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Macronutrient content and export with biomass and lysimetric water from a field experiment with barley (*Hordeum vulgare* L.) grown as after-effect

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Abstract

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The influence of mineral fertilization on the yield, content and export of macronutrients with the biomass and lysimetric waters in the cultivation of barley (*Hordeum vulgare* L.), grown as after-effect was studied. The experiment was conducted on Fluvisos (WRBSR, 2006) in Tzalapitza experimental field near Plovdiv with tomatoes as previous crop, fertilized with $N_{120}P_{80}K_{140}$; $N_{240}P_{120}K_{180}$ and $N_{360}P_{160}K_{220}$. The norms of fertilization of the previous crop had significant influence on the agrochemical characteristics of the studied soil and the productivity parameters of barley crop. The yield formed in the variants $N_{240}P_{120}K_{180}$ and $N_{360}P_{160}K_{220}$ was 4247.6 and 4360.7 kg.ha^{-1}, respectively, and it was twice as high as in the control. Significant differences in the export of macronutrients with barley biomass depending on the fertilization of the predecessor were established. It was found that calcium, magnesium, nitrates and sulphates contents in lysimetric waters were sensitive to the anthropogenic impacts and their contents increased with the increasing of the fertilization rates of the predecessor, while pH values and the bicarbonates contents decreased.

Keywords: barley; yield; lysimetric waters; uptake of macroelements

Introduction

Barley (*Hordeum vulgare* L.) is one of the main cereal crops grown traditionally in Bulgaria. In recent years it takes third place of sown areas in the country after wheat and maize (according to the Statistics and Analyses of the Ministry of Agriculture). Some authors reported that barley is less sensitive to changes in the environmental conditions, which makes it suitable in a number of crop rotations (Ryan et al., 2009; Koteva, 2013). The after-effect of mineral fertilization, liming, tillage and crop rotation on the productivity of barley were investigated by (Hejcman et al., 2013; D'yachenko & Shevelev, 2020; Skorokhodov et al., 2021). There were relatively few investigations related to the content and export of macroelements when cultivating barley (Delogu et al., 1998; Hejcman et al., 2013). The export of elements with the biomass of the crop is one of the main steps of nutrient balance in the soil-water-plant system (Stoicheva et al., 2011; Nikolova et al., 2014). Agricultural systems are frequently based on the use of large amounts of mineral fertilizers, especially of nitrogen, without taking into account soil reserves and the mineralization process (Moreno et al., 2003). According to some researchers (Saghatelyan et al., 2013; Piccini et al., 2016) the fertilizers applied have a significant impact not only on crop yields, but also on various components of the agroecosystem. From an ecological point of view, the type, the rate and the time of application of nitrogen fertilizers are essential for the migration of nutrients due to the chemical nature and complex transformation processes of nitrogen. It is found that the liquid soil phase could be used as a good diagnostic parameter reflecting the behavior of nitrogen under the influence of various agricultural practices (Zhao et al., 2010; Singh et al., 2018).

The aim of the present study was to determine the effect of mineral fertilization of the previous crop on the yield, content and export of basic macronutrients with biomass and lysimetric waters in a field experiment with barley grown as after-effect.

Material and Methods

In the spring of 2019 on the area of a long-term vegetable experiment, in a test field of Tzalapitza village near Plovdiv, a study was carried out with spring barley, grown as after-effect on Fluvisols. Mineral fertilization was not applied to this crop, as one of the aims of the study was to achieve balancing of nutrients in the soil on the experimental area, as well as to stop weed development. In the conducted experiment Bulgarian variety of winter-spring barley – Obzor was used, sown on February 21st , 2019. The ear of this variety is two-row, 7 – 8 cm long, resistant to breakage, the grain is large (45 – 47 g) and suitable for brewing purposes. The recommended sowing density was 400 – 450 germinating seeds per 1 m^2. Barley was grown under non-irrigated conditions in accordance with the necessary agro-technical activities. In the previous 2018, Rugby variety of tomatoes were grown on the experimental area in the following fertilization rates: $N_{120}P_{80}K_{140}$; $N_{240}P_{120}K_{180}$; $N_{360}P_{160}K_{220}$ and a control variant – $N_0P_0K_0$ – without fertilization. The scheme of the fertilization of the previous crop is presented here because barley was grown as after-effect, using the stock of nutrients remained after growing tomatoes. A randomized block design with three replicates was used. The size of the experimental plot was 120 m^2.

In the phase of full maturity of barley, in July 2019, plant samples were taken from the variants of the experiment in three replicates and the grain yield (kg. ha^{-1}) was determined, as well as the content and export of N, P, K, Ca and Mg by the grain, chaff and straw. Nitrogen in plant biomass was determined by wet digestion of samples using the Ginzburg method and subsequent distillation by the Kjeldahl method (Peterburgskii, 1986), phosphorus was analyzed colorimetrically with molybdenum blue, and potassium by flame photometer (Peterburgskii, 1986), calcium and magnesium were determined by ICP-OES.

For the analysis of the main agrochemical characteristics of the soil, samples were taken from a depth of 0 – 30 cm and 30 – 60 cm, before (January 2019) and after (September 2019) barley cultivation. The following parameters were determined: pH – potentiometrically (ISO 10390:2002), $N – NH_4 + NO_3$ by the method of Bremner & Kiney (Bremner, 1965), mobile forms of P_2O_5 and K_2O by the method of Ivanov (1984). To study the migration of the chemical elements along the soil profile, at a depth of 0 – 100 cm from the soil surface the modified Ebermayer type of lysimeters were installed (Stoychev, 1974). Lysimetric waters were taken 3-4 times a year depending on the amount of infiltrate. The waters were analyzed for the content of: K^+, Na^+, Ca^{2+}, Mg^{2+}, NO_3^-N, HCO_3^-, Cl^-, SO_4^{2-} and for pH values. Data were averaged over the growing season.

Statistical processing of the data was performed using One-way ANOVA from the statistical package Statgraphics Centurion.

Results and Discussion

Climatic characteristics of the studied area (Tzalapitza village) for the investigated period are presented in Figure 1. The sum of precipitation during the winter months (January – March) was 41.5 mm, and it was significantly lower than the amount for a thirty-year period, accepted as a norm – 113.5 mm. This deficit of moisture was compensated to some extent in the spring months April and May, when the amount of precipitation were close to the average for the multiannual period. The temperature during the study period was relatively high, especially for the winter months January – March. Barley is considered less dependent than other crops on the temperature during germination. Relatively higher temperatures during the studied period did not adversely affect the initial stages of its development. Climatic conditions during the experimental period were assessed as favorable for growing of spring barley.

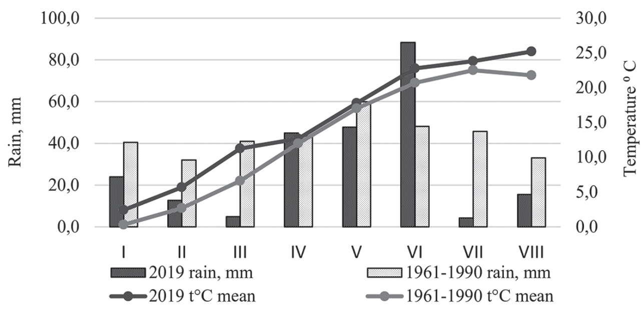

Fig. 1. Climatic characteristics on the experimental field, for January – August 2019, compared with a long-term period accepted as a norm 1961–1990

Content of available nutrients in soil is a major indicator of its fertility. Agrochemical characteristics of the Fluvisol, before and after barley growing are presented in Table 1. Cation exchange capacity of the investigated soil is on average 22.4 cmol.kg^{-1} in the layer 0-20 cm and the humus content is on average 1.23 %, which could be characterized as low (Simeonova et al., 2021).

Soil pH (H_2O) in the studied variants decreased regularly from the control $N_0P_0K_0$ to the variant of maximum fertilization of the previous crop $N_{360}P_{160}K_{220}$ (Table 1). This tendency was better expressed regarding the pH values before barley sowing (in January 2019) and it was a consequence of the long-term mineral fertilization applied on the area. A similar trend was observed by Ning et al. (2020) in a multi-year field experiment, as the authors found not only acidification but deterioration of the microbiological status of soil after fertilization. The use of organic fertilizers leads to enrichment of soil with cations (Li et al., 2018), whose buffering ability prevents soil from acidification, while using mineral fertilizers, the process is opposite. Before barley sowing, the stock of soil mineral nitrogen N – (NH_4 + NO_3) in the arable soil layer of the control variant was very low, 9.8 mg.kg^{-1}. It increased to 19,0 mg.kg^{-1} in the variant ($N_{360}P_{160}K_{220}$) with maximal rate of fertilization of the previous crop. After barley growing, mineralization of the available soil organic matter led to a slight increase in N mineral stock and the differences between the variants in were less pronounced. Mineral fertilization of the predecessor had a significant effect on the reserves of mobile forms of phosphorus and potassium before barley cultivation, too. Phosphorus content was the lowest in the control variant at a depth of 30 – 60 cm (2.2 mg.100 g^{-1}), and it was the highest (19.8 mg.100 g^{-1}) in the arable soil layer of the variant $N_{360}P_{160}K_{220}$. The same tendency was observed regarding available potassium. After barley growing, there was some equalizing of the stock of mobile forms of phosphorus and potassium in the soil, as they remained the lowest in the control variant $N_0P_0K_0$.

After statistical processing of the data for barley grain yield (kg.ha^{-1}) depending on the variants of fertilization of the previous crop (tomatoes in 2018) significant differences were observed between the variants ($P \geq 95\%$) presented in Table 2.

Table 2. Barley grain yield (kg.ha^{-1}) influenced by the variants of fertilization of the previous crop

Variants of fertilization of previous crop	Barley yield, kg.ha^{-1}	StDev	Homogenous groups
$N_0P_0K_0$	1904.8	242.2	a
$N_{120}P_{80}K_{140}$	2004.5	746.8	a
$N_{240}P_{120}K_{180}$	4247.6	731.7	b
$N_{360}P_{160}K_{220}$	4360.7	807.8	b
LSD ($P \geq 95\%$)	1265.0		

Two homogenous groups were formed (Table 2), the first one included barley grain yield obtained by the control and the variant with lower fertilization rate of the previous crop $N_{120}P_{80}K_{140}$, the second group included the variants with optimal and maximal fertilization rate of the precursor $N_{240}P_{120}K_{180}$ and $N_{360}P_{160}K_{220}$. In the study of Koteva et al. (2013) barley grown in the conditions of organic farming, without the use of mineral or liquid organic fertilizers reached 46% of its productive potential, which was expressed in yields between 2270 and 2400 kg.ha^{-1}. These results were close to those, obtained in the variants forming homogenous group "a" in the present study. A number of authors reported the positive effect of mineral fertilization on barley yields (Skorokhodov et al., 2021; Moreno et al., 2003). Not only the fertilizer rate but also the type of the previous crop and especially climatic conditions during vegetation play an important role in achieving high barley productivity. In the present experiment, the stock of soil nutrients left after growing tomatoes was essential for the differences obtained in the formed barley yields. According to the data present-

Table 1. Agrochemical characteristics of the investigated soil before and after growing of spring barley, 2019

Variants of fertilization of previous crop	Depth, cm	pH (H_2O)		N (NH_4 + NO_3), mg.kg^{-1}		P_2O_5, mg.100 g^{-1}		K_2O, mg.100 g^{-1}	
		before	after	before	after	before	after	before	after
$N_0P_0K_0$	0-30	7.1	7.3	9.8	12.1	6.0	7.9	13.7	18.8
	30-60	7.1	7.0	6.9	15.6	2.2	4.3	15.1	18.2
$N_{120}P_{80}K_{140}$	0-30	6.5	7.2	13.2	18.4	13.8	12.3	23.4	27.7
	30-60	7.0	6.7	11.5	15.0	18.7	12.1	27.3	21.8
$N_{240}P_{120}K_{180}$	0-30	6.2	7.2	17.3	19.0	18.1	14.7	26.8	25.2
	30-60	6.5	6.8	14.4	20.2	18.9	12.6	26.5	18.8
$N_{360}P_{160}K_{220}$	0-30	6.3	7.2	19.0	17.3	19.8	12.3	36.9	29.2
	30-60	6.3	6.7	10.9	15.6	17.4	17.0	31.6	22.6

ed by Statistics and Analyses of the Ministry of Agriculture (Bulgaria), in 2018 the average yields of barley grain for the country were 4220 kg.ha^{-1}. The yields obtained in variants $N_{240}P_{120}K_{180}$ and $N_{360}P_{160}K_{220}$ were very close to the national average – 4247.6 and 4360.7 kg.ha^{-1}, respectively. This was mainly due to the fertilization applied in the previous year and the relatively favorable climatic conditions during the experimental period.

Content of macronutrients N, P, K, Ca and Mg in the absolutely dry weight of barley (ADW) are presented in Table 3.

Table 3. Content of macronutrients (% of ADW) in barley biomass, 2019

Variants of fertilization of previous crop	Parts of barley biomass	Macroelements content, %				
		N	P	K	Ca	Mg
$N_0P_0K_0$	Grain	1.42	0.41	0.46	0.15	0.06
	Chaff	0.87	0.30	0.42	0.15	0.16
	Straw	0.46	0.17	1.67	0.12	0.31
$N_{120}P_{80}K_{140}$	Grain	1.68	0.41	0.46	0.15	0.05
	Chaff	1.10	0.35	0.48	0.16	0.14
	Straw	0.51	0.19	1.35	0.13	0.34
$N_{240}P_{120}K_{180}$	Grain	1.81	0.38	0.41	0.15	0.05
	Chaff	1.13	0.27	0.42	0.13	0.16
	Straw	0.48	0.15	1.60	0.13	0.33
$N_{360}P_{106}K_{220}$	Grain	1.89	0.42	0.41	0.16	0.06
	Chaff	0.95	0.23	0.39	0.12	0.19
	Straw	0.38	0.12	1.55	0.11	0.25

A positive effect of the fertilization of the predecessor on the nitrogen content in barley biomass was established (Table 3). The lowest was the nitrogen content in the grain of the control variant $N_0P_0K_0$ (1.42%) and the highest in the grain of the variant $N_{360}P_{106}K_{220}$ (1.89%). Nitrogen content decreased in the chaff and the straw. Similar results were observed by Hejkman et al. (2013), as in their investigation the nitrogen content of barley grain was between 1.53% in the control variant and 2.16% in the variant with poultry manure fertilization. The content of phosphorus in barley grain was almost unchanged and varied in the range of 0.38 – 0.41%. Differences in phosphorus concentrations were observed between grain and straw, the trend being the same as for nitrogen – phosphorus predominated in the grain and decreased in the straw. Potassium content in the biomass of barley varied from 0.39% in the chaff of the variant $N_{360}P_{106}K_{220}$ to 1.67% in the straw of the variant $N_0P_0K_0$ as significant differences depending on the fertilization of the previous crop were not observed. According to Prajapati and Modi (2012) if the soil is well supplied with potassium, the whole plant in the heading phase contains between 1.5% and 3.0% of potassium. Nikolova et al. (2014) reported even higher average values of potassium in barley biomass, between 3.2% and 4.5% but in earlier growing stages. Magnesium content, similarly to potassium was also predominant in barley straw, while calcium was evenly distributed in grain and chaff, and in straw its values decreased. In general, no significant ($p < 0.05$) differences were observed between P, K, Ca and Mg concentrations at the various fertilization levels in the different sources of barley produce (Table 3), only the nitrogen content was positively influenced. The results obtained indicates that plants exhibit buffering against excess levels of these nutrients, in spite of higher P and K levels in soil in the beginning of the experiment. On the other hand, P and K concentrations in soil in the end of the experiment decreased, most probably due to sorption to soil constituents and plant uptake.

Based on the absolutely dry weight (ADW) of barley biomass (grain, chaff and straw) and the content of nutrients in it, the export of nitrogen, phosphorus, potassium, calcium and magnesium was calculated (Table 4).

Total absolutely dry weight (ADW) of barley varied from 5772.2 to 15727.9 kg.ha^{-1} depending on the variants in the experiment. It was within the normal range for the studied crop (Delogu et al., 1998), taking into account that during the experimental period fertilization was not applied. With the biological yield of barley between 45.7 and 129.4 kg.ha^{-1} of nitrogen were exported from the field. When recalculating the nitrogen export per unit of production (of 1000 kg), on average 17 kg.t^{-1} with the grain and 4,6 kg.t^{-1} with the straw were exported. These results were very close to those presented by Nikolova et al. (2014) where the total export per unit of grain and straw production were 22.5 kg.t^{-1}. Nitrogen exports in the variants $N_{240}P_{120}K_{180}$ and $N_{360}P_{180}K_{220}$ increased almost threefold compared to the control, mainly due to the higher yields obtained. Phosphorus exports were relatively low from 14.7 to 32.7 kg.ha^{-1}. Exports of potassium with barley varied from 68.3 to 180.2 kg.ha^{-1} depending on the variants of fertilization of the previous crop. Recalculated per unit of produce (kg.t^{-1}) the potassium export was 4.4 kg.t^{-1} for the grain and 15.4 kg.t^{-1} for the straw. The export of potassium per unit of grain produce is close to the average for barley crop (Nikolova et al., 2014), the export with straw is relatively high. The amount of exported calcium with the total biomass varied between 7.7 – 19.1 kg.ha^{-1}, and for magnesium ranged from 12.7 to 31.1 kg.ha^{-1}, the differences were determined by the higher biological yield obtained in the variants of fertilization of the predecessor.

Table 4. Export of macronutrients (kg.ha^{-1}) with absolutely dry weight (ADW) of barley

Variants of fertilization of previous crop (tomatoes)	Parts of barley biomass	ADW kg.ha^{-1}	Uptake of macroelements, kg.ha^{-1}				
			N	P	K	Ca	Mg
$N_0P_0K_0$	Grain	1755.6	24.9	7.2	8.1	2.6	1.1
	Chaff	551.1	4.8	1.7	2.3	0.8	0.9
	Straw	3465.6	15.9	5.9	57.9	4.2	10.7
	Total	5772.2	45.7	14.7	68.3	7.7	12.7
$N_{120}P_{80}K_{140}$	Grain	1833.5	30.8	7.5	8.4	2.8	1.0
	Chaff	672.0	7.4	2.4	3.2	1.1	0.9
	Straw	5166.8	26.4	9.8	69.8	6.8	17.4
	Total	7672.2	64.5	19.7	81.4	10.6	19.4
$N_{240}P_{120}K_{180}$	Grain	3922.0	71.0	14.9	16.1	5.9	2.1
	Chaff	986.7	11.2	2.7	4.1	1.3	1.6
	Straw	9113.7	43.7	13.7	145.8	11.5	30.1
	Total	14022.4	125.9	31.2	166.0	18.7	33.7
$N_{360}P_{180}K_{220}$	Grain	4038.1	76.3	17.0	16.6	6.4	2.4
	Chaff	1516.6	14.4	3.5	5.9	1.8	2.9
	Straw	10173.2	38.7	12.2	157.7	10.9	25.8
	Total	15727.9	129.4	32.7	180.2	19.1	31.1

Chemical composition and export of elements with lysimetric waters

The volume of the infiltrated lysimetric waters below 0-100 cm of soil layer, when growing barley varied in the range from 9.62 l.m^2 to 30.13 l.m^2. The highest percentage of infiltrated water in relation to the total amount of incoming water in this soil is obtained when large amounts of precipitation coincide with the applied irrigation (Koleva & Stoycheva, 2005). The quantities of infiltrates obtained for 2019 are from 2 to 7%, and they were lower due to the fact that no irrigation was applied.

Lysimetric waters are a dynamic soil component which gives an idea of the extent to which changes in the acid-alkaline balance of the soil influence geological materials and groundwater. It's evident (Table 5) that pH values of the lysimetric waters from the variants of fertilization of previous crop were about 0.8 units lower compared to those obtained from the control variant $N_0P_0K_0$. It was observed that in these variants the acid-base balance of the liquid phase was not restored, in cultivating barley as after-effect.

The average chemical composition of the lysimetric waters during the vegetation period of barley showed that, in general the differences between the variants of fertilization (of the previous crop) and the control remained sustainable (Table 5). Higher content of alkaline elements in the waters circulating under the control variant was observed. This could be explained by the stimulating effect of the surface tillage and the maintenance of a deficient water regime (in the predecessor – tomatoes), on the processes of weathering and release of ions in the liquid soil phase. The cultivation of barley, even without fertilization, is associated with the distribution of cations between the geochemical and biological cycles of the materials. This process is very pronounced as regards the potassium status. It could be seen, that the content in the lysimetric waters under fertilized variants was several times lower than in the control. This tendency

Table 5. Content of chemical elements (mg.l^{-1}) in the lysimetric waters when growing barley

Variants*	pH	Content of chemical elements, mg.l^{-1}								
		K^+	Na^+	Ca^{2+}	Mg^{2+}	N		HCO_3^-	Cl^-	SO_4^{2-}
						NH_4^+	NO_3^-			
$N_0P_0K_0$	7.85	5.5	15.9	96.5	27.8	1.2	8.6	168.2	13.7	65.0
$N_{120}P_{80}K_{140}$	7.40	2.0	24.7	61.5	17.5	2.2	10.1	104.7	19.4	73.9
$N_{240}P_{120}K_{180}$	7.35	1.3	26.0	64.8	20.4	2.4	15.0	87.1	22.1	77.4
$N_{360}P_{160}K_{220}$	7.05	2.0	21.9	82.8	25.0	2.2	16.8	62.2	20.2	81.1

* Variants of fertilization of previous crop (tomatoes)

is clearly expressed concerning the calcium content, and less pronounced regarding magnesium. The amount of calcium for the fertilized variants varied between 61.5 and 82.8 $mg.l^{-1}$, while the highest values were found below $N_0P_0K_0$. The higher concentration of some of the elements in the lysimetric waters under the control variant could also be explained by weaker export with the plant produce, as lower yields were formed in this variant (Table 4).

The nitrates content in lysimetric waters was the highest in maximum fertilized variant of the predecessor $N_{360}P_{160}K_{220}$ – 16.8 $mg.l^{-1}$ compared to the control, where the values were about two times lower. This indicated that the accumulated mineral nitrogen and a the larger amount of plant residues in the maximum fertilized variant released higher amounts of nitrates in the soil solution. Only a part (30-50%) of the nitrogen applied into the soil with fertilization is utilised by plants (Koutev et al., 2010), so the residual amounts could be washed away by the drainage runoff. Understanding the impact of anthropogenic pressure on the transformations and movement of nitrogen is a precondition for regulating the supply of crops with nutrients and maintaining higher yields without allowing migration of chemical elements with the infiltration outflow. The content of bicarbonates varied in the range from 62.2 to 168.2 $mg.l^{-1}$, with a certain decrease in the fertilized variants. It is possible that some of the divalent cations displaced by the ammonium fertilizers from the soil colloids were immobilized in the corresponding soil carbonates, resulting in bicarbonates decrease in the fertilized variants. Chloride contents vary between 13.7 and 22.13 $mg.l^{-1}$ without any dependence on the factor tested. The concentration of sulfates was from 65.0 to 89.0 $mg.l^{-1}$, with the lowest values observed in the control, and the highest in the maximum fertilized variant of the previous crop $N_{360}P_{160}K_{220}$.

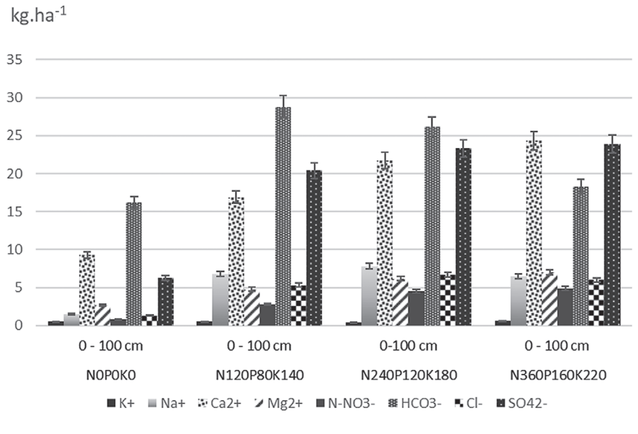

Fig. 2. Export of the elements ($kg.ha^{-1}$) by the lysimetric waters

The export of the elements with drainage runoff and their loss under the one-meter soil layer was calculated using averaged data (from three replicates) for the infiltrate quantities, which vary between 9 and 30 $l.m^2$ for all studied variants. The infiltrated quantities of water were determined by the physical properties of the soil, by the created water regime, as well as by the type of the cultivated crop. In addition, the studied soil is characterized by significant spatial heterogeneity and high diversity in the arrangement of alluvial materials throughout the soil profile, where it is possible to observe differences in the resulting drainage under different variants.

The analysis of the data on the export of nitrate nitrogen (Figure 2) showed that the exported quantities were the lowest from the control $N_0P_0K_0$ – 0.80 $kg.ha^{-1}$ compared to the fertilized variants. The data obtained showed an increase in nitrogen losses from the fertilized variants $N_{240}P_{120}K_{180}$ and $N_{360}P_{160}K_{220}$ between 4.50 and 4.90 $kg.ha^{-1}$, which depend on the amount of infiltrate and its content in lysimetric waters. When growing barley as after-effect, with lysimetric water were exported from 9.30 to 24.30 $kg.ha^{-1}$ Ca, from 2.70 to 7.00 $kg.ha^{-1}$ Mg, potassium from 0.40 to 0, 60 $kg.ha^{-1}$, between 16.20 and 28.80 $kg.ha^{-1}$ HCO_3^- and from 6.90 to 23.90 $kg.ha^{-1}$ sulfates.

Conclusions

As a result of the fertilization of the previous crop (tomatoes grown in 2018), residual amounts of nutrients were found in the soil, leading to higher yields of barley obtained in variants $N_{240}P_{120}K_{180}$ and $N_{360}P_{160}K_{220}$ – 4247.6 and 4360.7 $kg.ha^{-1}$, respectively, twice as high as those formed in the control. The content of macronutrients P, K, Ca and Mg in the grain and biomass of barley were not significantly affected by the fertilization of the previous crop. Only nitrogen content increased significantly under the influence of the studied factor. Barley (ADW) exports between 45.7 and 129.4 $kg.ha^{-1}$ N, between 14.7 and 32.7 $kg.ha^{-1}$ P and between 68.3 and 180.2 $kg.ha^{-1}$ K, the differences being determined by the higher amount of total biomass obtained.

Regarding the liquid phase of the soil, the results obtained showed that during the growing season of barley, the differences between the control variant and the fertilized variants of the predecessor remained. It was found that calcium, magnesium, nitrates and sulphates were sensitive to the anthropogenic impacts and their content increased with the increasing of the fertilizer rates of the previous crop, while pH values and the bicarbonates contents decreased. It was established that the export of NO_3-N, depending on the fertilization rates, ranged from 0.80 to 4.90 $kg.ha^{-1}$, and the calcium contents varied from 9.30 to 24.30 $kg.ha^{-1}$, respectively.

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