THE EFFECT OF NITROGEN INPUT ON POLARISED SUGAR PRODUCTION AND QUALITATIVE PARAMETERS OF SUGAR BEET

VPLYV VSTUPU DUSÍKA NA PRODUKCIU POLARIZAČNÉHO CUKRU A KVALITATÍVNE PARAMETRE REPY CUKROVEJ

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ABSTRACT

During 1998-2002, the application of different forms and doses of nitrogen on quantitative (polarised sugar production) and qualitative parameters (digestion, molasses forming components - potassium, sodium and α-amino nitrogen content) of sugar beet in vulnerable zones (Nitrate directive) was studied. Calculated input of nitrogen ranged from 12 kg up to 240 kg N.ha^{-1}. By increasing input of N from FYM application into the soil causes an increases of α-amino nitrogen content in root, which in consequence causes a decreases the sugar content (negative correlation r= -0.8659^{+}). The application of straw instead FYM of analogues treatments caused significant decrease (straw versus FYM) and highly significant decrease (straw plus N fertilizers versus FYM plus N fertilizers) of α-amino nitrogen content in sugar beet root living the productive parameters unchanged. The content of α-amino nitrogen in root of sugar beet indicate an environmentally friendly management practices with causal relation to water protection from nitrate.

KEYWORDS: nitrogen fertilization, qualitative parameters, sugar beet, α-amino nitrogen, nitrate directive, vulnerable zones

SÚHRN

V rokoch 1998-2002 bol sledovaný vplyv vstupov dusíka na kvantitatívne (polarizačného cukru) a kvalitatívne parametre (digescia, obsah melasotvorných látok - draslíka, sodíka a α- amino dusíka) repy cukrovej pestovanej v zraniteľnej oblasti vôd. Celkový vstup dusíka bol kalkulovaný v rozsahu 12 až 240 kg.ha^{-1} dusíka. V závislosti od rastu vstupov dusíka formou aplikácie maštaľného hnoja sa zvýšil obsah α-amino dusíka v buľvách, ktorý súčasne znižoval digesciu (negatívna korelácia r=-0,8659). Nahradenie maštaľného hnoja slamou predplodiny znížilo obsah amidického dusíka buliev. Došlo k preukaznému (slama - maštaľný hnoj) až k vysokopreukaznému zníženiu obsahu α-amino dusíka (slama + NPK - maštaľný hnoj + NPK) pri zachovaní produkčných parametrov. Obsah α-amino dusíka v buľvách repy indikoval ekologickú a produkčnú akceptovateľnosť environmentálne vhodných pestovateľských postupov vo vzťahu ochrane vôd v zraniteľných oblastiach.

Kľúčové slová: hnojenie dusíkom, kvalitatívne parametre, repa cukrová, α-amino dusík, dusičnanová smernica, zraniteľné oblasti

DETAILED ABSTRACT

V poľnom pokuse na trnavskej pahorkatine bol rokoch 1998-2002 sledovaný vplyv vstupov dusíka na kvantitatívny parameter (úroda polarizačného cukru) a kvalitatívne parametre (digescia, obsah melasotvorných látok - draslíka, sodíka a α-amino dusíka) cukrovej repy pestovanej v zraniteľnej oblasti vôd (v zmysle Nitrátovej smernice 91/676/EEC). Repa cukrová sa pestovala na černozemi hnedozemnej v konvenčnom osevnom postupe (lucerna - lucerna - pšenica ozimná - repa cukrová). Celkový vstup dusíka bol kalkulovaný v rozsahu 12 až 240 kg.ha^{-1}. Kalkulácia vstupov dusíka na hektár bola nasledovná: depozícia (12 kg), dusík zo slamy ozimnej pšenice (40 kg), dusík zo slamy plus kompenzačná dávka minerálneho dusíka (40+66 kg), dusík z maštaľného hnoja (168 kg) a vstup dusíka s minerálnych hnojív (60 kg).

Priemerná digescia (tabuľka 3) varírovala v intervale od 13,9 °S (1998) do 16,46 °S (2000) s celkovým priemerom 15,45 °S. Hlavným zdrojom variability digescie boli podmienky ročníka a vstup dusíka (tabuľka 5). Priemerná úroda polarizačného cukru bola 10,00 t.ha^{-1}, v intervale od 7,86 t.ha^{-1} (2000) do 12,17 t.ha^{-1} (1999). Štatisticky preukazný rozdiel priemernej úrody polarizačného cukru bol dosiahnutý iba pri variante s aplikáciou maštaľného hnoja (9,34 t.ha^{-1}) v porovnaní s variantom hnojenom iba P, K hnojivami. Dosiahnuté 5 ročné výsledky úrody polarizačného cukru uvedené v tabuľke 3 dokumentujú nepreukazné rozdiely medzi ostatnými sledovanými variantmi.

Obsah α-amino dusíka bol preukazne ovplyvňovaný podmienkami počasia a úrovňou vstupu dusíka (tabuľka 5). Obsah α-amino dusíka varíroval od 4,3% (2001) do 6,67% (1999) s priemernou hodnotou 5,43% (tabuľka 4). Najvyšší obsah α-amino dusíka bol nameraný v buľvách repy pestovanej na variantoch s aplikáciou maštaľného hnoja (5,51 - 6,64%). V závislosti od rastu vstupov dusíka formou aplikácie maštaľného hnoja bol zistený vyšší obsah α-amino dusíka v buľvách, ktorý súčasne znižoval digesciu (negatívna korelácia r=-0,8659). Nahradenie maštaľného hnoja slamou predplodiny znížilo obsah amidického dusíka v koreňoch repy. V závislosti od variantov pokusu došlo k preukaznému (slama - maštaľný hnoj) až k vysokopreukaznému zníženiu obsahu α-amino dusíka (slama + NPK - maštaľný hnoj + NPK) pri zachovaní produkčných parametrov. Obsah α-amino dusíka v buľvách repy indikoval ekologickú a produkčnú akceptovateľnosť environmentálne vhodných pestovateľských postupov vo vzťahu ochrane vôd v zraniteľných oblastiach. Problematika implementácie environmentálne prijateľných poľnohospodárskych postupov a znečisťovania vôd je vážny ekologický a ekonomický problém aktuálny najmä v zraniteľných oblastiach oráčinovej krajiny.

INTRODUCTION

Balance nutrition of field crops, mainly with nitrogen regarding with accumulation of nitrogen in soils, crops uptake and protection of environment is one of the challenges of research in sustainable agricultural production in the 21st century [7, 18].

Farm yard manure is considered as a key element in conventional system of sugar beet nutrition and fertilization. On the soils with high mineralization ability high nitrogen release it is possible to application of cereals straw with compensation dose of nitrogen from mineral fertilizers or dung water or incorporation of straw without compensation dose of nitrogen [16]. FYM applications with mineral fertilization negatively affect refined sugar yielding and losses of sugar in molasses [25] Lower level of mineral nitrogen fertilization combines with leaf liquid fertilizers decrease the content of potassium sodium and α-amino nitrogen [24]. Extensified compared with intensive farms could reduce negative effects on ground water mainly by renouncing mineral nitrogen fertilizer [14]. In the Lower Rhine valley intensive agricultural land use causes high nitrate concentration in groundwater supplies, reduction of nitrogen input by shifting to more suitable farming practices reduced leaching loses of nitrogen by more than 15%-50% [15]. The major source of the nitrate leached from agricultural land is usually mineralization of soil organic matter, crop residues or animal manures. More accessible forms of nitrogen are released from fertile soils with higher content of soil organic matter. The intensive variability of the level of inorganic nitrogen in soils depends on hydro-thermic conditions [26].

Conventional system of sugar beet growing under certain conditions (water protected areas, conventional crop sequence lucerne - lucerne - winter wheat - sugar beet with direct application of farm yard manure with mineral fertilizers NPK) is the potential source of nitrogen pollution of waters [19].

The Council Directive 91/676 [1] concerning the protection of waters against pollution caused by nitrate from agricultural sources was introduced to reduce water pollution by nitrates from agricultural sources and for prevention of further pollution. It was proposed to groups of the agricultural landscape into different categories of polluted water and landscape group “Largely agricultural landscape” is characterised as water strongly polluted [10]. Nitrate vulnerable zones cover about 37% of the EU-15 total area [2]. In Slovakia the 27% of total

Table 1: The nitrogen input (kg.ha^{-1}) in different fertilization in the field experiment on vulnerable zones during 1998-2002.
Tabuľka 1: Vstup dusíka (kg.ha^{-1}) v jednotlivých variatoch poľného pokusu v zraniteľnej oblasti, počas rokov 1998-2002.

Treatments	Deposition	Straw	Compensation dose	FYM	Mineral fertilizers	Total input of nitrogen
PK	12	-	-	-	-	12
PK+straw	12	40	-	-	-	52
NPK	12	-	-	-	60	72
NPK+straw	12	40	66	-	60	178
FYM	12	-	-	168	-	180
FYM+NPK	12	-	-	168	60	240

area has been designed as vulnerable zones which are predominantly concentrated to intensive agriculture land use [7]. Nitrogen pollution in Slovakia demands special attention at the most fertile area with high level of intensity of nitrogen releases with rich resources of groundwater - Danube Lowland which represents the main sugar beet growing region [21].

The main objective of this work was to asses the different forms and doses of nitrogen inputs related to polarised sugar production and quantitative parameters of sugar beet.

MATERIALS AND METHODS

A field stationary experiment was carried out during 1998-2002 at the Research Farm Borovce, RIPP Piešťany, Trnava hilly region, Slovakia. The long-term (1950-1980) average temperature is 9.2 °C with annual rainfall 595 mm. The soil is classified as a medium-heavy haplic Chernozems formed on alluvial deposits.

The applied nitrogen fertilization was as follows: nitrogen from straw (0.58% calculated content) with average amount of 40 kg.ha^{-1} N forecrop straw according Kováčik's method [20], 168 kg N.ha^{-1} from farm yard manure (FYM) according Fecenko and Ložek's method [12] and 10 kg N as compensation dose per 1000 kg of incorporated forecrop winter wheat straw with average amount of 66 kg.ha^{-1} and additional input of 60 kg N.ha^{-1} from mineral fertilizers. The same doses of phosphorus (P) and potassium (K) nutrient were used in all treatments: P-35 kg.ha^{-1}, K-166 kg.ha^{-1} from mineral fertilizers except treatments with FYM application only. The scheme of the experiment is described in Table 1.

Standard chemical weed control has been used in all treatments except treatment with single FYM application were was applied mechanic weed control nly according IFOAM (International Federation of Organic Agriculture Movements).

The sugar beet variety Intera was grown in following crop rotation: lucerne - lucerne - winter wheat - sugar beet. The experiment was carried out by using block method in four replications. The size of trial plot was 6 x 12 metres and harvested area for yield of sugar beet was 10.8m^2 (two rows along the length of plots). The 25 pieces of beet were taken from two replications for the analysis of technological quality. The physical and chemical analyses were made by Venema analyser (Selekt Bučany) - digestion (Dg) in °S, content of potassium (K), sodium (Na) and α-amino nitrogen in mmol.100g^{-1} beet. Polarizing sugar (PS) production was calculated according formula: PS (t.ha^{-1}) = yield of beet (t.ha^{-1}). Dg (%). The data were subjected to analysis of variance ANOVA (software KANRO).

RESULTS AND DISCUSSION

The weather conditions of growing season i.e. spring and summer in the years 1998-2002 are collected in Table 2. The hottest year 2002 was characterised with extraordinary hot May, July and August. The driest year 1998 was characterized with dry July and very dry May and August with extraordinary wet September (see Tab. 2).

The average digestion (Tab. 3) varied from 13.9 °S (1998) to 16.46 °S (2000) with total average 15.45 °S. Digestion was influenced by weather conditions, fertilization and the interaction of year and fertilization (see Tab. 5). The main sources of digestion variability were the meteorological condition in the years under investigation and the applied nitrogen fertilization (see Tab. 2 and 5). The significant effect of weather condition on digestion at eastern part of Trnava plate was also noted [11]. The lowest digestion was reached after application of FYM (15.06°S) and FYM together with mineral nitrogen

Table 2: Weather condition in experimental years 1998-2002 (Borovce near Piešťany)
Tabuľka 2: Podmienky počasia v experimentálnych rokoch 1998-2002 (Borovce pri Piešťanoch)

Month	n 30 (1950-1980)	1998	1999	2000	2001	2002
Temperatures (°C)						
April	9.4	12.0	11.6	12.8	7.7	11.1
May	14.1	15.2	15.8	15.8	15.4	18.7
June	17.7	19.5	18.4	18.2	15.4	19.9
$\bar{x}$ Spring (April-June)	13.7	15.6	15.3	15.6	12.8	16.6
July	18.9	20.7	21.2	16.9	19.2	22.8
August	18.4	20.1	18.9	20.6	20.1	22.4
September	14.5	15.3	18.7	13.6	11.9	15.6
$\bar{x}$ Summer (July-September)	17.3	18.7	19.6	17.0	17.1	20.3
Precipitation (mm)						
April	43	35.0	48.3	9.7	31.8	27.8
May	54	19.1	27.4	35.9	30.1	50.4
June	80	46.1	118.4	39.1	43.0	95.3
∑Spring (April-June)	177	100.2	194.1	84.7	104.9	173.5
July	76	38.5	87.0	69.1	119.0	67.6
August	68	22.1	36.3	20.8	10.0	71.7
September	38	167.0	36.6	42.9	115.0	34.5
∑Summer (July-September)	182	227.6	159.9	132.8	244.0	173.8

n30 - long-term (30-year) average, dlhodobý (30 ročný) priemer

(14.84°S), and the highest digestion was reached after forecrop straw application (16.00°S) as it is see in Table 3. The digestion decreased with increasing of nitrogen fertilization level. Fecenko and Ložek [13] also quoted the significantly higher digestion (16.46°S) on treatment with straw incorporation with comparison to FYM on medium-heavy loam clay soil. Our results are in agreement also with another result [22].

The average production of polarised sugar was 10.00 $t.ha^{-1}$ and was in the range of 7.86 $t.ha^{-1}$ (2000) to 12.17 $t.ha^{-1}$ (1999) (Tab. 3). The average polarised sugar production depends on the applied fertilization and varied in the range 9.34 $t.ha^{-1}$ (FYM treatment) up to 10.50 $t.ha^{-1}$ (PK treatment).

According to our 5 year experiment, the combination of straw incorporation with low or without nitrogen doses gained the special importance for water protected areas-vulnerable zones and has an influence on the nitrogen immobilisation processes. Above mentioned is related to the other results [23], ascertained the higher potential nitrification ability in long-term experiments in treatments fertilized with mineral fertilizers together with FYM. In

Table 3: Digestion (°S) and polarised sugar production ($t.ha^{-1}$) in the years of 1998-2002
Tabuľka 3: Digescia (°S) a produkcia polarizačného cukru ($t.ha^{-1}$) v rokoch 1998-2002

Treatments /Years	1998		1999		2000		2001		2002		1998-2002	
	°S	(t/ha)	°S	(t/ha)	°S	(t/ha)	°S	(t/ha)	°S	(t/ha)	°S	(t/ha)
PK	13.49	8.40	16.79	13.54	16.75	8.35	15.64	10.40	17.03	11.81	15.93	10.50
PK+straw	13.96	7.81	16.72	11.91	17.03	8.16	15.60	10.33	16.72	12.27	16.00	10.09
NPK	13.91	7.98	15.97	13.21	16.14	8.12	15.54	9.61	15.36	10.48	15.38	9.88
NPK+straw	14.34	8.50	15.80	11.52	16.27	8.29	14.77	10.43	16.20	11.62	15.47	10.07
FYM	14.03	8.51	14.48	11.06	16.45	6.99	14.69	9.71	15.65	10.34	15.06	9.34
FYM+NPK	13.68	9.75	14.52	11.81	16.16	7.25	15.65	10.59	15.14	11.46	14.84	10.17
$\bar{x}$	13.90	8.49	15.71	12.17	16.46	7.86	15.31	10.18	16.01	11.33	15.45	10.00
LSD P<0.05	0.84	2.82	0.36	2.63	0.83	2.11	0.88	1.77	0.98	2.08	0.39	0.85
LSD P<0.01	1.06	3.57	0.45	3.32	1.05	2.66	1.11	2.23	1.24	2.62	0.47	1.02

Table 4: The content of α-amino nitrogen, potassium and sodium in sugar beet root ($mmol.100\ g^{-1}$ of beet) in the years 1998-2002
Tabuľka 4: Obsah α-amino dusíka, draslíka a sodíka v buľvách repy cukrovej ($mmol.100\ g^{-1}$ repy) v rokoch 1998-2002.

Parameter	Years	Treatments							LSD	
		PK	PK + straw	NPK	NPK + straw	FYM	FYM+NPK	Average	P<0.05	P<0.01
α - amino nitrogen	1998	6.23	6.18	5.97	5.96	6.25	7.00	6.27	0.64	0.80
	1999	5.86	5.21	6.98	6.64	7.68	7.88	6.67	0.74	0.4
	2000	3.96	3.02	4.30	4.15	4.37	6.24	4.33	1.07	1.35
	2001	4.50	4.38	3.54	4.11	4.26	4.98	4.30	1.05	1.44
	2002	5.17	4.88	5.95	5.32	5.01	7.09	5.57	1.14	1.44
	$\bar{x}$	5.14	4.73	5.34	5.23	5.51	6.64	5.43	0.74	0.89
K	1998	5.40	5.58	5.74	5.42	5.20	6.01	5.56	0.68	0.86
	1999	5.43	5.88	5.25	5.06	6.44	5.49	5.59	0.25	0.32
	2000	6.97	6.85	6.64	7.18	5.43	6.79	6.64	1.11	1.14
	2001	5.19	4.90	4.91	5.07	4.49	4.64	4.86	0.53	0.67
	2002	4.60	4.79	4.54	4.49	4.24	5.82	4.75	1.25	1.58
	$\bar{x}$	5.51	5.59	5.41	5.44	5.16	5.75	5.48	0.40	0.48
Na	1998	1.25	1.48	1.29	1.36	1.36	1.01	1.29	0.71	0.90
	1999	0.87	0.90	0.77	0.70	1.31	1.32	0.98	0.65	0.82
	2000	0.68	0.47	0.53	0.62	0.64	0.76	0.62	0.21	0.26
	2001	0.62	0.68	0.65	0.73	0.94	0.82	0.90	0.22	0.28
	2002	1.12	1.41	1.80	1.39	1.78	1.74	1.54	0.47	0.60
	$\bar{x}$	0.91	0.98	1.00	0.95	1.20	1.13	1.03	0.19	0.22

Table 5: Variance analysis of the production and quality parameters
Tabuľka 5: Analýza variancie produkčného parametra a kvalitatívnych parametrov

Source of variability	Degree of freedom	Mean square				
		Digestion	Production of polarised sugar	α-amino nitrogen	Na	K
Years (Y)	4	23.38 ++	80.33 ++	34.76 ++	3.51 ++	11.18 ++
Fertilization (F)	5	4.25 ++	3.08 +	4.50 ++	0.25 ++	0.88 +
Interaction Y x F	20	0.98 ++	1.75	2.44 ++	0.13 ++	0.43 ++

Fig. 1: Relation between nitrogen input and alfa amino nitrogen (AAN) content of sugar beet in the years 1998-2002
Obrázok 1: Vzťah medzi vstupom dusíka a obsahom alfa amino dusíka (AAN) v cukrovej repe v rokoch 1998-2002

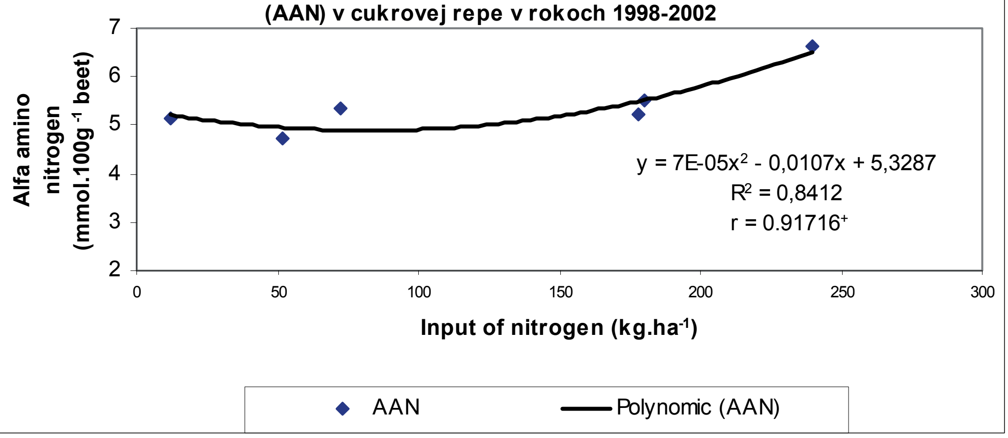


Fig. 2: Relation between nitrogen input into soil and digestion of sugar beet in the years 1998-2002
Obrázok 2: Vzťah medzi vstupom dusíka do pôdy a digesciou repy cukrovej v rokoch 1998-2002

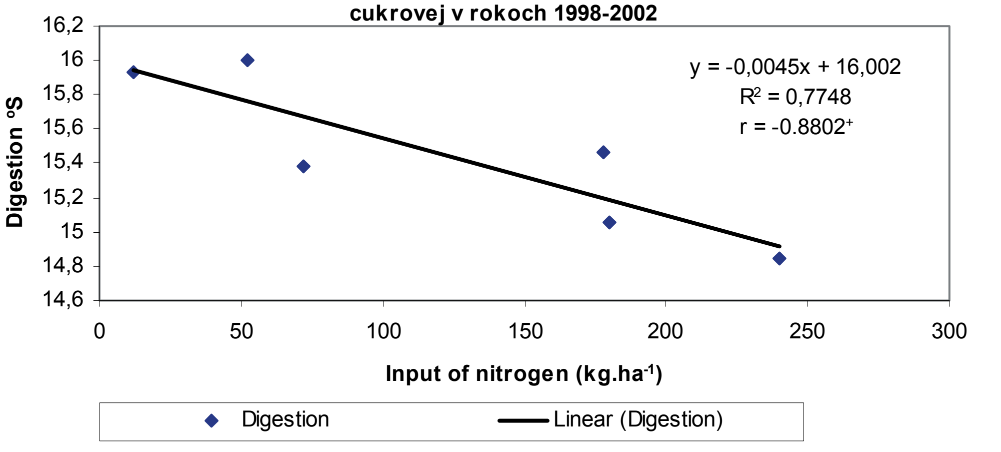
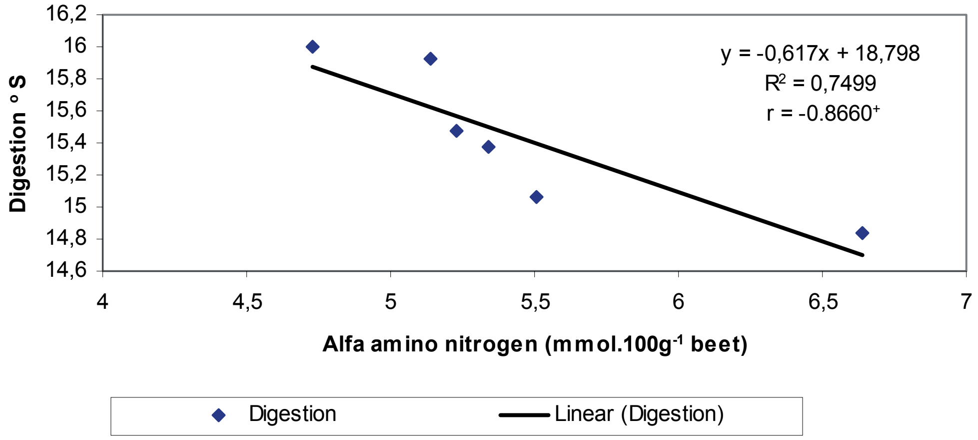


Fig. 3: Relation between content of alfa amino nitrogen and digestiont of sugar beet in the years 1998-2002
Obrázok 3: Vzťah medzi obsahom alfa amino dusíka a digesciou v repe cukrovej v rokoch 1998-2002



autumn before the soil is getting frozen the high content of nitrogen substances is the source of nitrogen losses due to leaching and denitrification in non-vegetation period.

The variability of α-amino nitrogen content was dependent on weather condition and on different nitrogen fertilization (Tab. 5). The content of α-amino nitrogen varied in average from 4.30% (2001) to 6.67% (1999) with average value 5.43% (Tab. 4). The highest average content of α-amino nitrogen was in treatments with FYM application (5.51 - 6.64%). Application of FYM induced higher content of α-amino nitrogen in comparison to analogues straw-in application except the 2002 year. The application of straw instead FYM caused significant (straw only in comparison to FYM treatment) and highly significant (straw plus N mineral fertilizer in comparison to FYM plus N mineral fertilizer) decrease of α-amino nitrogen content in beet. Biological immobilisation of nitrogen in soil due to application of organic material with broad of C:N ratio positively influenced the decrease content of α-amino nitrogen in beet. Incorporation of 6 $t.ha^{-1}$ winter wheat straw can immobilized up to 108 kg doses of nitrogen per hectare [6]. Variability of α-amino nitrogen content in the beet's roots was on the interaction of fertilization and years (Tab. 5). The relationship between nitrogen application (different sources and amounts) and α-amino nitrogen content can be described by the curve of second order (Fig. 1). The determination coefficient for the relationship is 84%.

The nitrogen application has a strong negative influence on the content of sugar in roots of beet (Fig. 2). The FYM application to sugar beet cultivation on fertile haplic Chernozems causes an increases of α-amino nitrogen content in beet and causes decrease of digestion (Tab. 3 and 4). The negative causes between the content of α-amino nitrogen and digestion (-0.8802^{+}) is shown in Fig. 3. The results obtained on Trnava hilly region showed that the content of α-amino nitrogen in root of sugar beet can be considered not only as regular quality indicator but also as a bio-indicator of potential nitrogen overload in specific condition. The acquired results, deepen the knowledge that nitrogen fertilization causes the decreased of sugar content and refined sugar production and also cause an increase of α-amino nitrogen and sodium in root of sugar beet [5].

The critical loading of soil by nitrogen can be expressed as the difference between input of N (mineral sable N, biologically fixed N, atmospheric deposition, N from manure) and ability of ecosystem safely fix this element [8]. The content of α-amino nitrogen in beet is also positively depended on the content of nitrogen in the soil [17]. By way of evaluation of nitrogen fixation and metabolism of groundwater dependent plants is also possible to monitor the content of nitrate, ammonia and α-amino nitrogen in the soil. Observed concentration of all forms of nitrogen was greater in upper soil layers and decreased with depth [4].

The variability of potassium content in beet root was more influenced by weather condition of years (highly significantly) than nitrogen input (significantly). The sodium content was determined by both the weather conditions and nitrogen application as well. The FYM application causes an increase of the sodium content in the roots up to 1.13-1.20 $mmol.100g^{-1}$. The fertilization without FYM caused that the sodium content in roots reached maximum 1.00 mmol.100g^{-1} (Tab. 4).

Excluding FYM application on fertile soils increased qualitative parameters of production. Additions doses of N input from inorganic or organic fertilizers over the requirements and the incorporation of forecrop residues with compensation dose of nitrogen and/or FYM for optimum production of sugar beet add to the potential for N leaching losses. The degree to which losses occur (and compensation is required) depends not only on soil and weather conditions, but also on many management decisions, including those for manure [9]. The available data of α-amino nitrogen content in beet can indicate an overload input of nitrogen in growing system in specific soil and climate condition.

The application of straw brings benefit due to better qualitative parameters of sugar beet production and compliance with Regulation 392/2004 [3].

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