THE EFFECT OF THE CONTENT OF HUMUS AND SOME NITROGEN FRACTIONS IN SOILS ON THE YIELD OF SPRING BARLEY*

V. Hejnák[1], V. N. Jefimov[2], F. Hnilička[1]

[1]*Czech University of Agriculture, Department of Botany and Plant Physiology, Prague, Czech Republic*
[2]*Sankt-Peterburg State University of Agriculture, Department of Agrochemistry, Sankt-Peterburg, Russia*

Productivity of spring barley was increasing under the given conditions of cultivation (humus content 0.8–4.9%, neutral reaction, micro-plot experiments) with increase of the humus content in soil. A close correlation dependence between the humus content and barley yield (r = 0.98) was found for soils with humus content ranging from 0.8 to 4.9% as well as between humus content, rate of nitrogen fertilizer and barley productivity (r = 0.91 at the rate 60 kg $N.ha^{-1}$ and r = 0.86 at the rate 120 kg $N.ha^{-1}$). Close correlations were found also between productivity of spring barley and selected fractions of soil nitrogen (N_{tot}, $N_{mineralizable}$, N_{min}). Gradated nitrogen fertilization did not increase nitrogen content in grain and straw dry matter on any soil.

spring barley; micro-plot experiments; humus content in soil; soil nitrogen; nitrogen fertilization

INTRODUCTION

Humus has favourable effects on numerous chemical, physical and biological processes in soil and therefore it has a direct relationship to potential soil fertility, to more perfect use of applied fertilizers etc. (Kolář, Pezlarová, 1990). Particularly soil physical properties, nitrogen content and capacity of soil to supply plants with this nutrient are in close correlation with humus content. High humus content is therefore a decisive prerequisite for high soil fertility, though not its guarantee. Optimal soil supply with organic substances is fully effective in terms of the utilisation of yield potential of

* The study has been financed by the research project MSM 412100002.

plants solely in the complex with all others measurements and factors (K ö r s c h e n s, 1990).

To assess production capacities of soils, it is very important to know the limit of minimum humus content whose exceeding worsens physical and chemical as well as biological qualities of soil to such a degree that irreversible processes of its degradation occur. Minimum humus in soil is preserved under natural conditions and at omission of any fertilization and under black fallow. It is practically unimpressionable and depends on soil texture. For example, K ö r s c h e n s (1990) reports that on chernozem on loess of Bad Lauchstadt 2.5% of humus is a limit value that represents fully depleted soil. On sandy soils of the north of Germany under the same conditions the value 0.5% of humus was attained. It means that without knowing a soil texture it is not possible to make a picture of the degree of soil reserve with humus or of the amount of humus, that should stay in soil for securing of optimum yield level of field crops within the whole crop rotation. For example, under the conditions of Belorussia K u l a k o v s k a j a (1982) considers optimum humus content in loam sandy soils 1.6 to 2.0%, in sandy loam soils 1.8 to 2.2% and in loam soils 2.0 to 2.5%. J e f i m o v and O s i p o v (1991) report for non-chernozem region of the European part of Russia as an optimum humus content from 2 to 3% for wheat cultivation, for potatoes over then 3%. M i n e j e v (1990) classified the soils in Russia according to humus content and pH into soils with weak (humus < 2%, pH_{KCl} < 4.5), medium (humus = 2–3%, pH_{KCl} = 4.5–5.5) and good (humus > 3%, pH_{KCl} > 5.5) production capacity.

As reported Š k a r d a (1980) most of arable land of the Czech Republic contains in topsoil layer 2–3% of humus, whilst long-term observations did not show any more significant changes. The lowest humus content (about 1%) have light luvisols on sands, cambisol have approximately 1.5–2.0%, medium heavy fluvisols and chernitsa on fluvial deposits contain 3–4% and also in chernozems there is a percentage humus content similar or even higher. It is considerable that ratio of humic acids to fulvic acids worsened significantly, what reduced humus quality, above all due to acidification of soils, bad quality of used organic fertilizers and worsening physical properties.

The content and fractionation of nitrogen in soil is in close correlation with the humus content. Conditions, when mainly mineralization or on the contrary immobilization processes take place, are affected by carbon content and its form in soil, by the ration C : N, moisture and temperature conditions and many other factors (V a n ě k et al., 1989, 1997). It means that the content of mineral for the plants available nitrogen in soil is much varying quantity and utilization of the results of soil analyses on the content of mineral nitrogen is very needed, but excessively complicated, for practical nutrition of plants

in variable hydrothermal conditions of the Czech Republic. Despite it, its content is considered one of the basic information for optimisation of nitrogen rates before sowing and during the growing season of different agricultural crops. The capacity of soils to supply the plants with available nitrogen forms can be judged by the content of N_{inorg}.

Easy-hydrolyzable forms of soil organic nitrogen from which nitrogen is released and made available to plants through mineralization during the growing season substances participate significantly in the nutrition of plants. This is the so-called releasable or mineralizable nitrogen. If we find the content of mineral nitrogen and amount of mineralizable nitrogen, released during the growing season, we obtain the basic data for making dosage of nitrogen fertilizers more accurate. An aerobic incubation of soils with sand seems to be the most suitable method of all the tested ones to determine mineralizable nitrogen. Weekly or fortnight incubations at 30 °C are used most frequently, as they correlate very well with intake of nitrogen by plants (P a v l í k o v á et al., 1992).

The aim of this contribution has been to obtain new knowledge on the relationship of humus in soil, on some fractions of soil nitrogen and nitrogen fertilization for yield formation of spring barley.

MATERIAL AND METHOD

Micro-plot trial with spring barley has been established each year at the experimental site at Sojovice near Lysá nad Labem in the years 1990–1992. Micro-plots were of an area 0.029 m^2 and were formed by cylindrical pots without bottom of 19 cm in diameter and embedded 30 cm into soil profile. Spring barley of the cultivar Jaspis, 15 plants cultivated per pot, was an experimental crop.

Soils used in the experiments were sampled in 1990 before the spring from two sites from the region of regosols (soils 1, 2) and four sites from the region of chernitsa (soils 3–6) and were stored at the experimental site.

Samples from stored soil were taken before establishment of the experiments to set the basic agrochemical characteristics. The humus content after Tjurin, pH/KCl and the content of available nutrients (phosphorus after Egner, potassium and magnesium after Schachtschabel) were determined in soil samples dried at 40 °C and homogenised. In addition, soil samples were taken to set the content of nitrogen. Mineral nitrogen (N_{min}) in 1% K_2SO_4 extraction was determined by ion-selective electrodes from freshly taken samples after their homogenisation. Moreover, samples were dried at 40 °C and further analyses were carried out from fine earth. The total nitrogen (organic + $N - NH_4^+$) was determined by mineralization by concentrated sulphuric acid by the methods after Kjeldahl, subsequent distillation and titration. Aerobic incubation method was used to set mineralizable nitrogen. Soils diluted with sand in ration 1 : 1 were incubated for seven days at 60% moisture of maximum water capacity and temperature of 30 °C. Determination of mineral nitrogen in 1% K_2SO_4 extraction by ion selective electrodes followed then. Mineral N is the content of mineral nitrogen before incubation and mineralizable nitrogen represents a gain of mineral N during incubation. Agrochemical characteristics and grain-size composition of soils are presented in Tables I and II.

I. Agrochemical characteristics and grain size composition of soil

Soil	humus – Tjurin (%)	pH/KCl	Content of available nutrients (mg.kg^{-1})			Grain-size category (% in dry soil)				Grain-size classification after Novák
			P – Egner	K – Schacht-schabel	Mg – Schacht-schabel	2.0–0.1 mm	0.1–0.05 mm	0.05–0.01 mm	0.01–0.001 mm	
1	0.80	7.07	72	93	40	79.10	6.40	3.00	11.50	loam sandy
2	0.92	6.99	58	103	49	71.00	12.80	6.50	9.70	sandy
3	1.83	7.44	99	158	61	65.60	12.00	7.60	14.80	loam sandy
4	2.10	7.48	46	310	72	41.30	19.80	13.10	25.80	sand loamy
5	3.71	7.60	20	93	64	14.40	12.10	32.80	40.70	loamy
6	4.93	7.50	31	193	83	23.00	31.70	21.60	17.70	loam sandy

II. Agrochemical characteristics of soils – nitrogen content

Soil	Humus – Tjurin (%)	N_{tot}	N_{min} (mg.kg^{-1})			N_{min} after incubation (mg.kg^{-1})	$N_{mineralizable}$ (mg.kg^{-1})
			NH_4^+	NO_3^-	Σ		
1	0.80	0.10	17	7	24	26	2
2	0.92	0.11	2	4	6	8	2
3	1.83	0.19	24	34	58	71	13
4	2.10	0.22	3	13	16	29	13
5	3.71	0.36	41	41	82	150	68
6	4.93	0.39	54	52	106	174	68

Slightly arid climate with average annual temperature 8.6 °C, 14.8 °C during the growing season (April–September) and average annual sum of precipitation 542 mm, 353 mm of it during the growing season, are typical for the region of the experimental site. The growing season of the years 1990–1992 can be characterised as warm and very dry.

The scheme of the trial included four variants with six replicates. Only potassium and phosphorus were used as the fertilizers on the control variant, gradated nitrogen rates (170, 255 and 340 mg per pot or 60, 90 and 120 kg.ha^{-1}, respectively) were used in further three variants. Ammonium sulphate was used as nitrogen fertilizer. Phosphorus and potassium were supplied at a rate 255 mg per pot in the form potassium mono- and dihydrogen phosphate in ration 1 : 1.4. All fertilizers were applied in the form of solution dispersed with the whole volume of soil before filling of the pot. After emergence of plants the moisture of soils was adjusted by distilled water watering to 60% of maximum water capacity. In further course of the vegetation barley plants were neither watered nor treated chemically.

After harvest we found the content of total nitrogen in grain and straw by the method after Kudejarov and the trial was evaluated statistically by computer program Statgraphics by regression analysis.

RESULTS AND DISCUSSION

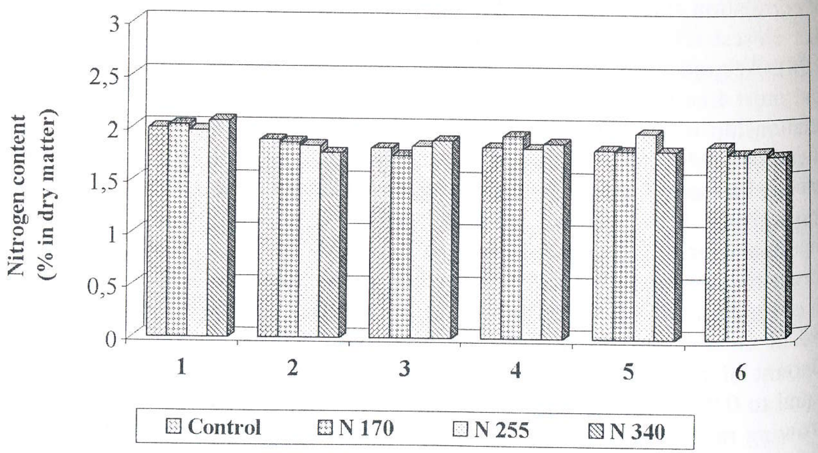
The dependence of the grain and straw yields of spring barley on the humus content and rate of nitrogen fertilization is confirmed by the results of correlation analysis from Table III. It follows from correlation coefficients that closest relationship between these indicators is in the variant PK (r = 0.98). At gradated nitrogen rates the closeness of the relationship is falling and most free relatively, though statistically significantly very close is this relationship in the variant N 340 at the rate 120 kg N.ha^{-1} (r = 0.86–0. 88). It can be read from the values of correlation analysis that very close dependence is between soil fertility and nitrogen content or some its fraction in soil, respectively. It can be deduced also from the fact that indices of correlation that characterise connections between the yields of grain and straw and different fractions of soil nitrogen attain the values identical with those reached in evaluation of the relationship of yields to humus content in soil. The yields are in closest correlation with the content of total N in soil and with an amount of mineralizable nitrogen. In both the cases index correlation r is equal to 0.99 in the variant PK and determination index R^2 is 98–99%. With growing rates of nitrogen fertilization the values are falling, but still remain on a high level. In the variant N 340 r = 0.87 to 0.89 and R^2 = 75–80%. Significant and particularly in the variant PK as well as at lower rates of nitrogen fertilization statistically highly significant relationships were also found between the yields and the content of mineral nitrogen (N_{min}). Correlation index r = 0.82 in the control variant, in the variant N 170 it is ranging between 0.77 and 0.79 and is falling continuously through 0.74 to 0.75 in the variant N 255 to 0.66–0.67 in the variant N 340. Similarly, the values of determination index have a falling trend at gradated nitrogen rates from 68% in the control to 44–45% in the variant N 340.

Ložek et al. (1991) found a close dependence between N_{inorg} in soil and the yield and quality of grain of spring barley. The content of N_{inorg} in soil was influenced highly significantly by the factors, such as a year (53.4%), nutrition (23.8%) and time of sampling (22.8%).

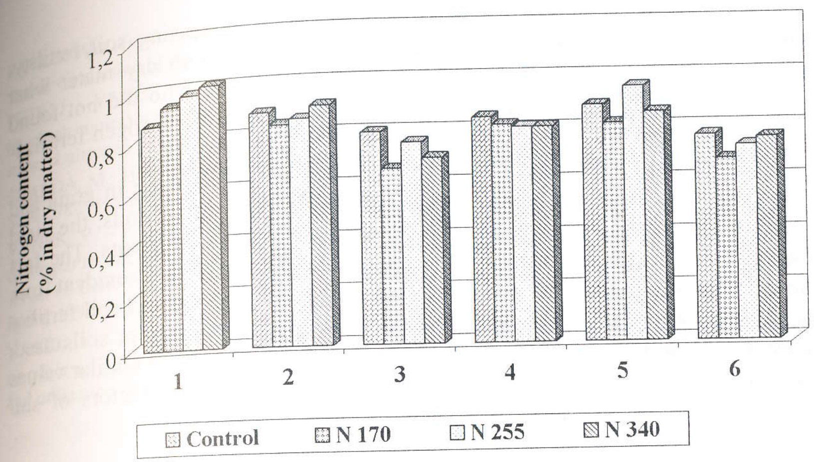
Petr et al. (1995) found a positive influence of the clover stand on the content of N_{min} in soil. A positive correlation was also found between N_{min} content and wheat yield. These relationships were not confirmed with potatoes. In addition, a positive correlation has been found between the content of N_{min} in spring period and uptake of N by wheat and between N_{min} content in autumn and intake of N by potato harvest.

Bízik (1997) found a very close correlation between soil N_{min} and maize yield.

As can be seen from Figs. 1 and 2, percentage content of nitrogen in dry matter of grain and straw was not affected significantly by soil. Nitrogen content in grain attained the values from 1.73% to 2.06% and in straw it ranged between 0.73 and 1.01%. Certain trend to decrease of nitrogen content



1. Nitrogen content (% in dry matter) in spring barley grain (average over the years 1990–1992)



2. Nitrogen content (% in dry matter) in spring barley straw (average over the years 1990–1992)

III. Dependence between yield characteristics and selected factors of soil fertility – correlation (r) and determination index (R^2)

Studied parameter	Variant	Humus		Total N		N_{min}		N_{min} after incubation		$N_{mineralizable}$	
		r	R^2	r	R^2	r	R^2	r	R^2	r	R^2
Grain yield	PK	0.98	97.1	0.99	98.3	0.82	68.2	0.91	83.9	0.99	98.9
	N 170	0.91	83.7	0.91	84.1	0.79	62.4	0.83	69.5	0.93	87.5
	N 255	0.91	84.5	0.92	85.0	0.75	57.1	0.80	64.2	0.92	84.7
	N 340	0.86	74.7	0.87	75.8	0.67	45.9	0.72	52.6	0.87	77.0
Straw yield	PK	0.98	97.5	0.99	99.4	0.82	68.8	0.90	81.9	0.99	98.6
	N 170	0.92	85.9	0.93	87.1	0.77	59.7	0.82	68.2	0.93	87.7
	N 255	0.93	86.7	0.93	87.8	0.74	55.6	.079	63.7	0.93	87.6
	N 340	0.88	78.5	0.89	80.2	0.66	44.4	0.74	55.2	0.89	80.9
Uptake of N by plants	PK	0.95	88.2	0.98	96.3	0.77	59.9	0.85	72.9	0.97	94.1
	N 170	0.89	80.9	0.91	84.3	0.65	42.4	0.73	53.9	0.91	83.9
	N 255	0.92	85.7	0.94	88.4	0.74	55.2	0.83	68.9	0.93	88.0
	N 340	0.91	84.4	0.93	87.1	0.69	49.2	0.77	60.2	0.93	87.8

in grain and straw can be seen from figures with increasing soil fertility. Nitrogen fertilization did not increase nitrogen content in dry mater what corresponds with the knowledge of Kandera (1995) who did not found the growth of nitrogen substances in grain at high rates of nitrogen fertilization.

With respect to the above facts that the content of nitrogen in grain and straw was almost on the same level in most variants in most soils, the yield of grain and straw was decisive for uptake of nitrogen by plants. The fact that uptake of nitrogen corresponds with grain and straw yield is evident from the correlations found between uptake of nitrogen by plants and soil fertility or between humus content and selected fractions of nitrogen at soils used, respectively. Indices of correlation and determination reach the similar values like in the evaluation of the relationship of these selected factors of soil fertility to the yield of grain and straw (Table III).

References

BÍZIK, J.: Distribution and movement of plant available forms of nitrogen in soil for maize during spring time. Rostl. Výr., *43*, 1997: 19–24.

JEFIMOV, V. N. – OSIPOV, A. I.: Gumus i azot v zemleděliji nečernozemnoj zony. Počvoveděnije, 1991 (1): 67–77.

KANDERA, M.: Účinok hnojenia dusíkom a výsevku na kvalitatívne vlastnosti zrna jarného jačmeňa (The effect of nitrogen fertilization and sowing rate on qualitative properties of spring barley grain). In: Zbor. Abstr. VII. Dni fyziológie rastlín (Proc. of VIIth Days of Plant Physiology), VŠP, Nitra, 1995: 146.

KOLÁŘ, L. – PEZLAROVÁ, J.: Vliv chemismu půdy na změnu stupně humifikace půdní organické hmoty a její vztah k frakcím organického a minerálního fosforu (The effect of soil chemism on the change of the degree of humification of soil organic matter and its relationship to fractions of organic and mineral phosphorus). In: Humusové látky – aktivní složka systému půda – rostlina (Humus substances – active component of the system soil – plant). VÚRV, Česká zemědělská společnost, Praha, 1990: 4–8.

KÖRSCHENS, M.: Humus – půdní úrodnost – využití dusíku (Humus – soil fertility – utilization of nitrogen). In: Humusové látky – aktivní složka systému půda – rostlina (Humus substances – active component of the system soil – plant). VÚRV, Česká zemědělská společnost, Praha, 1990: 42–54.

KULAKOVSKAJA, T. N.: Problemy rasširennogo vosproizvodstva plodorodija děrnogo-podzolistych počv v uslovijach vozrastajuščej chimizaciji selskogo chozjajstva. Vestn. sel.-choz. Nauki, 1982 (9): 33–44.

LOŽEK, O. – BÍZIK, J. – FECENKO, J.: Dynamika anorganického dusíku v pôde a jej vplyv na úrodu a kvalitu jarného jačmeňa (Dynamics of inorganic nitrogen in the soil and its influence on the yield and quality of spring barley). Rostl. Výr., *37*, 1991: 441–451.

MINEJEV, V. G.: Chimizacija zemleďelija i prirodnaja sreda. Moskva, Agropromizdat 1990. 287 pp.

PAVLÍKOVÁ, D. – VANĚK, V. – VLKOVÁ, O.: Hodnocení metod mineralizovatelného dusíku v půdě (Evaluation of the methods of mineralizable nitrogen in soil). Rostl. Výr., *38*, 1992: 983–988.

PETR, J. – VANĚK, V. – PROCHÁZKA, J. – NAJMANOVÁ, J.: Vliv dlouhodobého hnojení na obsah minerálního dusíku v půdě (The effect of long-term fertilization on the content of mineral nitrogen in soil). Rostl. Výr., *41*, 1995: 103–108.

ŠKARDA, M.: Hospodaření s organickými hnojivy (Management with organic fertilizers). Praha, SZN 1982. 328 pp.

VANĚK, V. – PAVLÍKOVÁ, D. – BALÍK, J. – TLUSTOŠ, P.: Dusík v půdě a jeho přeměny (Nitrogen in soil and its conversions). In: Sbor. Konf. Racionální použití průmyslových hnojiv (Proc. of Conf. Rational Utilization of Fertilizers), Katedra agrochemie a výživy rostlin ČZU, Praha, 1997: 8–14.

VANĚK, V. – VOSTAL, J. – PAVLÍKOVÁ, D. – VLKOVÁ, O.: Vliv doby aplikace močoviny na odběr a využití dusíku ozimou pšenicí (The effect of time of application of urea on the uptake and utilization of nitrogen by winter wheat). Rostl. Výr., *35*, 1989: 681–687.

Received for publication on December 8, 2000
Accepted for publication on March 15, 2001

HEJNÁK, V. – JEFIMOV, V. N. – HNILIČKA, F. (Česká zemědělská univerzita, katedra botaniky a fyziologie rostlin, Praha, Česká republika; Sankt-Petěrburgská státní zemědělská univerzita, katedra agrochemie, Sankt-Petěrburg, Rusko):

Vliv obsahu humusu a některých frakcí dusíku v půdě na tvorbu výnosu jarního ječmene.

Scientia Agric. Bohem., *32*, 2001: 161–170.

V letech 1990–1992 byl na pokusném stanovišti v Sojovicích u Lysé nad Labem každoročně zakládán mikroparcelkový pokus s jarním ječmenem. Mikroparcelky měly plochu 0,029 m^2 a byly vytvořeny cylindrickými nádobami bez dna o průměru 19 cm a zapuštěnými 30 cm do půdního profilu. Pokusnou plodinou byl jarní ječmen odrůdy Jaspis, pěstovaný po 15 rostlinách v každé nádobě. Zeminy použité v pokusech byly odebrány v předjaří 1990 ze dvou stanovišť z oblasti regozemí (zemina 1, 2) a čtyř stanovišť z oblasti černic (zeminy 3–6) a byly uskladněny na pokusném stanovišti. Před založením pokusů byly odebrány z uskladněné zeminy vzorky pro stanovení základních agrochemických charakteristik (tab. I a II).

Schéma pokusu zahrnovalo 4 varianty se 6 opakováními. Na kontrolní variantě bylo hnojeno pouze draslíkem a fosforem, u dalších tří bylo použito stupňovaných dávek dusíku (170, 255 a 340 mg na nádobu, resp. 60, 90 a 120 $kg.ha^{-1}$). Jako dusíkaté hnojivo byl použit síran amonný. Fosfor a draslík byly dodány v dávce 255 mg na nádobu ve formě mono- a dihydrogenfosforečnanu draselného v poměru 1 : 1,4. Všechna hnojiva byla aplikována ve formě roztoku promísením s celým objemem zeminy před naplněním nádoby. Po vzejití rostlin byla vlhkost zemin upravena zálivkou destilovanou vodou na 60 % maximální vodní kapacity. V dalším průběhu vegetace nebyl ječmen zaléván ani chemicky ošetřován. Po sklizni jsme

zjistili v zrnu a ve slámě obsah celkového dusíku metodou podle Kudějarova a pokus byl statisticky vyhodnocen počítačovým programem Statgraphics regresní analýzou.

Za daných podmínek pěstování (obsah humusu 0,8–4,9 %, neutrální reakce, mikroparcelkové pokusy) se produktivita jarního ječmene zvyšovala s růstem obsahu humusu v půdě. Jak vyplývá z tab. III, pro půdy s obsahem humusu od 0,8 do 4,9 % byla zjištěna těsná korelační závislost mezi jeho množstvím a výnosem ječmene (r = 0,98) a také mezi množstvím humusu, dávkou dusíkatého hnojiva a produktivitou ječmene (r = 0,91 při dávce 60 kg $N.ha^{-1}$ a r = 0,86 při dávce 120 kg $N.ha^{-1}$). Těsné korelační vztahy byly nalezeny také mezi produktivitou jarního ječmene a vybranými frakcemi půdního dusíku (N_{tot}, $N_{mineralizovatelný}$, N_{min}).

Jak je vidět z obr. 1 a 2, procentuální obsah dusíku v sušině zrna a slámy nebyl zeminou významně ovlivněn. Obsah dusíku dosahoval v zrnu hodnot od 1,73 do 2,06 % a ve slámě se pohyboval od 0,73 do 1,01 %. Stupňované hnojení dusíkem přitom obsah dusíku v sušině nezvyšovalo.

Vzhledem k výše uvedené skutečnosti, že obsah dusíku v zrnu i slámě byl u většiny variant na většině zemin na přibližně stejné úrovni, byl pro odběr dusíku rozhodující výnos zrna a slámy. Že odběr dusíku koresponduje s výnosem zrna a slámy, je zřejmé ze zjištěných korelací mezi odběrem dusíku rostlinami a půdní úrodností, resp. obsahem humusu a vybraných frakcí dusíku v použitých zeminách. Indexy korelace a determinace dosahují podobných hodnot jako při hodnocení vztahu těchto vybraných faktorů půdní úrodnosti k výnosu zrna a slámy (tab. III).

jarní ječmen; mikroparcelkové pokusy; obsah humusu v půdě; půdní dusík; hnojení dusíkem

Contact Address:

Ing. Václav Hejnák, Ph.D., Česká zemědělská univerzita, Agronomická fakulta, katedra botaniky a fyziologie rostlin, Kamýcká 129, 165 21 Praha 6-Suchdol, Česká republika, tel. 02/24 38 25 14, e-mail: hejnak@af.czu.cz