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Content and uptake of macroelements by the biomass and grain of barley (*Hordeum vulgare* L.) grown as aftereffect

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Съдържание и износ на основни макроелементи с биомасата и зърното на ечемик (*Hordeum vulgare* L.) отглеждан като последействие

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ABSTRACT

A field study with spring barley (*Hordeum vulgare* L.) was conducted on the area of long-term balance experiment in Tsalapitsa village near Plovdiv (Bulgaria), on alluvial-meadow soil. Mineral fertilization was not applied to this crop in order to equalize the area regarding nutrient content. The crop grown before barley was maize with 4 variants of fertilization and one control variant: N_0P_0, $N_{100}P_{50}$, $N_{150}P_{100}$, $N_{200}P_{150}$, and $N_{250}P_{200}$. The present study aimed to evaluate the productivity, content and uptake of macronutrients (N, P, K, Ca and Mg) with the biomass of barley, grown as aftereffect. Due to the fertilization of the previous crop, different residual amounts of nutrients in soil lead to significant variability in barley yields. The highest grain yield was obtained in variant $N_{250}P_{200}$ - 3978.8 kg/ha, approximately four times higher than the yield in the control. Nitrogen content in the grain of barley is also influenced by the variants, being the lowest in the control - 1.25%, and the highest in variants $N_{250}P_{200}$ and $N_{200}P_{150}$ - 2.13% and 2.09%, respectively. The variability of P, K, Ca and Mg contents by variants is lower. With the total biomass of barley, depending on the variants of the experiment, between 23.2 - 132.7 kg N/ha; 26.6 - 146.3 kg K/ha and 9.3 - 36.5 kg P/ha were exported from the field. A good regression relationship was found between barley grain yield and nitrogen export with the total biomass ($R^2 = 0.859$, $P \leq 0.001$).

Keywords: fertilization, aftereffect, yield, macro elements, uptake, barley

РЕЗЮМЕ

Върху площта на многогодишен балансов опит в ОП Цалапица, Пловдивско (България), на Алувиално-ливадна почва е проведен полски експеримент с пролетен ечемик (*Hordeum vulgare* L.). При този посев не се прилага минерално торене, с цел изравняване на площта по отношение на съдържанието на хранителни елементи. Предшественик на ечемика е царевица с 4 варианта на торене и един контролен вариант: N_0P_0, $N_{100}P_{50}$, $N_{150}P_{100}$, $N_{200}P_{150}$ и $N_{250}P_{200}$. Целта на настоящото изследване е да се оценят продуктивността, съдържанието и износа на основни макроелементи (N, P, K, Ca и Mg) с биомасата на ечемик, отглеждан като последействие. Вследствие на торенето на предшественика остатъчните количества хранителни елементи в почвата водят до доказано вариране на добивите от ечемик. Най-висок добив зърно е получен при вариант $N_{250}P_{200}$ - 3978.8 kg/ha, който е приблизително 4 пъти по-висок, отколкото в контролата. Съдържанието на азот в зърното на ечемика също се повлиява доказано от вариантите в опита, като е най-ниско в контролата – 1.25%, а най-високо във варианти $N_{250}P_{200}$ и $N_{200}P_{150}$, съответно 2.13 и 2.09%. Съдържанието на пепелни елементи - P, K, Ca и Mg, варира по-слабо по варианти. С получената обща биомаса на ечемика, в зависимост от вариантите в опита от полето се изнасят между 23.2 kg и 132.7 kg N/ha, между 26.6 и 146.3 kg K/ha и между 9.3 и 36.5 kg P/ha. Установява се много добра регресионна зависимост $R^2 = 0.859$, $P \leq 0.001$ между добива от зърно и износа на азот с общата биомаса на ечемика.

Ключови думи: торене, последействие, добив, макроелементи, износ, ечемик

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the main cereal crops with great economic importance worldwide. It is mainly used for fodder, as food and for beer production. Barley is well adapted to a wider range of environmental conditions (Ryan et al., 2009). It needs less water to produce one unit of grain, compared to other cereals, owing to the lower level of transpiration (Poehlman, 1985). Due to its ecological plasticity, barley is preferred in various crop rotations, for example with fodder legumes, particularly vetch (*Vicia sativa*) (Christiansen et al., 2000; Martin-Rueda et al., 2007). In a crop rotation with corn, clover and wheat, barley grown as aftereffect demonstrated dependence of the yield to a great extent on the precipitation during the growing season and on the use of complex fertilizer (D'yanchenko and Shevelev, 2020). Favorable weather conditions are an important factor for receiving good yields from different barley cultivars (Đekić et al., 2019). In the study of Prusinski et al. (2016), barley and leguminous crops were grown as precursors of winter triticale under the conditions of low-intensity farming. The authors concluded that cereal cultivation after leguminous plants guarantees obtaining at least average yields with better protein content in grain. The productivity of barley cultivated after various predecessors (corn for silage, millet, and peas) on two nutritional backgrounds showed a positive reaction to mineral fertilizer in 12 from 18 years of the experiment (Skorokhodov et al., 2021). Corn was not the best predecessor for barley cultivation as an attenuation of microbiological activity was observed after removing the plants from the field. Barley is often used as a test crop in several field experiments related to organic farming (Maneva et al., 2012; Koteva et al., 2013).

In many cases, agricultural systems are based on the use of large amounts of fertilizers, especially of nitrogen, often more than the requirements of the crop, without considering the residual reserves in the soil and their mineralization (Stoicheva et al., 2002; Moreno et al., 2003; Stoicheva et al., 2011). To achieve an ecological balance in agroecosystems, it is essential to study the balance of nutrients in the soil-plant-atmosphere system. An important item in this balance is the export of nutrients with the production and biomass of the crop (Simeonova et al., 2015).

The aim of the present study was to evaluate the productivity, the content, and the export of basic macronutrients with the biomass and the grain of barley, grown as aftereffect (with maize as the previous crop) on alluvial-meadow soil.

MATERIALS AND METHODS

In 2019, a field experiment with spring barley, grown as an aftereffect on alluvial-meadow soil (Dystric Fluvisol according to IUSS Working Group WRB, 2015) was carried out at the experimental station of Tsalapitsa village near Plovdiv. In this type of experiment (aftereffect or leveling crop) fertilization was not applied as it aims to equalize the experimental area in terms of the stocked nutrients in the soil, as well as to destroy the weeding from the previous year. A variety of two-row spring barley "Wilma" was sown, with long ears and high absolute grain mass. This variety is characterized by good tolerance to temperature anomalies and disease resistance. The sowing rate of barley is 200 kg/ha and it was grown under non-irrigated conditions.

Before barley sowing, in the previous year 2018 in the area of long-term balance experiment (more than 40 years) maize was grown. The experimental scheme for growing of maize included four variants of fertilization with NP, as no K fertilizer was applied. The variants of the experiment (with maize) were: control – without fertilization; $N_{100}P_{50}$ – 50% of the optimal rate; $N_{150}P_{100}$ - 75% of the optimal rate; $N_{200}P_{150}$ – optimal rate; and $N_{250}P_{200}$ - 125% of the optimal rate. When determining the optimal fertilization rate, a balanced approach was used, which is based on the quantities of nutrients exported by the biomass. For the experiment a randomized block design was used with three replications. The area of experimental unit was 206 m^2. Nitrogen was applied once, pre-sowing in the form of ammonium nitrate, and phosphorus as triple superphosphate.

Soil samples for agrochemical analysis were taken at two depths, 0 - 30 and 30 - 60 cm, from the variants of the experiment, before barley sowing and after the end of the vegetation period, in three replications. Soil pH (H_2O) was determined potentiometrically (Arinushkina, 1962), mineral N was determined by the method of Bremner and Kiney (Bremner, 1965), mobile forms of P_2O_2 and K_2O by the method of Ivanov (1984), and humus content by the method of Turin (Kononova, 1963).

Plant samples were taken in the phase of full maturity of barley in three replications. The number of plants per m^2, the length of the whole plant and the length of the ears and the absolute dry matter yields of the plant grain, chaff and straw per unit area were determined. The content and the export of N, P, K, Ca and Mg with the biomass and barley grain were calculated. Nitrogen content of plants was determined by wet combustion by the Ginsburg method and subsequent distillation by the Kjeldahl method (Peterburgskii, 1986), phosphorus was determined colorimetrically with molybdenum blue and potassium by a flame photometer (Peterburgskii, 1986), calcium and magnesium were determined by ICP-OES.

Statistical processing of the data was performed by the method of One-way Anova, and Simple regression (for the N uptake with total barley biomass and grain yield), using Statgraphics Centurion 18.

RESULTS AND DISCUSSION

Soil mineral nitrogen and available forms of phosphorus and potassium contents in the arable soil layer are important parameters for the assessment of the nutrient status of the field during the vegetation of the crop. Agrochemical characteristics of the soil before barley sowing in the early spring of 2019 are presented in Table 1.

The mineral fertilization of the predecessor had its influence on all studied characteristics (Table 1). Soi pH values at a depth of 0 – 30 cm in the variant with maximum fertilization of maize - $N_{250}P_{200}$ were more than one unit lower compared to the control. A tendency of decreasing pH values in the arable soil layer, due to the multiannual fertilization applied on the field in variants $N_{200}P_{150}$, $N_{150}P_{100}$, and $N_{100}P_{50}$ was observed as well. The long-term application of chemical fertilizers reduces soil pH values (Li et al., 2018), conversely, enrichment of cations increases the soil pH when organic fertilizers were applied. At a depth of 30 - 60 cm, the decrease of soil pH under fertilized variants was less pronounced. Soil mineral nitrogen stock was relatively poor and varied considerably depending on the variants of fertilization of maize (grown before barley). The highest soil nutrient content was found under variants $N_{250}P_{200}$ and $N_{200}P_{150}$ - maximum and optimal fertilization rate of the precursor, that we attribute to the low maize yields obtained in 2018. The variation of mobile phosphorus and potassium was significantly less pronounced. At a depth of 0 - 30 cm, higher phosphorus contents were observed in the variants $N_{250}P_{200}$ and $N_{200}P_{150}$ (23.2 and 16.5 mg/100 g, respectively) as the content decreased along with the depth of the profile. Similar results were reported by Li et al. (2018), as they established reduction of available potassium after NP-mineral fertilization. Humus content in soil ranged from 1.8 to 2.1% and did not vary significantly between treatments.

Based on the grain yield data for 1 m^2, barley yield in kg/ha was calculated (Figure 1).

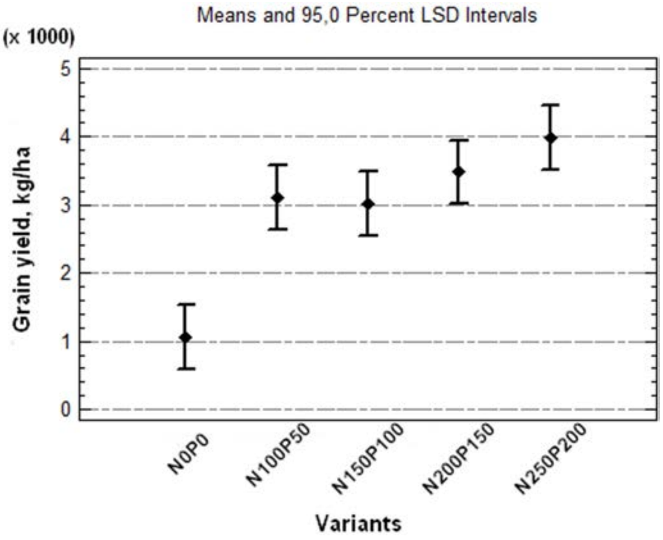

Figure 1. Barley yields (kg/ha) obtained in 2019, influenced by the soil nutrient stock after growing maize in 2018

Table 1. Agrochemical characteristic of the investigated soil before barley sowing

Variants[1]	Soil depth, cm	pH H_2O	StD	Nmin mg/kg	StD	P_2O_2 mg/100 g	StD	K_2O mg/100 g	StD	Humus%	StD
N_0P_0	0-30	6.9	±0.3	17.9	±1.5	8.3	±2.6	23.7	±4.7	1.9	±0.3
$N_{100}P_{50}$		6.5	±0.7	18.8	±6.7	14.1	±6.0	19.9	±7.1	1.9	±0.2
$N_{150}P_{100}$		6.3	±0.3	20.3	±6.4	13.8	±3.6	20.8	±7.2	2.1	±0.1
$N_{200}P_{150}$		6.1	±0.6	23.1	±4.0	16.5	±2.4	17.9	±3.1	2.0	±0.1
$N_{250}P_{200}$		5.8	±1.1	26.5	±10.5	23.2	±7.1	25.2	±9.8	2.0	±0.2
N_0P_0	30-60	6.8	±0.3	20.9	±2.8	6.5	±4.7	20.6	±3.3	1.8	±0.4
$N_{100}P_{50}$		6.6	±0.5	21.1	±6.6	4.9	±2.1	17.8	±4.1	1.8	±0.3
$N_{150}P_{100}$		6.3	±0.2	15.5	±2.1	11.4	±5.2	18.5	±0.5	2.1	±0.4
$N_{200}P_{150}$		6.1	±0.5	26.7	±11.9	9.1	±4.2	16.0	±1.5	1.5	±0.1
$N_{250}P_{200}$		6.2	±0.1	24.8	±4.7	13.0	±1.5	18.8	±6.3	1.8	±0.2

[1] Variants of fertilization of the previous crop – maize in 2018

Significant effect of the fertilization of previous crop (maize) on the yields of barley was observed (Fig. 1). As noted, when discussing agrochemical characteristics of the soil, different contents of available nutrients were reported, as they were higher in the variants with optimal and maximum fertilization rates of maize - $N_{200}P_{150}$ and $N_{250}P_{200}$. In these two variants, barley yields were 3479.2 kg/ha and 3978.8 kg/ha, respectively, and they were close to the average yields obtained in the last year for the country, i.e. 4220 kg/ha (according to the Agrostatistics Agency of the Ministry of Agriculture, Food and Forestry in Bulgaria). Increased barley yields after mineral or organic fertilization were reported by D'yanchenko and Shevelev (2020), Kühling et al. (2021) and Skorokhodov et al. (2021). Weather conditions, soil type and different cultivars are also key parameters controlling the productivity of the crop (Đekić et al., 2019; D'yanchenko and Shevelev, 2020). In our study, significant differences between the yields obtained from the control variant (N_0P_0) and all other variants in the experiment were observed (LSD = 938.2, $P≤0.001$).

Structural characteristics of a sample of 5 plants were made for the characterization of some biometrical parameters of plants as the length of stems and ears, a number of barley plants per 1 m^2, and others (Table 2). Statistical processing of the data showed that fertilization of the preceding crop affected not only barley productivity parameters but also biometric traits. Statistical differences in all of the parameters compared to the control were observed at high levels of significance ($P≤0.05$; $P≤0.01$). The height of plants increased on average by 40%, compared to the control, the length of the barley ears was almost double in the variants with fertilization (aftereffect) compared to control. The weight of five barley plants and their different organs increased between 4 and 5 times in the fertilized variants compared to the N_0P_0 variant.

Content of macroelements N, P, K, Ca and Mg in % in the biomass of barley is presented in Table 3.

The content of nitrogen (N%) in barley grain varied from 1.25% in the control to 2.13% in the $N_{250}P_{200}$ variant (Table 3). Significant differences between the control and the variants $N_{250}P_{200}$ and $N_{200}P_{150}$ ($P≤0.01$), LSD = 0.50 were observed. Similar results were presented for barley grain by Hejcman et al. (2013), N% varying from 1.53% to 2.16%. In the study of Nikolova et al. (2014) higher N% concentrations in barley organs were reported but for earlier growth stages.

Table 2. Structural and biometrical characteristics of barley plants (N=5)

Variants	Number of plants, m^2	Weight, g	Length, cm	Length of the ear, cm	Weight of the ears, g	Weight of stem, g	Weight of grain, g
		Of 5 plants					
N_0P_0	52.0	22.3	39.3	4.6	9.4	12.9	8.6
StD	6.9	11.2	3.1	1.2	3.1	8.1	2.6
$N_{100}P_{50}$	77.3	55.1**	50.2**	8.1**	25.0**	30.1*	23.4*
StD	22.0	6.4	0.9	0.5	5.8	1.4	5.2
$N_{150}P_{100}$	97.3**	54.0**	54.1**	8.2**	28.2**	25.8	24.3*
StD	14.0	18.7	3.0	1.0	9.9	9.2	9.6
$N_{200}P_{150}$	126.7**	41.1	52.5**	8.2**	19.6	21.8	17.3
StD	18.9	2.3	2.5	0.6	4.3	3.8	2.7
$N_{250}P_{200}$	94.7**	74.4**	53.9**	9.1**	37.7**	40.0**	30.4**
StD	15.4	12.1	5.1	0.4	4.4	11.8	10.7
LSD 95%	29.5	21.0	5.8	1.5	10.9	14.2	12.8
LSD 99%	42.0	29.9	8.3	2.1	15.1	20.2	18.3

* Significance at 95%; ** Significance at 99%

Table 3. Content of N, P, K, Ca and Mg in % in the biomass of barley

Variants[1]	Plant organs	Content of macroelements in the biomass of barley%									
		N	StD	P	StD	K	StD	Ca	StD	Mg	StD
N_0P_0	Grain	1.25	±0.09	0.54	±0.13	0.49	±0.03	0.15	±0.00	0.07	±0.01
	Chaff	1.05	±0.21	0.34	±0.06	0.48	±0.06	0.20	±0.03	0.19	±0.04
	Straw	0.38	±0.04	0.15	±0.02	1.08	±0.20	0.09	±0.00	0.28	±0.03
$N_{100}P_{50}$	Grain	1.23	±0.30	0.37	±0.03	0.47	±0.01	0.15	±0.00	0.05	±0.00
	Chaff	1.06	±0.11	0.27	±0.05	0.64	±0.06	0.18	±0.02	0.19	±0.01
	Straw	0.31	±0.11	0.12	±0.02	1.17	±0.12	0.09	±0.01	0.26	±0.02
$N_{150}P_{100}$	Grain	1.73	±0.35	0.40	±0.02	0.46	±0.01	0.14	±0.00	0.06	±0.00
	Chaff	0.99	±0.01	0.33	±0.11	0.59	±0.05	0.16	±0.00	0.19	±0.02
	Straw	0.52	±0.35	0.16	±0.01	1.15	±0.35	0.10	±0.01	0.35	±0.04
$N_{200}P_{150}$	Grain	2.06	±0.39	0.51	±0.22	0.49	±0.02	0.16	±0.01	0.07	±0.00
	Chaff	1.01	±0.29	0.40	±0.15	0.64	±0.11	0.15	±0.02	0.23	±0.02
	Straw	0.46	±0.30	0.15	±0.03	1.13	±0.12	0.10	±0.02	0.35	±0.02
$N_{250}P_{200}$	Grain	2.13	±0.07	0.48	±0.06	0.46	±0.02	0.15	±0.00	0.07	±0.02
	Chaff	1.05	±0.13	0.40	±0.09	0.53	±0.02	0.15	±0.01	0.25	±0.05
	Straw	0.41	±0.17	0.14	±0.01	1.28	±0.51	0.11	±0.01	0.35	±0.05

[1] Variants of fertilization of the previous crop – maize in 2018

In straw and chaff, the nitrogen content varied in a narrow range, and it was not significantly affected by the fertilization applied. The phosphorus content in barley biomass and grain varied from 0.54% in the grain of the control to 0.12% in the straw of variant $N_{100}P_{50}$. As with nitrogen, the highest was the content of phosphorus in the grain, followed by the chaff, and the lowest was in the straw of the plant. Unlike nitrogen and phosphorus, potassium accumulates in higher amounts in barley straw, than in grain and chaff. Its values ranged from 0.46% to 1.28%, with no significant differences depending on the fertilization of the previous crop. Calcium content was the highest in the chaff of barley (0.20 – 0.15%). Although all the values were low, there were significant differences between variants, and the highest contents were found in the control and $N_{100}P_{50}$ variant. Magnesium content was the lowest in barley grain - on average about 0.05%, increased in chaff and it was the highest in the straw - on average of 0.35% for $N_{200}P_{150}$ and $N_{250}P_{200}$ variants. Its regular increase with the increase of the fertilization rate was established. As already noted by Hejcman et al. (2013), we also observed a positive effect of fertilizer application (aftereffect) on the concentrations of nitrogen, phosphorus, and potassium, but no such differences in the concentrations of calcium and magnesium.

Based on the absolute dry weight (ADW) of plant organs and the content of macronutrients in them, the uptake of (N, P, K, Ca and Mg) was determined (Table 4).

In 2019, the total biomass (ADW, kg/ha) of barley varied from 3227.0 kg/ha in the control variant (N_0P_0) to 14407.8 kg/ha in variant $N_{250}P_{200}$ (maximum rate of fertilization of the previous crop). With that biomass, between 23.2 kg - 132.7 kg N per hectare; 26.6 - 146.3 kg K per hectare and between 9.3 - 36.5 kg P per hectare were exported from the field. Exports of Ca and Mg were lower, with magnesium levels close to that of phosphorus. The influence of the fertilization of maize, grown in the previous vegetation period was significant for the uptake of all studied elements. Good regression relationship was established between nitrogen uptake with total barley biomass and barley grain yield (R^2 = 0.859; $P \leq 0.001$), Figure 2. This relationship allows us to predict nitrogen exports with total barley biomass by determining grain yield, taking into account the specific soil and climatic conditions of the field. Such a dependence was observed by Soper et al. (1971), where the relationship between the content of nitrate nitrogen in the soil at different depths and its export with the biomass of barley was studied.

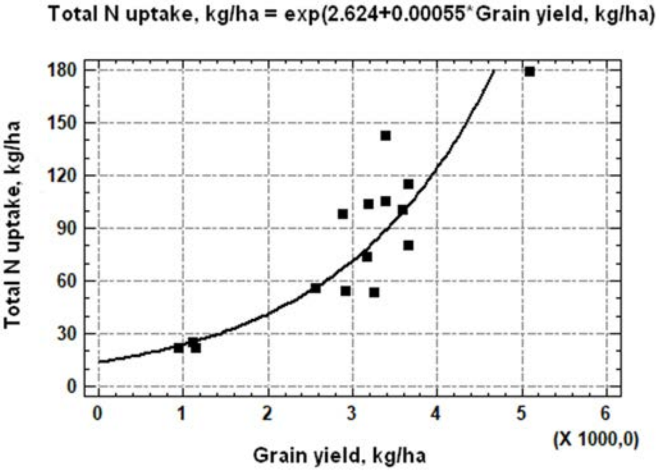

Figure 2. Simple regression between N uptake with total barley biomass and grain yield (kg/ha)

Some acidifications of the alluvial-meadow soil were observed after barley cultivation (Table 5). It was more pronounced in the variant with maximum fertilization rate of the previous crop ($N_{250}P_{200}$) at the two studied depths. This acidification could be due to the long-term fertilizer application on the experimental area (Meng et al., 2013; Simeonova et al., 2017). Another reason could be the seasonal variation of soil pH (Stattery and Ronnfeldt, 1992). The content of soil mineral nitrogen after the end of the experiment showed a general tendency to decrease, with the exception of variant $N_{150}P_{100}$ (Table 5). In the arable soil layer (0 - 30 cm) the decrease of Nmin in variant $N_{250}P_{200}$ was most significant - on average 6 mg/kg (Tables 1 and 5). At a depth of 30 - 60 cm, Nmin decreased on average by 5 mg/kg in most variants, including the control. The decrease of Nmin was probably due to the relatively good yields of barley obtained and to its export with the plant production. The values of mobile phosphorus and potassium also decreased in all variants in the experiment at both studied depths, but to a lower extent.

Table 4. Endophytic isolates obtained from two soybean cultivars

Variants[1]	Plant organs	ADW kg/ha	Uptake of macro elements, kg/ha				
				P	K	Ca	Mg
N_0P_0	Grain	979.4	12.3	5.2	4.8	1.5	0.7
	Chaff	373.7	3.9	1.3	1.8	0.7	0.7
	Straw	1873.9	7.0	2.8	19.9	1.7	5.2
	Total	**3227.0**	**23.2**	**9.3**	**26.6**	**3.9**	**6.6**
$N_{100}P_{50}$	Grain	2860.8	35.1	10.2	13.5	4.2	1.6
	Chaff	960.2	10.2	2.7	6.2	1.7	1.8
	Straw	4909.8	15.2	6.0	57.0	4.3	12.9
	Total	**8730.8**	**60.5**	**18.8**	**76.6**	**10.3**	**16.3**
$N_{150}P_{100}$	Grain	2775.6	47.9	11.2	12.7	4.0	1.6
	Chaff	1004.5	9.9	3.4	6.0	1.6	1.9
	Straw	4982.9	27.0	7.9	54.7	5.1	17.9
	Total	**8763.0**	**84.8**	**22.5**	**73.3**	**10.8**	**21.4**
$N_{200}P_{150}$	Grain	3191.6	65.3	16.0	15.7	5.0	2.1
	Chaff	1100.2	10.9	4.5	6.9	1.6	2.5
	Straw	7039.1	33.3	10.3	79.7	7.4	24.7
	Total	**11330.9**	**109.5**	**30.8**	**102.4**	**14.0**	**29.3**
$N_{250}P_{200}$	Grain	3659.6	78.4	17.3	16.8	5.6	2.7
	Chaff	1414.4	14.9	5.7	7.5	2.1	3.6
	Straw	9333.8	39.4	13.4	122.0	10.6	36.1
	Total	**14407.8**	**132.7**	**36.5**	**146.3**	**18.3**	**42.5**

[1] Variants of fertilization of the previous crop – maize in 2018

Table 5. Agrochemical characteristic of the investigated soil after barley growing

Variants[1]	Soil depth, cm	pH H_2O	StD	Nmin mg/kg	StD	P_2O_2 mg/100 g	StD	K_2O mg/100 g	StD	Humus%	StD
N_0P_0	0-30	6.7	±0.1	16.9	±4.6	7.8	±3.8	21.2	±5.3	2.1	±0.8
$N_{100}P_{50}$		6.2	±0.1	12.1	±3.3	6.5	±2.6	18.5	±9.2	2.0	±0.2
$N_{150}P_{100}$		5.9	±0.3	21.3	±3.6	9.8	±1.8	20.6	±9.2	1.9	±0.4
$N_{200}P_{150}$		5.7	±0.2	20.1	±6.2	13.5	±2.2	17.8	±7.9	2.6	±0.8
$N_{250}P_{200}$		5.0	±0.0	20.5	±6.9	12.5	±5.9	19.8	±5.7	2.2	±0.7
N_0P_0	30-60	6.4	±0.2	15.4	±1.2	3.6	±3.8	16.2	±0.3	1.5	±0.2
$N_{100}P_{50}$		6.2	±0.1	17.1	±3.4	2.8	±1.8	17.9	±3.8	1.4	±0.2
$N_{150}P_{100}$		6.1	±0.1	17.9	±0.6	6.8	±5.3	22.6	±7.0	1.5	±0.4
$N_{200}P_{150}$		5.9	±0.3	17.7	±2.6	7.3	±3.2	14.5	±2.4	1.7	±0.1
$N_{250}P_{200}$		5.6	±0.2	19.8	±9.5	7.5	±3.7	18.4	±5.0	1.6	±0.1

[1] Variants of fertilization of the previous crop – maize in 2018

The humus content in the soil samples after the cultivation of barley was slightly higher than before the vegetation of the crop. The tendency of lower humus content at a depth of 30 - 60 cm compared to the arable soil layer remained.

CONCLUSIONS

The present research was conducted to study whether soil nutrient stock after cultivation of maize with increasing levels of mineral fertilization (NP) is affecting the productivity and some quality parameters of spring barley grown as aftereffect.

The results obtained clearly showed the influence of the fertilization of the previous crop (maize) on the yield, content and export of basic macronutrients with the biomass and the grain of barley. Statistically significant differences between the yield of fertilized variants and the non-fertilized control were established. The highest yield was reported in variant $N_{250}P_{200}$ - 3978.8 kg/ha with the maximum fertilization rate of the previous crop.

The strongest positive effect of fertilization (aftereffect) was observed on the nitrogen content in the organs of barley, the concentrations of phosphorus, potassium, calcium and magnesium were less affected.

Nitrogen uptake with barley biomass ranged between 23.2 kg and 132.7 kg per hectare, potassium was between 26.6 and 146.3 kg per hectare, and phosphorus between 9.3 and 36.5 kg per hectare. Exports of magnesium vary between 6.6 and 42.5 kg/ha, but were insignificant for calcium. A good regression relationship between nitrogen uptake with total barley biomass and grain yield (R^2 = 0.859; $P \leq 0.001$) was found, which could be useful in the practice.

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