si_{800}$	10. $N_{200}P_{160}K_{140}Si_{800}$
3.$N_{400}P_{160}K_{140}Si_{800}$	11. $N_{300}P_{240}K_{70}Si_{400}$
4. $N_{200}P_0K_{140}Si_{800}$	12. $N_{300}P_{80}K_{210}Si_{400}$
5.$N_{200}P_{320}K_{140}Si_{800}$	13. $N_{300}P_{80}K_{70}Si_{1200}$
6. $N_{200}P_{160}K_0Si_{800}$	14. $N_{100}P_{240}K_{210}Si_{400}$
7.$N_{200}P_{160}K_{280}Si_{800}$	15. $N_{100}P_{240}K_{70}Si_{1200}$
8.$N_{200}P_{160}K_{140}Si_0$	16. $N_{100}P_{80}K_{210}Si_{1200}$

The following soil analyses were performed before and after the vegetation experiments: pH - potentiometric in H_2O and KCl (Arinushkina, 1962); total and mineral nitrogen content - Bremner and Kinney method (Bremner,1965a, Bremner,1965b); mobile forms of phosphorus and potassium (P_2O_5 и K_2O) - by the acetate-lactate method (Ivanov, P.,1986); organic carbon (humus) content - according to Turin's method (Kononova, 1963).
Statistical analysis of the obtained results was done with Statgraphics statistical product (ANOVA). Fisher's method for comparison of means at least significant difference (LSD) was used to detect differences between the variants studied.

RESULTS AND DISCUSSION

From the obtained data, it was reported that the lowest fresh weight is in the control variant and the highest in the variantsV11 ($N_{300}P_{240}K_{70}Si_{400}$)-345,708g, B12 ($N_{300}P_{80}K_{210}Si_{400}$)-330,576gand B3 ($N_{400}P_{160}K_{140}Si_{800}$) -328,248g.It is evident that these are the variants with the high norms of nitrogen, the differences between them were insignificant. Similar results are also obtained for other plants (Vasileva, V. & Ilieva, A., 2017).Noticeably lower are the weights in variants B2($N_0P_{160}K_{140}Si_{800}$)abd B14($N_{100}P_{240}K_{210}Si_{400}$) without N and low N norm. The combinations of different rates and types of mineral fertilizers used failed to emit the most favorable combination that influenced the plant's fresh and dry weight index at the budding stage of sunflower in the pot experiment.It can be said that N_{300} and N_{200} in combination with lower rates of the other macronutrients are most conducive to sunflower development. It is noteworthy that the highest result was not achieved in the variant with the highest nitrogen rate (N_{400}).It may noticed that the dry weight of the total biomass obtained from 1 plant per pot varies in proportion to the corresponding fresh weight in the different variants.

As a result of the conducted pot fertilizer experiment and the one-way ANOVA analysis of the data for the amount of plant biomass on the 67th days, the leading role of nitrogen fertilization in the norm of 200 mg/per pot was established (the difference between the variants are at the high level of significance $P \leq 0.001$) (Table 2).Nitrogen is an essential nutrient that determines the growth of oilseeds and increases the amount of protein and yield.The accumulation of biomass in sunflower is associated with the absorption of nutrients during the whole growing season (Hassan, F., & Kaleem, S., 2014).

Table 2. Influence of fertilization rate and fertilizer combinations on the yield of fresh biomass from the aboveground part of sunflower plants (One-way ANOVA analysis)

Fresh weight of Sunflower plants (g/ per pot)

Variants	Bozhurishte-67 day	
1. $N_0P_0K_0Si_0$	29,82	a
2. $N_0P_{160}K_{140}Si_{800}$	50,46	b
3. $N_{400}P_{160}K_{140}Si_{800}$	76,43	c
4. $N_{200}P_0K_{140}Si_{800}$	80,70	d
5. $N_{200}P_{320}K_{140}Si_{800}$	89,23	e
6. $N_{200}P_{160}K_0Si_{800}$	90,80	e
7. $N_{200}P_{160}K_{280}Si_{800}$	94,67	f
8. $N_{200}P_{160}K_{140}Si_0$	97,40	fg
9. $N_{200}P_{160}K_{140}Si_{2000}$	97,43	fg
10. $N_{200}P_{160}K_{140}Si_{800}$	98,97	gh
11. $N_{300}P_{240}K_{70}Si_{400}$	100,10	gh
12. $N_{300}P_{80}K_{210}Si_{400}$	101,67	h
13. $N_{300}P_{80}K_{70}Si_{1200}$	108,63	i
14. $N_{100}P_{240}K_{210}Si_{400}$	109,43	i
15. $N_{100}P_{240}K_{70}Si_{1200}$	110,20	i
16. $N_{100}P_{80}K_{210}Si_{1200}$	115,23	j
Average	**90,69**	
Stnd. deviation	**22,167**	
Stnd. error	**2,78**	
LSD≥95%		

Under the influence of mineral nutrition, significant changes occur in the amount of nutrients absorbed by the biomass of sunflower plants (Table 3).The content of total N in the dry biomass of plants varies from 1,67in the control to 2.87% in variant B11 ($N_{300}P_{240}K_{70}Si_{400}$). Approximately in the same order is the content of total N in variants B4 ($N_{200}P_0K_{140}Si_{800}$), B12($N_{300}P_{80}K_{210}Si_{400}$) and B13($N_{300}P_{80}K_{70}Si_{1200}$). The average content of total N in the seventh variants with norm N200 and in the three variants with norm N300 is 2.1 and 2.48%,respectively.The application of mineral nitrogen in the soil in most cases is accompanied by an increase in the content of N in plants(Hara, Sonoda, 1979; Atanassova, 2005; Kolota, Chohura, 2015; Nenova, Mitova, 2018, Vasileva, Ilieva., 2017). This trend was also confirmed in the current experiment.

The content of phosphorus in sunflower plants is significantly lower than the nitrogen content and varies less depending on the combinations of rates and types of mineral fertilizers applied- from 0.26 inthecontrolto 0.30% inthefertilized variants.The phosphorus content is the highest in the B11($N_{300}P_{240}K_{70}Si_{400}$) variant, which contains the highest norm of triple superphosphate.There is only a very slight tendency to increase the phosphorus content in the plants with increasing fertilizer rate in Haplic Vertisol.

The potassium content is slightly higher than the phosphorus content and ranges from 1.07 in the control to 2.14% in the variant with the potassium norm (K_{140}). Other authors have reported similar results. Summarized results from a large number of experiments show that "economically" nitrogen, high phosphorus, and abundant potassium fertilization are suitable for sunflower cultivation. On magnesium-poor soils, both yields and oil content can be increased by magnesium fertilization (Nikolova, 2010).

The calcium content is high and ranges from1.21 to 1.96% but it is significantly higher in the fertilized variants. It cannot be argued that the higher fertilization rates lead to a higher accumulation of Ca in sunflower plants.The change in the content of Mg varies similarly, but the amount in the control variant is lowher - 0.36%, and in the fertilized variants it is between 0.37 and 0.77%.It can be concluded that fertilization has a significantly lower effect on the accumulation of Mg in sunflower plants.

Of interest is the Si content, which increases from 0.0112% in the control variant to 0.0285% in the variant with the highest Si rate.The combinations of norms and fertilizers used in the experiment do not establish a direct relationship between increasing the accumulation of Si in plants with increasing the imported Si level.In the studies by Peixoto, et al., 2022, a higher total leaf area of Si-treated plants leads to increased overall CO_2 uptake by the plant.Plants treated with Si have an increase of 24-39% in biomass yield.

Table 3. Content of total N, P, K, Si, Ca, and Mg in sunflower biomass (in% of absolutely dry weight) by variants (pot experiment on haplicvertisol, 2021).

Variants	N	P	K	Si	Ca	Mg
			%			
1.$N_0P_0K_0Si_0$	1,67	0,26	1,96	0,0112	1,78	0,36
2.$N_0P_{160}K_{140}Si_{800}$	1,00	0,23	1,87	0,0292	1,71	0,34
3.$N_{400}P_{160}K_{140}Si_{800}$	1,93	0,29	1,68	0,0700	1,96	0,69
4.$N_{200}P_0K_{140}Si_{800}$	2,84	0,24	2,14	0,0348	1,93	0,60
5.$N_{200}P_{320}K_{140}Si_{800}$	2,05	0,27	1,07	0,0830	1,25	0,43
6.$N_{200}P_{160}K_0Si_{800}$	2,65	0,29	1,61	0,0514	1,85	0,60

7.$N_{200}P_{160}K_{280}Si_{800}$	2,02	0,26	1,80	0,0263	0,16	0,50
8.$N_{200}P_{160}K_{140}Si_{0}$	1,83	0,26	1,59	0,0263	1,61	0,66
9.$N_{200}P_{160}K_{140}Si_{2000}$	1,69	0,24	1,53	0,0285	1,70	0,60
10.$N_{200}P_{160}K_{140}Si_{800}$	1,60	0,26	1,50	0,0290	1,76	0,61
11.$N_{300}P_{240}K_{70}Si_{400}$	2,87	0,30	1,52	0,0304	1,76	0,77
12.$N_{300}P_{80}K_{210}Si_{400}$	2,33	0,23	1,91	0,0320	1,92	0,63
13.$N_{300}P_{80}K_{70}Si_{1200}$	2,25	0,19	1,50	0,0267	1,62	0,67
14.$N_{100}P_{240}K_{210}Si_{400}$	1,77	0,27	2,01	0,0362	1,79	0,52
15.$N_{100}P_{240}K_{70}Si_{1200}$	1,47	0,28	1,74	0,0278	1,67	0,51
16. $N_{100}P_{80}K_{210}Si_{1200}$	1,83	0,21	1,50	0,0207	1,21	0,37

Based on the obtained dry biomassand the content of N, P, K, Si, Ca, and Mg in it(Table 3), the export from the soil of the studied elements was calculated.From the obtained results it is evident that the changes in the exports of the studied macroelements significantly follow the changes in the quantities of the respective elements in the dry biomass according to the variants of the experiment. As the fertilization rates increase, not only the content but also the exports of N, P, K, and Si increase.

Figures 1 to 4 show the regression curves of the exports of N, P, K, and Si depending on the imported quantities of the respective elements, presented as polynomials of the second degree.

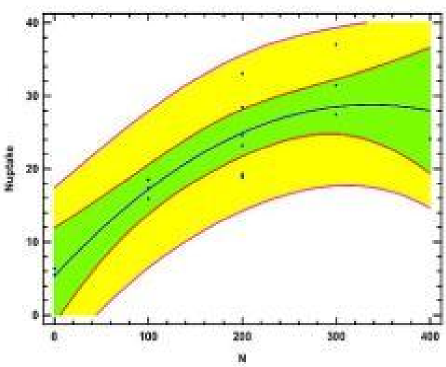

Fig. 1. Nitrogen export

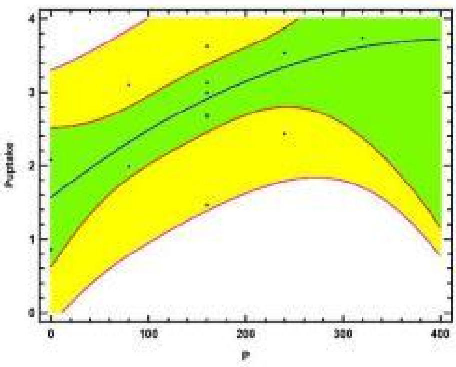

Fig.2. Phosphorus export

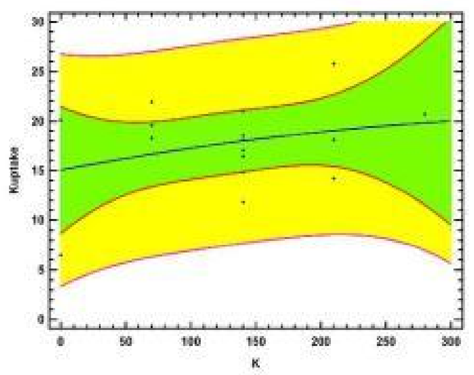

Fig. 3. Potassium export

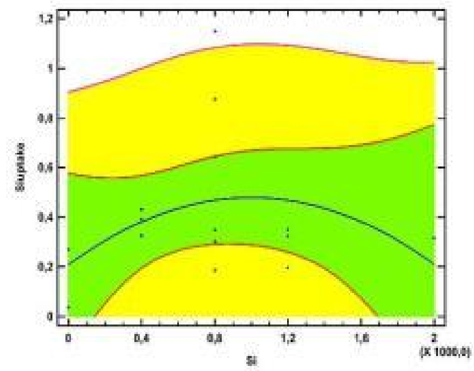

Fig. 4. Silicon export

Table 4 is compiled by conversion following the imported fertilization rates and the average values of exports with the relevant macronutrients, the patterns established for N, P, K, and Si are very clear. From this table, we can summarize that the difference between the imported quantities of active substances with fertilizers and the export with the obtained biomass is significant. This means that in the variants with high fertilization rates, large amounts of nutrients are available, which will be able to ensure the nutrition of sunflower even after the "R4" phase until the end of the growing period.

Table 4. Average export of N, P, K, and Si with biomass of sunflower ($kg.da^{-1}$) by variants and rates of fertilization ($kg.da^{-1}$)

norms of N	average export of N	norms of P	average export of P	norms of K	average export of K	norms of Si	average export of Si
0	5,50	0	0,86	0	6,45	0	0,04
30	28,74	24	2,47	21	19,94	120	0,38
60	33,14	48	2,88	42	16,82	240	0,54
90	34,48	72	3,28	63	21,93	360	0,29
120	33,38	96	3,74	84	20,7	600	0,32

CONCLUSION

The leading role of nitrogen fertilization with high norms of 200, 300, and 400 mg/pot and silicon 800 mg/pot was established as a result of the experiment carried out on a haplicvertisol in a vegetation house and from the single-factor dispersion analysis of the values for the amount of biomass of sunflower plants on the 67th day, (the proven difference between variants is at a high confidencelevel $P \leq 0.001$).

According to the experimental data obtained on the fresh and absolutely dry biomass from the above-ground part, the content and export of the studied macroelements (N, P, K, Si, Ca and Mg) with biomass are significantly influenced by imported soil fertilization norms and combinations. The highest is the nitrogen exports in the N200, N300 and N400 variants. Exports of nitrogen with sunflower biomass are the highest compared to the exports of all other elements examined. There is only a very slight tendency to increase the phosphorus content in the plants with increasing fertilizer rate in haplic vertisol.

Changes in exports of the macroelements examined have been found to follow changes in the quantities of the relevant elements in dry biomass in the variants of the experiment. With an increase in fertilization rates, not only the content is increased, but also the exports of N, P, and Si. In potassium, this trend is expressed to a lesser extent.

The calcium content is high and ranges from1.21 to 1.96% but it is significantly higher in the fertilized variants. The change in the content of Mg varies similarly, but the amount in the control is lower - 0.36%, and in the fertilized variants it is between 0.37 and 0.77%. It can be concluded that fertilization has a significantly lower effect on the accumulation of Mg in sunflower plants.

Si content increases from 0.0112% in the control variant to 0.0285% in the variant with the highest Si rate.The combinations of norms and fertilizers used in the experiment do not establish a direct relationship between increasing the accumulation of Si in plants with increasing the imported Si level.

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