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Fertilization and uptake of macroelements with maize biomass – a pot experiment with Haplic Vertisol

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Abstract

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The study was conducted in a pot experiment on Leached Smolnitsa (Haplic Vertisol, FAO). The aim was to evaluate the effect of different norms and combinations of nitrogen, phosphorus, potassium, and silicon fertilizers and their impact on the content and uptake of some main macro elements on the growth of maize (*Zea mays* L.), an early to medium-early hybrid, P-8834 from group 310 FAO "Pioneer". The experiment includes 16 variants of fertilization with three repetitions. Solid granular ammonium nitrate was used as a source of nitrogen, triple superphosphate as a phosphorus (P) fertilizer, solid potassium sulfate as a potassium (K) macronutrient, and silicon (Si) as diatomic earth. These fertilizers varied in the amounts of active substances in mg/pot and were added to the experimental containers, each with a 3 kg capacity, before sowing the seeds. Data were obtained on the yield of fresh and dry biomass from the above-ground part, as well as the content of N, P, K, and Si in the resulting dry biomass from the plants. According to the experimental data obtained, the content and export of the examined macroelements in maize biomass were significantly influenced by the imported norms and combinations of fertilizers. The highest uptake of nitrogen was observed in the variants with the following norms: N_{400}, N_{300}, and N_{200}. On the Leached Smolnitsa, the export of K with maize was higher compared to the exports of all other elements examined. It was established that the changes in the uptake of macroelements significantly follow changes in the quantities of the relevant aspects in dry biomass across the experiment variants, with increasing rates of K fertilization, not only the content but also its export with maize increases. For the remaining elements, N, P, and Si, exports increase with the increase in the fertilization rate up to the N_{300}, P_{240}, and Si_{1200} rates. At the same time, at the highest rates, respectively, P_{320} and Si_{2000}, their exports with plants slightly decrease.

Keywords: fertilization rates; nitrogen; phosphorus, potassium, and silicon fertilizers; N, P, K, Si export by dry matter of maize biomass

Introduction

Maize is a heat-loving plant, whose high-temperature requirements are evident from the sowing period. Germination occurs at a soil temperature of 8-10°C; at lower temperatures, the seeds can rot. In May, the temperature should not be lower than 13°C, and in June, July, and August it should not fall below 18°C. An extremely critical period in the development of maize is flowering. The optimal temperature in this phase is 25–28°C. In Bulgaria, there are favorable conditions for cultivating early, middle-early, middle-late, and late hybrids, with early and middle-early varieties being preferred. When choosing a hybrid, each farmer must consider the local climatic conditions, including the frequency of drought periods and high temperatures, particularly during flowering and pollination.

New hybrids and promising lines of maize, distinguished by several of their characteristics and physiological requirements, are constantly used in practice. In recent years, hybrids of the early and mid-early groups have been preferred by grain producers. They are suitable for cultivation in all regions of the country and can also be used as a second crop. In terms of nutrient availability, hybrids with the highest potential for yield and quality across all maturity groups and directions of use are characterized by the highest requirements (Huqe et al., 2021). In the country, complex scientific research in the fields of genetics, biotechnology, selection, and seed production, the physiology and biochemistry of maize, the influence of soil tillage and mineral fertilization on the yield and its structural elements of maize is conducted at the Maize Institute in Knezha (Glogova et al., 2023; Valkova, 2013; Petrovska & Genova, 2008). Soil-climatic conditions significantly influence the growth and productivity of plants (Epstein, 1999). Maize is a crop that demands specific properties and composition of the soil. She is not growing well on acidic and slightly humus soils. Without applying appropriate rates and combinations of fertilizers, it is impossible to obtain good yields. Maize yields are affected by many factors, but the primary one is nitrogen fertilization, which is why farmers often resort to excessive one-sided fertilization. It is important that fertilization is balanced and adapted to the soil-climatic conditions and the physiological requirements and characteristics of the hybrids used (Hristov &Hristova, 1995; Coskun et al., 2019; Detmann et al., 2012; Colomb et al., 2007; Pencheva et al., 2022). To ensure an optimal nutritional regime for crops, it is necessary to establish the export and consumption of nutrients that form a unit of production and their balance in the soil for different soil conditions (Ouda et al., 2008; Epstein & Bloom, 2008). Establishing the balance of nutrients is an effective method for assessing their use by crops (Zhang et al., 2007; Petkova & Sadovski, 2022). In this way, the negative consequences of improper fertilization could be avoided. In addition, balanced nutrition plays a key role in obtaining stable yields of high quality. To optimize maize nutrition, numerous vegetation and field fertilizer experiments were conducted with the main nutritional elements – N, P, and K; however, there are no scientific studies on fertilizing with silicon in Bulgarian soils.

The objective of the present study was to determine the content and export of macronutrients (N, P, K, and Si) with dry biomass of maize (*Zea maize* L.), under the influence of increasing fertilizer rates of nitrogen, phosphorus, potassium, and silicon in a pot experiment with Leached Smolnitsa.

Materials and Methods

To achieve the goal in the spring of 22. In May 2020, a pot experiment was conducted in the vegetation house of the Institute of Soil Science, Agrotechnologies, and Plant Protection "Nikola Poushkarov". The study was conducted with a medium-early hybrid of corn "R-8834" from group 310 of "Pioneer" with good productivity and resistance to stressors. Experimental pots with a capacity of 3 kg were used, in which soil was placed supplied from the experimental field in Bozhurishte, Sofia region. The soil type is Leached Smolnitza, which is a representative of the heaviest soil variety in terms of mechanical composition. According to the classification of soils in Bulgaria (Koinov et al., 1987), it is defined as a Haplic Vertisol (FAO, 2015) and is a typical representative of clay soils in Sofia. The content of physical clay is 78-80%, and of il 62%. The relative density of the soil is 2.68. The bulk density in the dry state is 1.95-2.0 g/cm³, and the Soil Water Capacity is 1.23-1.25 g/cm³. The agrochemical analysis conducted before setting up the experiment determined the soil to be medium-humic (3.02%). The soil response in the humic horizon is slightly acidic $pH_{(H2O)}$ 6.4, $pH_{(KCl)}$ 5.6). The total nitrogen content was in a low to moderate amount (0.139%), but the mineral nitrogen content was not high, ranging from 12.67 to 14.98 mg N per 1000g of soil. In terms of mobile phosphorus content, the collateral is also low, ranging from 0.20 to 0.34 mg P_2O_5 per 100g of soil, but it is well-stocked with absorbable potassium, up to 30.11 mg K_2O per 100 g. The total quantity of SiO_2 is 73.56% and it has a significant share in the total chemical composition of the different soil types in Bulgaria (Raikov & Ganev, 1972). The content of soluble and exchangeable Si was approximately 160 mg/100 g soil and 680 mg/100 g soil, as determined by extraction with 0.01 M $CaCl_2$ and 0.5 M CH_3COOH solutions, respectively (Berthelsen & Korndörfer, 2005). The studied soil was well-stocked with Silicon. The experiment consists of 16 variants in 3 replications (it is a multifactorial scheme with four factors varied at five levels (Sadovski, 2020). The experimental design is shown in Table 1. Solid granular ammonium nitrate was used as a source of nitrogen, triple superphosphate as a phosphorus (P) fertilizer, solid potassium sulfate as a potassium (K) macronutrient, and silicon (Si) as diatomic earth. These fertilizers varied in the amounts of active substances in mg/pot and were added to the experimental containers, each with a 3 kg capacity, before sowing the seeds, as presented in Table 1. Seven seeds were sown, leaving four plants in each pot at a later stage (June 16). On the 67th day of vegetation in the phase "8-9 leaves", the plants were harvested, weighed, and prepared for chemical analysis. The content (%) of ab-

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

V1. $N_0P_0K_0Si_0$ – Control	V5. $N_{200}P_{320}K_{140}Si_{800}$	V9.$N_{200}P_{160}K_{140}Si_{2000}$	V13. $N_{300}P_{80}K_{70}Si_{1200}$
V2. $N_0P_{160}K_{140}Si_{800}$	V6.$N_{200}P_{160}K_0Si_{800}$	V10.$N_{200}P_{160}K_{140}Si_{800}$	V14. $N_{100}P_{240}K_{210}Si_{400}$
V3. $N_{400}P_{160}K_{140}Si_{800}$	V7. $N_{200}P_{160}K_{280}Si_{800}$	V11. $N_{300}P_{240}K_{70}Si_{400}$	V15. $N_{100}P_{240}K_{70}Si_{1200}$
V4.$N_{200}P_0K_{140}Si_{800}$	V8.$N_{200}P_{160}K_{140}Si_0$	V12. $N_{300}P_{80}K_{210}Si_{400}$	V16. $N_{100}P_{80}K_{210}Si_{1200}$

solutely dry weight (a.d.w.) of macronutrients N, P, K, and Si in maize plant biomass was determined by acid digestion and ICP readings (5800 ICP – OES system – Agilent). The base data, including the export of the tested elements with the plant production, was calculated.

Results and Discussion

The data obtained for the yield of fresh and dry biomass (in g/pot), after harvesting the experiment on the 67th day of sowing (22.05.2020) from the above-ground part of the test crop, are presented in Figure 1. The highest values were obtained in variants V11 ($N_{300}P_{240}K_{70}Si_{400}$) and V13 ($N_{300}P_{80}K_{70}Si_{1200}$). The one-factor analysis of variance of the yield of fresh maize biomass (One-way ANOVA) resulted in a distribution of the variants into five homogeneous classes: A, B, C, D, and E (Table 2). The variants, which were in separate homogeneous classes (from A to E), were proven to be different from one another. The lowest values were the weights of plants in the control variant V1 – 90 g per pot, falling into homogeneous class A, followed by variant V2 – 95 g per pot, falling into class AB. These were the two variants without nitrogen input- No. The highest yields (230 g/pot) were in variant V3 ($N_{400}P_{160}K_{140}Si_{800}$), where the highest rate of nitrogen was applied, and also in variant V11 ($N_{300}P_{240}K_{70}Si_{400}$) – 229 g/pot. These two variants fall into homogeneous class E. It gives the impression that in variant V9, in which the highest rate of Si_{2000} was imported, the yields of biomass and plant height were relatively low. The results of the analysis of variance of the maize dry biomass data showed that six homogeneous groups were formed. The effect of the applied combined fertilization is the highest in variant V11 (42.83 g/pot falling into homogeneous class group **f**) at the rate N_{300} in combination with P_{240}, K_{70}, and Si_{400}. Very close to it were the variants V13 and V3 (38.99 and 38.47 g/pot, respectively, falling into the intermediate class **ef** and **def**), in which the nitrogen rates N_{300} and N_{400} were combined with different amounts of phosphorus, potassium, and silicon fertilizers. They were lower in the variants V14, V15, and V16, with various combinations of the rate N_{100} mg/pot in soil, including phosphorus, potassium, and silicon (groups **a, b,** and **c**). It was clear that variants V4 to V8 and V15 fell into the same **cdef** intermediate group, i.e., the amount of dry biomass obtained in these variants was very close and has not been proven statistically. It was relatively straight forward to observe that the dry weight of the total biomass obtained per pot changed proportionally to the corresponding fresh weight in the different variants (Figure 1). The tendencies es-

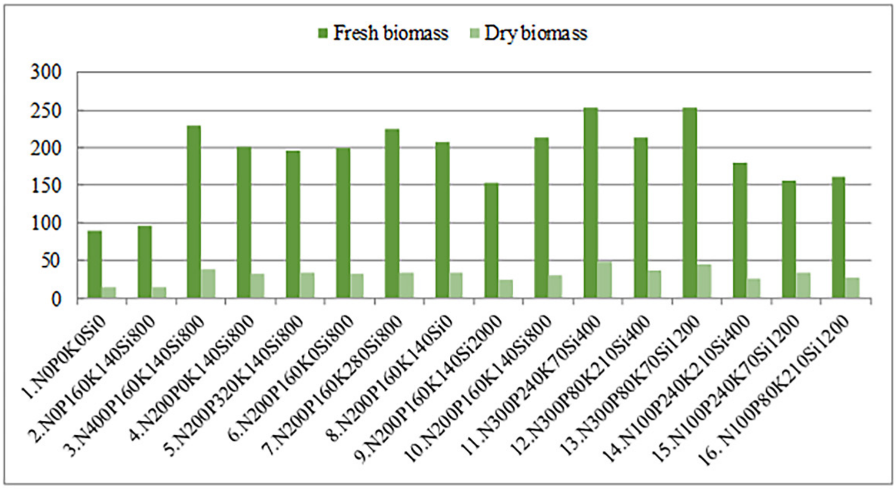

Fig. 1. The yield of plant biomass in g/pot – maize at harvest on the 67th day of vegetation

tablished from the statistical processing of the data for plant height (during the maize growing season up to day 67) were presented in a previous paper (Petkova et al., 2021). They correlated with fresh and dry biomass yield data depending on the fertilization variants. As a result of One-way ANOVA analysis of the data for the amount of maize biomass, the leading role of nitrogen fertilization at the rate of 400, 300, and 200 mg/pot was established until the 67th day from the beginning of the experiment (proven difference between variants is at a high level of confidence $p \leq 0.05$).

From the combinations of different rates and types of mineral fertilizers, the most successful was V11, in which the maximum yield of dry biomass from the maize at the V8-V9 stage was achieved. It can be seen that $N_{400,}$ $N_{300,}$ and $N_{200,}$ in combination with the smaller rates of the other macronutrients, favoured the development of maize to the highest degree. Nitrogen is an essential nutrient that determines the growth of all crops and increases the amount of protein and yield. Biomass accumulation in maize was related to nutrient uptake throughout the growing season (Salvagiotti et al., 2017).

Table 2. One-way ANOVA of data for fresh and dry weight of maize plants at harvest on the 67th day after sowing in g/pot at a confidence level of 95% (V8)

Variants	Fresh biomass	Dry biomass
V1.$N_0P_0K_0Si_0$	90.00 a	15.02 ab
V2.$N_0P_{160}K_{140}Si_{800}$	95.00 **ab**	14.17 a
V3.$N_{400}P_{160}K_{140}Si_{800}$	230.00 e	38.47 def
V4. $N_{200}P_0K_{140}Si_{800}$	199.67 cde	32.77 cdef
V5.$N_{200}P_{320}K_{140}Si_{800}$	196.67 cde	33.66 cdef
V6.$N_{200}P_{160}K_0Si_{800}$	199.00 cde	32.34 cdef
V7.$N_{200}P_{160}K_{280}Si_{800}$	225.33 de	34.34 cdef
V8.$N_{200}P_{160}K_{140}Si_0$	207.00cde	33.06 cdef
V9.$N_{200}P_{160}K_{140}Si_{2000}$	153.00 abc	24.14 abc
V10.$N_{200}P_{160}K_{140}Si_{800}$	213.67 cde	29.78 cde
V11.$N_{300}P_{240}K_{70}Si_{400}$	229.00 e	42.83 f
V12.$N_{300}P_{80}K_{210}Si_{400}$	213.00 cde	37.39 def
V13.$N_{300}P_{80}K_{70}Si_{1200}$	223.67 cde	38.99 ef
V14.$N_{100}P_{240}K_{210}Si_{400}$	165.00 bcde	23.89 abc
V15.$N_{100}P_{240}K_{70}Si_{1200}$	156.67 abcd	33.45 cdef
V16. $N_{100}P_{80}K_{210}Si_{1200}$	161.33 bcde	26.58 bcd
Average	191.06	30.68
St. deviation	71.84	9.91

The mean parameter values, followed by the same letter, did not differ significantly with the application of mineral fertilization. Under the influence of mineral nutrition, significant changes in the amount of nutrients absorbed by maize plants occurred (Table 3). The content of total N in plant dry biomass varied from 0.60% in the control to 1.76% in V3 ($N_{400}P_{160}K_{140}Si_{800}$) and 1.98% in V9 ($N_{200}P_{160}K_{140}Si_{2000}$). The content of total N in V4 ($N_{200}P_0K_{140}Si_{800}$), V12 ($N_{300}P_{80}K_{210}Si_{400}$), and V13 ($N_{300}P_{80}K_{70}Si_{1200}$) was approximately in this order. The average content of total N in the V7 with a rate of N_{200} and in the V3 with a rate of N_{300} was approximately the same, at 1.32-1.33%. The application of mineral nitrogen into the soil is, in most cases, accompanied by an increase in the N content in plants (Epstein & Bloom, 2008). In the experiment, this tendency was also confirmed only in the variants with the high N_{400} rate. The content of phosphorus in maize plants was significantly lower than that of nitrogen. It varied within a narrow range, depending

Table 3. Content of N, P, K, and Si in maize biomass (absolutely dry weight), depending on the variants

Variants	N %	P %	K %	Si mg.kg^{-1}
V1.$N_0P_0K_0Si_0$	0.60	0.44	4.1	95.5
V2.$N_0P_{160}K_{140}Si_{800}$	0.56	0.75	4.5	145.6
V3.$N_{400}P_{160}K_{140}Si_{800}$	1.76	0.48	1.9	184
V4. $N_{200}P_0K_{140}Si_{800}$	1.12	0.27	2.5	197
V5.$N_{200}P_{320}K_{140}Si_{800}$	1.00	0.44	1.9	215
V6.$N_{200}P_{160}K_0Si_{800}$	1.27	0.38	1.1	235
V7.$N_{200}P_{160}K_{280}Si_{800}$	1.27	0.60	3.8	220
V8.$N_{200}P_{160}K_{140}Si_0$	1.30	0.41	1.7	195.2
V9.$N_{200}P_{160}K_{140}Si_{2000}$	1.98	0.40	1.6	356.3
V10.$N_{200}P_{160}K_{140}Si_{800}$	1.06	0.46	1.6	229.6
V11.$N_{300}P_{240}K_{70}Si_{400}$	0.93	0.44	1.5	200.3
V12.$N_{300}P_{80}K_{210}Si_{400}$	1.52	0.38	2.0	223.7
V13.$N_{300}P_{80}K_{70}Si_{1200}$	1.52	0.37	1.5	359.6
V14.$N_{100}P_{240}K_{210}Si_{400}$	0.85	0.52	3.0	195.2
V15.$N_{100}P_{240}K_{70}Si_{1200}$	1.20	0.49	1.9	385.3
V16.$N_{100}P_{80}K_{210}Si_{1200}$	1.10	0.37	2.4	302.8

on the applied combinations of norms and types of mineral fertilizers – from 0.27% in the control to 0.75% in the fertilized variants. Phosphorus content was the highest in variant V2 – 0.75 % ($N_0P_{160}K_{140}Si_{800}$), in which a rate of 160 mg/pot of triple super phosphate was introduced. Generally, the influence of the phosphorus fertilizer rate has little effect on the phosphorus content of plants in Leached Smolnitsa (Sucunza et al., 2018). Potassium content had higher values than phosphorus and varied from 1.1 to 4.5% in the variant with a potassium rate (K_{140}). Summarized results from a large number of experiments showed that nitrogen, phosphorus, and optimal potassium fertilization were suitable for maize cultivation (Nikolova, 2010; Zhang et al., 2010). Of interest was the Si content, which increased from 95 mg kg^{-1} in the control variant to 356 mg kg^{-1} in the variant with the highest Si rate applied – 2000 mg/pot. The combinations of rates and fertilizers used in the present experiment did not establish a direct relationship between the accumulation of Si in plants and the increase in the applied silicon dose. In studies by Pavlovich et al. (2021), the higher total leaf area of Si-treated plants resulted in an increase in total CO_2 uptake by plants. In another investigation, plants treated with Si had a 24-39% increase in biomass yield (Li et al., 2018; Muhammad et al., 2021).

Based on the formed dry biomass (Figure 1 and Table 2) and the percentage content of N, P, K, and Si in it (Table 3), the export and permanent removal of the studied elements from the soil through plant production was calculated. The obtained results indicated that the changes in the exports of the studied macroelements to a significant extent followed the changes in the quantities of the corresponding elements in the dry biomass (Table 4). With increasing fertilization rates, not only the content but also the export of N, P, and Si increased. N export with plant biomass varied from 2.70 kg ha ^{1} in the control to 20.31 kg ha ^{1}in variant V3 ($N_{400}P_{160}K_{140}Si_{800}$) with the highest nitrogen rate applied. The export of nitrogen in plants was higher in the three variants, with rates of 300 mg/pot, respectively, 13.23, 17.05, and 20.07 kg/ha. The introduction of mineral nitrogen into the soil, in most cases, is accompanied by an increase in the nitrogen content in plants, which logically increases its export from the soil (Zhang et al., 2007). The export of phosphorus by maize plants was significantly lower than that of nitrogen. It varied less depending on the applied combinations of mineral fertilizers – from 1.983kg.ha^{-1} in the control to 6.258 kg.ha^{-1} in the variant V11 ($N_{300}P_{240}K_{70}Si_{400}$) at a rate of 240 mg/pot triple superphosphate (P_{240}) (Table 4). The export of potassium was higher than that of phosphorus and varied from 10.67 to 39.15 $kgha^{-1}$ across the different fertilizer options. The highest export of potassium was observed in V7 ($N_{200}P_{160}K_{280}Si_{800}$), which received the highest rate of potassium (K_{280}) applied. A better understanding of the N-K interaction mechanism can serve as a helpful guide for optimal nutrient management in agricultural practice, enabling higher yields with improved nutrient use efficiency (Zhang et al., 2010) (Table 4). Silicon export in the present study was the lowest in the control – 0.430 kg.ha^{-1} and increased to 4.749 kg.ha^{-1} in the variant V13 ($N_{300}P_{80}K_{70}Si_{1200}$) at a rate of 1200 mg/pot silicon (Si_{1200}). The combinations of fertilization rates used in the experiment did not establish a direct dependence between the export of Si by plants and the increase in the imported rate of silicon. In research by Muhammad et al. (2021), it was found that maize treated with Si grew better, leading to an increase in biomass yield (Table 4).

Table 4. Export of N, P, K, and Si by maize biomass (kg/ha), depending on the variants

Variants	N	P	K	Si
	Export by maize, kg.h^{a-1}			
V1.$N_0P_0K_0Si_0$	2.70	1.983	18.47	0.430
V2.$N_0P_{160}K_{140}Si_{800}$	2.38	3.188	19.13	0.619
V3.$N_{400}P_{160}K_{140}S_{i80}0$	20.31	5.540	21.93	2.124
V4. $N_{200}P_0K_{140}Si_{800}$	11.01	2.654	24.58	1.937
V5.$N_{200}P_{320}K_{140}Si_{800}$	10.10	4.443	19.19	2.171
V6.$N_{200}P_{160}K_0Si_{800}$	12.32	3.687	10.67	2.280
V7.$N_{200}P_{160}K_{280}Si_{800}$	13.08	6.181	39.15	2.266
V8.$N_{200}P_{160}K_{140}Si_0$	12.89	4.066	16.86	1.936
V9.$N_{200}P_{160}K_{140}Si_{2000}$	14.34	2.897	11.59	2.580
V10.$N_{200}P_{160}K_{140}Si_{800}$	9.47	4.110	14.29	2.051
V11.$N_{300}P_{240}K_{70}Si_{400}$	13.23	6.258	21.33	2.849
V12.$N_{300}P_{80}K_{210}Si_{400}$	17.05	4.262	22.43	2.509
V13.$N_{300}P_{80}K_{70}Si_{1200}$	20.07	2.32	18.28	4.749
V14.$N_{100}P_{240}K_{210}Si_{400}$	6.66	2.43	18.07	1.530
V15.$N_{100}P_{240}K_{70}Si_{1200}$	12.04	3.53	21.94	3.866
V16. $N_{100}P_{80}K_{210}Si_{1200}$	8.77	1.99	14.24	2.415

Table 5 presents a multiple comparison procedure to determine which mean values are significantly different from which others. Three homogeneous groups were identified, indicating statistically significant differences at the 95.0% confidence level.

Table 5. Multiple Range Tests (multiple comparison procedure)

	Count	*Mean*	*Homogeneous Groups*
Si export, kg/ha	16	2.2695	a
P export, kg/ha	16	4.13188	a
N export, kg/ha	16	11.6513	b
K export, kg/ha	16	20.0725	c

Figures 2 to 5 show the regression curves of the export of N, P, K, and Si as a function of the applied quantities of the respective elements, represented as polynomials of the second degree (Leached Smolnitsa – Bozhurishte).

The corresponding equations for the nutrients are:

Nupt = 5.2711 + 0.062766*N + 0.00005186*N^2

Pupt = 2.9804 + 0.031073*P – 0.00003030*P^2

Kupt = 12.9284 + 0.188841*K – 0.00067601*K^2

Siupt = 2.1388 + 0.002239*Si + 0.00000102*Si^2

With their help, the soil equivalents of the elements and the maximum values within the experimental limits can be determined (Sadovski, 2021). It can be seen that the exported amounts of nitrogen, phosphorus, and silicon in the experiment increased proportionally; only potassium reached a maximum export at 150 mg/pot.

The regularities established for N, P, K, and Si are presented in Table 6, which was compiled by converting the applied fertilization rates and averaging the corresponding values of the exports with the macroelements. The export of N and P increases with an increase in the fertilization rate up to the N_{300} and P_{240} rates, but at the highest rates, N_{400} and $P_{320,}$ respectively, their exports with the plants slightly decrease. There was a similar regularity with silicon. With potassium in the variant with the highest norm $K_{280,}$ the export of this element increased almost twice compared to the variants with the previous norm K_{210}. This was probably due to the higher potassium content available to plants in the Leached Smolnitsa, which also increased with the applied rates of potassium fertilizer. This may also be related to the development phase of the crop and its physiological

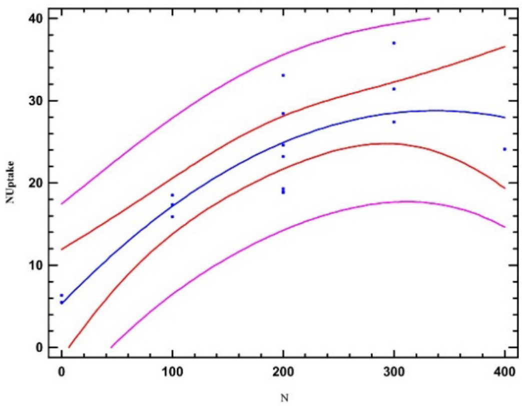

Fig. 2. N export

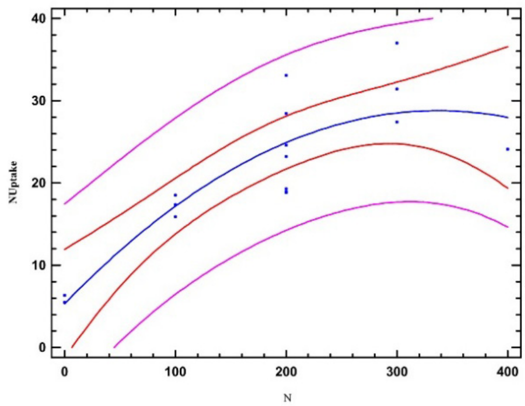

Fig. 4. K export

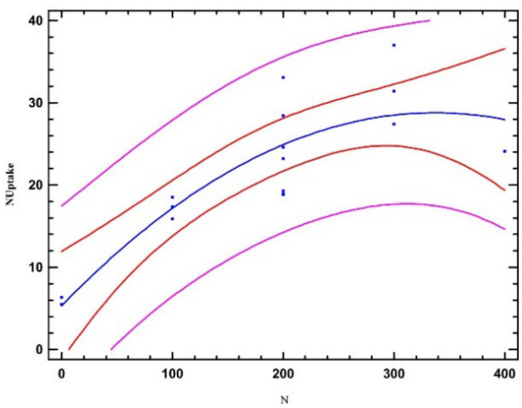

Fig. 3. P export

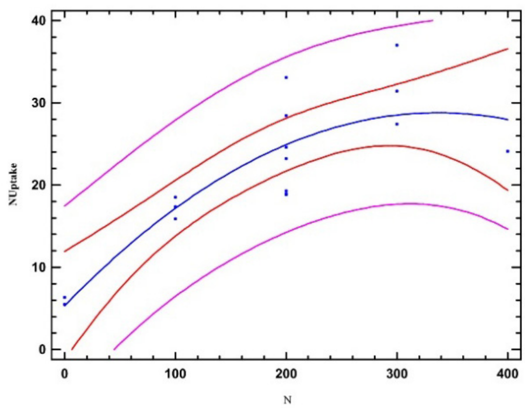

Fig. 5. Si export

Table 6. Averaged export of N, P, K, and Si by maize biomass ((kg/ha), depending on the variants of fertilization

Norms of N	Average export of N, kg.ha^{-1}	Norms of P	Average export of P, kg.ha^{-1}	Norms of K	Average export of K, kg.ha^{-1}	Norms of Si	Average export of Si, kg.ha^{-1}
0	2.7	0	2.6	0	18.47	0	0.430
100	9.16	80	4.03	70	20.07	400	2.296
200	11.89	160	4.87	140	18.22	800	1.921
300	26.81	240	5.09	210	21.7	1200	3.677
400	20.31	320	4.44	280	39.15	2000	2.580

requirements. From Table 6, it could be summarized that the difference between the applied amounts of active substances with the fertilizers and the export with the resulting biomass was significant. This means that, especially in the variants with higher fertilization rates, large amounts of nutrients were available, which will ensure the crops nutrition after the "8-9 leaf" phase until the end of the vegetation period.

Conclusion

As a result of the vegetation fertilizer experiment on Leached Smolnitsa and the one-factor dispersion analysis of the values for the amount of maize biomass, the fundamental role of nitrogen application at the rate of 400, 300, and 200 mg/pot was established until the 67th day from the beginning of the pot experiment (proven difference between variants is at a high level of confidence $p \leq 0.05$). Based on the formed dry biomass and the content of N, P, K, and Si in it, the export of the studied elements with the plant biomass was calculated. It has been found that the differences in exports of the studied macroelements were similar to the changes in the amounts of the corresponding elements in the dry biomass, depending on the fertilization variants. Nitrogen export was the highest for the N_{400}, $N_{300,}$ and N_{200} rate variants. The export of K with maize is higher compared to the exports of all the other elements studied. With an increase in the rates of fertilization with K, not only does the content increase, but also its export with maize. In the other elements, N, P, and Si, exports increase with increasing fertilization rates to N_{300}, P_{240}, and Si_{1200}. At the same time, at the highest norms, respectively, $P_{320,}$ and Si_{2000}, their exports with plants decreased slightly. Silicon export in the present study was the lowest in the control – 0.430 kg.ha^{-1} and increased to 4.749 kg.ha^{-1} in the variant V13 ($N_{300}P_{80}K_{70}Si_{1200}$) at a rate of 1200 mg/pot silicon (Si_{1200}). The combinations of fertilization rates used in the experiment did not establish a direct dependence between the export of Si by plants and the increase in the imported rate of silicon.

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