EFFECT OF FERTILIZERS ON THE YIELD, PROTEIN CONTENT AND AMINO ACID COMPOSITION OF WINTER CEREALS

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Abstract

The effect of different fertilizers (nitrogen, phosphorus, potassium) and their combinations on the yield, raw protein content and amino acid composition were studied in field experiments. The levels of treatment were 200 kg/ha for nitrogen, 500–1000 kg/ha for phosphorus and potassium. Winter rye, triticale and wheat cultivar were grown in two subsequent years.

Nitrogen fertilization in all cases increased the yield of grains and the raw protein content. The increase reached about 50% in average comparing with control samples grown without adding nitrogen fertilizers. Although there are significant differences between the different cereals studied, it can be generally stated that the increase in protein content is connected with a decrease in the essential to non-essential amino acid ratio. The decrease is higher if only nitrogen fertilizer is used and moderate if a combined treatment with nitrogen, phosphorus and potassium fertilizer is applied.

Keywords: cereals, rye, triticale, wheat, fertilizer effect, amino acid composition, yield.

Introduction

Plant nutrition is of great importance in improving the crop yield and quality of winter cereals. In Hungary, winter wheat is one of the main food crops, so its nutritive value is of importance in determining the quality. From this point of view important qualitative characteristics are e. g. the protein content or amino acid composition of wheat protein. Quality indices, just as other plant characteristics, have been determined in more or less wide ranges, typical for genus and species [23], [36], [39].

Within the given limits, environmental conditions may effect parameter variations. Among these factors, plant nutrition circumstances — use of fertilizers, soil supply conditions — suit best to modify, to improve certain parameters [34] by a conscious activity.

Among the factors influencing the growth of plants, the available mineral content of soil, the effect of fertilizing has been first at all studied [1, 4, 12, 13, 19, 20, 21, 34, 37].

A correlation was found between the N content in the crop, the amount of protein, and level of nitrogen fertilizers [2, 6, 8, 9, 17, 19, 21, 26]. Views concerning the changes of amino acids are often contradictory. According to Mengel [24], outer factor do not affect significantly the genetically defined amino acid composition in proteins. While, according to others, nitrogen fertilizers increase the protein content and cause a change in the proportions of protein fractions [35].

The aminoacid content in cereal grain crops is of importance both for nutrition and for foddering [13, 40]. According to views of several authors, variations in amino acid composition depend on fertilizing, first of all, on the level of nitrogen fertilizers [28, 31, 32, 38, 39].

Quantitative relations between fertilizer and crop yield of winter wheat have been widely studied and reported [22, 25, 26, 29, 33]. Also the problem of quality is a much discussed area of agrochemistry, where various positive and negative effects, or even inefficiency have been reported [5, 7, 16, 26, 30, 40].

Positive correlations between nitrogen fertilizer and raw protein contents of winter wheat grains have been discussed in several earlier and recent reports in this country and abroad [3, 7, 18]. There is much less information on the relation between the amino acid content and fertilizing, and even conclusions may be divergent or even contradictory, in particular, from analyses relating to individual amino acids [11, 27].

In the following, information will be offered on the protein yield, amino acid composition and in vitro biological value of grain crops from field fertilizing experiments realized in Hungary.

Materials and Methods

The first field experiment was realized on sandy, calcium rich soil at the Experimental Station of the Pedological and Agrochemical Research Institute of the Hungarian Academy of Sciences. Essential soil parameters at setting were: humus 0.8 to 1.2%; $CaCO_3$ 0 to 3%; elutriables 0.02 to 10–15%; Al–P_2O_5 6 to 9 mg%; Al–K_2O 5 to 8 mg%; total N 0.08 to 0.11%. Classic NPK deficiency test was arranged in four-times strip split-spot arrangement of winter rye and triticale, with N_{200}, and upfill P and K dosages (*Table 1*).

In the first year, winter rye (cultivar Kecskemét–H) a triticale prospective species KT–77 was grown. In the second year a winter wheat (cultivar MV–8) was used in field experiments.

Lot-wise (0.5 m^2 each) taken samples were analyzed. After sulphuric acid-peroxide destruction, nitrogen was determined by dead-stop titration

Table 1

Effect of fertilizers on the nitrogen-dry matter content and protein yield of winter rye and triticale grains

Treatment	Dry matter t/ha	N %	Raw protein yield kg/ha	Dry matter t/ha	N %	Raw protein yield kg/ha	Dry matter t/ha	N %	Raw protein yield kg/ha
	RYE			TRITICALE			AVERAGE		
Ø	2.45	1.83	280.5	1.41	1.79	157.9	1.93	1.81	218.7
N	3.26	2.10	428.7	2.67	2.47	412.8	2.96	2.28	422.5
P_1K_1	2.33	1.68	245.1	1.60	1.74	174.2	1.96	1.70	208.6
NP_1	3.85	1.99	479.7	3.25	2.36	480.0	3.55	2.17	482.2
NK_1	3.40	1.88	420.2	2.92	2.28	416.7	3.16	2.08	411.4
NP_1K_1	3.57	2.17	484.8	3.06	2.41	461.8	3.31	2.29	474.5
NP_2K_2	3.32	2.03	422.0	3.81	2.47	589.0	3.56	2.25	501.4
AVERAGE	3.17	1.95	387.1	2.67	2.21	369.3	2.92	2.08	380.2

N=200 kg/ha; P_1=500 kg P_2O_5/ha; P_2=1000 kg P_2O_5/ha;
K_1=1000 kg K_2O/ha; K_2=1000 kg K_2O/ha.

of the ammonia formed. The protein content was calculated by multiplying the N content by a factor of 6.25. Gross amino acid composition was determined in an automatic analyzer operating by the ion exchange principle (AA microtechna). Before testing, cystine was transformed to a stable oxidized form. Tryptophan was determined photometrically after alkaline hydrolysis.

The second field experiment was realized on a tchernoziom soil at the Nagyhörcsök Experimental Station of the Pedological and Agrochemical Research Institute of the Hungarian Academy of Sciences. Essential characteristics of the experimental soil at start were: humus 3.5%; $CaCO_3$ 4.5%; elutriables (0.02 mm) 40%; Al–P_2O_5 6 to 9 mg%; Al–K_2O 10 to 14 mg%; total nitrogen 0.28%. This soil was characterized by poor phosphorus, medium potassium and adequate nitrogen supply.

The in vitro biological value (nutritive value) of cereal grain proteins was determined by computation from the amino acid composition, by means of the so-called Transformed Gaussian Index (10). This index correlated well with in vivo human test results ($r = 0.9$).

The formula used for calculation was as follows:

$$\mathrm{TGI} = 100 \cdot \left[\prod_{i=1}^{8} q_i^{\alpha_i} \right]^{0.125},$$

where

$$q_i = \exp\left\{(-4.5)\left[\frac{\dfrac{a_i}{\sum_{i=1}^{8} a_i} - \dfrac{a_{ir}}{\sum_{i=1}^{8} a_{ir}}}{\dfrac{a_{ir}}{\sum_{i=1}^{8} a_{ir}}}\right]^2\right\},$$

where a_i = i-th essential amino acid concentration in the sample, in arbitrary units; and $a_{i,r}$ is the reference composition; actually: $a_{\mathrm{ILE}} = 110$, $a_{\mathrm{LEU}} = 179$, $a_{\mathrm{LYS}} = 141$, $a_{\mathrm{PHE+TYR}} = 212$, $a_{\mathrm{MET+CYS}} = 89$, $a_{\mathrm{THR}} = 99$, $a_{\mathrm{TRP}} = 30$, $a_{\mathrm{VAL}} = 140$. The values of the weighting factors α_i are, in this order: $\alpha_{\mathrm{LYS}} = 0.28$, $\alpha_{\mathrm{TRP}} = 0.19$, $\alpha_{\mathrm{THR}} = 3.32$, $\alpha_{\mathrm{MET+CYS}} = 0.67$, $\alpha_{\mathrm{PHE+TYR}} = 0.72$.

Results and Discussion

Winter Rye and Triticale

For both cereals, grain crop (*Table 1*) increased significantly, mainly due to the effects of N and P. In every treatment, and also in the test average, rye yield exceeded that of triticale. The nitrogen content in triticale is higher while the protein yield may be considered as practically equal for both cereals. Among fertilizers, the effect of nitrogen is unambiguous and can be mathematically proven in the tested parameters. The positive effect of phosphorus — as a trend for rye, and significant for triticale — is primarily manifested in the protein yield.

The comparison of the two cereals shows that upon NP_2K_2 treatment, the protein yield of triticale exceeded that of rye, mainly due to the increased N percentage, pointing out the relevant advantages of triticale [14, 15].

Percentage variations of certain amino acids in both cereals as a function of fertilizing have been tabulated in *Tables 2, 3,* and *4.* It has been generally observed that triticale contains a higher percentage of most amino acids other than threonine (THR), aspartic acid (ASP), isoleucine (ILE) and lysine (LYS). The effect of fertilizing is significant for most of the amino acids.

The increase was mostly due to nitrogen fertilizers, namely in nitrogen deficient treatments most of the amino acids showed lesser contents. The highest contents of the 18 amino acids were found in 7 cases for exclusive N treatment, in 5 cases for NPK, and in 3 cases each of NK and NP

Table 2
Effect of fertilizers on the essential amino acid content of grains (mg/g)

Treatment	THR	VAL	ILE	LEU	LYS	TRY	MET + CYS	PHE + TYR	Essential amino acids (Total)
RYE									
Ø	4.70	4.80	2.55	6.90	6.05	1.20	2.70	6.25	25.15
N	5.45	5.20	4.45	8.05	5.65	1.20	3.40	8.35	41.75
P_1K_1	4.00	4.10	2.60	5.85	4.20	1.00	2.60	7.00	31.35
NP_1	4.50	5.05	3.25	6.60	4.95	1.45	3.40	7.80	37.00
NK_1	4.95	4.45	2.85	7.45	5.45	1.45	3.15	8.25	38.00
NP_1K_1	5.05	4.80	3.55	7.25	5.75	1.30	3.20	9.15	40.05
NP_2K_2	4.35	3.75	3.60	5.75	4.50	1.25	3.60	7.25	33.05
AVERAGE:	4.71	4.59	3.12	6.84	5.22	1.26	3.15	7.82	36.61
TRITICALE									
Ø	3.50	4.00	3.00	7.10	3.90	1.00	3.35	7.95	33.80
N	3.95	5.45	3.90	10.85	5.90	1.20	3.95	11.40	46.60
P_1K_1	4.00	4.35	2.75	7.00	5.76	1.45	3.35	7.75	36.40
NP_1	4.95	4.00	2.20	9.60	5.00	1.50	4.30	9.20	40.75
NK_1	3.70	5.30	3.70	8.95	5.20	1.50	3.90	11.15	43.40
NP_1K_1	4.35	4.65	1.75	6.10	4.85	1.50	3.35	10.10	36.65
NP_2K_2	4.55	6.40	2.95	8.10	4.75	1.70	4.20	13.50	46.15
AVERAGE:	4.14	4.88	2.89	8.37	5.05	1.41	3.77	10.16	40.67
R+T AVERAGE									
Ø	4.10	4.40	2.77	7.00	4.97	1.00	3.02	7.10	34.36
N	4.70	3.52	4.17	9.45	5.77	1.20	3.67	9.87	42.35
P_1K_1	4.00	4.22	2.67	6.42	4.97	1.22	2.97	7.55	34.02
NP_1	4.72	4.52	2.72	8.10	4.97	1.47	3.84	8.57	38.91
NK_1	4.32	4.87	3.27	8.65	5.32	1.47	3.52	9.72	41.14
NP_1K_1	4.70	4.72	2.65	6.67	5.30	1.40	3.07	9.62	38.13
NP_2K_2	4.45	5.07	2.77	6.92	4.62	1.47	3.89	10.37	39.56
AVERAGE:	4.43	4.47	3.00	7.60	5.13	1.32	3.43	8.97	38.35

treatments. As to threonine (THR), histidine (HIS), leucine (LEU), and valine (VAL) contents, the increase was not significant. As an average of the two cereals (*Table 4*) fertilizing had a still more marked effect, and the amino acid contents exhibited a significant increase in all except three cases.

Amino acids are not equivalent: they are classified as non essential (replaceable) and essential ones. In the actual work, essential amino acids have been considered to be those irreplaceable for *adults* (*Table 2*), in conformity with the FAO/WHO Recommendation.

Table 3
Effect of fertilizers on the non-essential amino acid content of grains (mg/g)

Treatment	AMINO ACID ARG	HIS	SER	GLY	ALA	GLU	PRO	ASP	Non-essential amino acids (Total)
RYE									
Ø	5.60	2.85	5.45	5.80	3.60	27.7	10.3	9.55	70.85
N	7.25	2.05	7.40	5.60	4.55	51.9	17.9	12.05	108.90
P_1K_1	5.70	2.30	4.65	4.55	3.40	35.7	11.7	8.25	76.25
NP_1	5.60	2.25	5.85	3.80	5.05	32.8	16.9	11.15	83.40
NK_1	6.35	3.95	6.25	5.75	4.45	37.1	17.2	11.20	92.25
NP_1K_1	8.30	3.30	7.00	6.30	4.80	39.0	18.2	11.35	98.25
NP_2K_2	5.75	3.00	5.45	5.10	3.20	20.3	12.4	9.70	64.90
AVERAGE:	6.63	2.84	6.01	5.27	4.15	34.9	15.0	10.46	84.99
TRITICALE									
Ø	6.40	2.60	4.95	4.65	4.25	32.6	13.1	6.15	74.70
N	7.95	4.60	9.10	6.35	5.60	48.1	20.2	10.00	111.90
P_1K_1	6.95	4.25	6.35	5.80	4.40	31.5	11.5	8.95	79.70
NP_1	6.95	3.30	6.45	5.80	5.25	39.6	14.8	8.45	90.60
NK_1	6.70	4.85	8.85	6.10	5.80	45.2	17.5	12.30	107.30
NP_1K_1	7.60	3.30	6.70	5.30	4.75	50.2	15.7	7.45	101.00
NP_2K_2	8.05	3.80	6.75	5.80	5.90	40.8	17.2	7.80	96.10
AVERAGE:	7.23	3.81	7.02	5.69	5.14	41.2	15.7	8.73	94.62
R+T AVERAGE									
Ø	6.00	2.72	5.20	5.22	3.92	30.2	11.7	7.85	72.81
N	7.60	3.32	8.25	5.97	5.07	50.0	19.1	11.02	110.33
P_1K_1	6.32	3.27	5.50	5.17	3.90	33.6	11.6	8.60	77.96
NP_1	6.27	2.77	6.15	4.80	5.15	36.2	15.9	9.80	87.04
NK_1	6.52	4.40	7.55	5.92	5.12	41.2	17.4	11.75	99.86
NP_1K_1	7.95	3.40	6.85	5.80	4.77	44.6	16.9	9.40	99.67
NP_2K_2	6.90	3.40	6.10	5.45	4.55	30.6	14.8	8.75	80.55
AVERAGE:	6.80	3.33	6.51	5.48	4.64	38.1	15.3	9.60	89.75

Comparing essential amino acid contents in both cereals, higher quantities of threonine (THR), isoleucine (ILE) and lysine (LYS) were found in rye, while other amino acids occur in greater amount in triticale.

The effect of fertilizing proved to be significant, and the highest contents were found in both cereals due to N treatments. Nitrogen deficient treatment entrained lower contents in rye of all the essential amino acids except leucine (LEU). Non essential amino acid percentages are shown in *Table 3*. Comparing grain crops of both cereals, triticale had the higher content in all except aspartic acid (ASP). Fertilizing brought about varia-

Table 4
Effect of fertilizers on the amino acid content of rye and triticale grains
(mg/100 g)

Treatment	ESSENTIAL			NON-ESSENTIAL			TOTAL		
	R	T	Average	R	T	Average	R	T	Average
Ø	33.15	33.80	34.36	70.85	74.70	72.81	106.0	108.50	107.25
%	100	100	100	100	100	100	100	100	100
N	41.75	46.60	42.35	108.90	111.90	110.33	150.65	158.40	154.57
%	119	138	123	154	150	152	142	146	144
PK_1	31.35	36.40	34.02	76.25	79.70	77.96	107.60	116.10	111.85
%	89	108	99	108	107	107	102	107	104
NP_1	37.00	40.75	38.91	83.40	90.60	87.04	120.40	131.35	125.87
%	105	121	113	118	121	120	114	121	117
NK_1	38.00	43.40	41.14	92.25	107.30	99.86	130.25	150.70	140.47
%	108	128	120	130	144	137	123	139	131
NP_1K_1	40.05	36.65	38.13	98.25	101.00	99.67	138.30	137.65	137.98
%	114	108	111	139	137	137	130	127	129
NP_2K_2	33.05	46.15	39.56	64.90	96.10	80.55	97.95	142.25	120.10
%	94	136	115	92	129	111	92	131	112
AVERAGE:	36.68	40.67	38.35	84.99	94.62	87.75	121.60	135.29	128.44

R=RYE, T=TRITICALE

tions similar to those for essential amino acids. Also here, the grain crop of both cereals treated with N showed the highest contents. Important PK dosages were seen to markedly reduce the content of most amino acids, in particular, glutamic acid (GLU). The lowest amino acid contents were found in triticale for PK treatment, while in rye for NP_2K_2 treatment.

All the essential, and non-essential amino acid contents and their sums have been tabulated in *Table 4*. Clearly, non-essential and total amino acid contents in triticale due to single treatments, and as an average of treatments exceeded those in rye grains. The same was found for triticale concerning the total quantity of essential amino acids. Rye grains surpassed triticale grains only in control samples, for NP_1 and NP_1K_1 treatments. The majority of the differences was significant.

The effect of fertilizing was mainly manifested in the non-essential amino acid content of grains, the best (N) treatment entrained an increase by about 50%. At the same time, also the essentials content increased, but moderately, exceeding unfertilized treatment by max. 38%. The ratio of essential to non-essential amino acid content in the grain crop showed fertilizing to have caused shifts in some treatments. Nitrogen fertilizer changed the proportion between amino acids in favour of non-essential amino acids in the grain crop of both cereals (*Table 5*). In nitrogen deficient and high NP_2K_2 dosage treatments, there was a favourable change, increasing the proportion, i. e., the relative quantity of essential amino acids. The chemical index, characterizing the biological value of the given protein, clearly increased in winter rye upon fertilizing (*Table 12*). Nevertheless, no important differences were found between different kinds of fertilizer. The best results were found for NP_1 treatment.

Table 5
Effect of fertilizers on the ratio of essential and non-essential amino acid content of rye and triticale grains
(%)

Treatment	Non-essential amino acids Rye	Non-essential amino acids Triticale	Essential amino acids Rye	Essential amino acids Triticale
Ø	67	69	33	31
N	72	71	28	29
P_1K_1	71	69	29	31
NP_1	69	69	31	31
NK_1	71	71	29	29
NP_1K_1	71	73	29	27
NP_2K_2	66	68	34	32

Chemical indices for triticale proteins, also shown in *Table 12*, show a different picture. The best value was found in unfertilized control treatment. Among other treatments, indices for NP and NP_1 and NP_1K_1 treatments were the poorest.

The comparison of the biological values of grain crops of both cereals shows that the quality of triticale is better — both as an experimental average and separately in each of the treatments.

Winter Wheat (Grown on Calcium Rich Sandy Soil)

Upfill PK fertilizing improved supply conditions of the test soil, affecting also grain crop (*Table 6*). Against unfertilized control grain crop, the significant increase was due to fertilizer treatment. The effect of PK fertilizer was significantly increased by NP and NPK, that of single N fertilizer by NPK treatments.

Nitrogen fertilizer in N, NP, NK and NPK combinations increased the nitrogen and raw protein contents of the grain crop, compared to both the control and the PK treatment to a statistically significant degree. Fertilizing about tripled the raw protein yield by hectare compared to that of the control. An increase appeared upon nitrogen fertilizing, still enhanced

Table 6
Effect of fertilizers on crop yield of winter wheat
and on some quality parameters
(Őrbottyán, 1982. MV–8. cultivar)

Treatment	Grain yield t/ha	N %	Raw protein %	Raw protein kg/ha
Ø	1.46	2.15	13.44	196
N	2.39	2.56	16.00	382
P_1K	2.07	2.06	12.87	266
NP_1	2.72	2.60	16.25	442
NK_1	2.55	2.72	17.00	434
NP_1K_1	3.53	2.62	16.37	578
NP_2K_2	3.79	2.71	16.94	642
AVERAGE:	2.64	2.49	15.56	411

N=200 kg/ha, Autumn 1981. Spring 1982.
P_1= 500 kg P_2O_5/ha, P_2=1000 kg P_2O_5/ha, Autumn 1980.
K_1= 500 kg K_2O/ha, K_2=1000 kg K_2O/ha, Autumn 1980.

by the first-year after-effect of P and K fertilizer, so that maximum yield arose for a combined high-dose PK upfill and N fertilizer.

The non-essential amino acid content in winter wheat grains is shown in *Table 7.* Fertilizing produced significant positive or negative changes in all amino acids except proline (PRO), depending on the treatment. Compared to unfertilized treatment, N increased the contents in arginine (ARG), histidine (HIS) and alanine (ALA); PK in ARG; NP in ALA; NK in ARG, serine (SER), ALA, aspartic acid (ASP); NP_1K_1 in ARG, SER, HIS and ALA; while NP_2K_2 in ARG and ALA amino acids; on the other hand, PK treatment significantly reduced glycine (GLY), glutamic acid (GLU) and ASP contents; NPK treatment reduced GLY compared to the control.

Considering the total of non-essential amino acids, because of alternating effects, no statistically significant increase due to fertilizing could be demonstrated. While upon PK treatment, the decrease was significant.

As to the rate of the effect, N, NK and NPK treatments brought an about one tenth increase, while in PK treatment there was a decrease, by about one quarter compared to the control. For non-essential amino acids, maxima of GLY were found in the control, of PRO in N, of ARG in PK, of SER and ASP in NK, of HIS, ALA and GLU in NP_2K_2 treatments, at an important scatter between treatments.

Fertilizing caused significant changes in the quantity of essential amino acids except in valine (VAL) content, namely, increases in all amino acids except tryptophan (TRP) (*Table 8*). Compared to the control treatment, an increase was found upon N treatment in the amino acids isoleucine

Table 7
Effect of fertilizers on the content of non-essential amino acids of winter wheat grains (mg/g)
Winter wheat cultivar MV–8 (Örbottyán, 1982)

Treatment	ARG	HIS	SER	GLY	ALA	GLU	PRO	ASP	Total
1	5.60	2.50	5.55	7.40	2.75	63.0	15.3	8.80	110.9
2	6.35	3.20	6.05	6.65	3.85	66.0	19.5	9.90	121.8
3	6.95	2.10	5.00	5.00	2.90	39.4	11.3	7.00	79.7
4	5.85	2.50	6.50	7.10	3.90	61.3	18.3	9.60	115.1
5	6.55	2.50	7.10	7.00	3.75	68.2	17.4	10.45	123.0
6	6.90	3.60	6.70	6.40	3.50	65.1	19.0	9.70	120.9
7	6.35	3.70	5.95	6.20	4.05	71.0	15.0	10.00	122.3
AVERAGE:	6.36	2.87	6.12	6.54	3.53	62.0	16.5	9.35	113.3

(ILE), leucine (LEU), lysine (LYS), methionine + cystine (MET+CYS), phenylalanine + thyrosine (PHE+TYR); upon NP treatment in threonine (THR), ILE and LEU; upon NK treatment in THR; upon NP_1K_1 treatment in LYS; while upon NPK_2 treatment in ILE, LEU, LYS, MET+CYS and PHE+TYR. There was a significant decrease in tryptophan (TRP) content alone, due to NP, NK and NP_1K_2 treatments. Among amino acids, maxima were found for the control in TRP; for NP treatment in ILE, LEU; for NK treatment in THR; for NPK_1 in VAL; as well as for NP_2K_2 treatment in LYS, MET+CYS, and PHE+TYR contents.

Table 8
Effect of fertilizers on the essential amino acid content of winter wheat grains (mg/g)
Winter wheat cultivar MV–8 (Örbottyán, 1982)

Treatment	THR	VAL	ILE	LEU	LYS	TRY	MET	PHE	Total	Essential + non-essential amino acids (Total)
1	4.95	5.50	2.60	6.65	3.65	0.37	1.99	8.45	34.16	145.1
2	5.30	5.30	3.55	8.25	4.25	0.32	2.29	9.45	38.71	160.5
3	4.05	4.05	2.20	5.85	3.55	0.29	1.65	7.45	29.09	108.8
4	5.80	5.30	3.55	9.10	3.40	0.23	2.00	8.85	38.23	153.3
5	6.10	4.75	2.95	7.75	3.50	0.27	1.90	8.95	36.17	159.2
6	5.45	5.55	2.95	7.45	4.20	0.30	1.98	8.85	36.73	157.6
7	5.45	4.65	3.20	8.60	4.50	0.19	2.29	10.30	39.18	161.5
AVERAGE:	5.30	5.01	3.00	7.66	3.86	0.28	2.02	8.90	36.03	149.3

Study of the entity of essential amino acids shows N, NP, NPK treatments to result in significant excesses, as against reduction by PK treatment. Variation rates exceeded those in the entity of non-essentials. In N, NP and NPK treatments 7 to 15% increases were recorded compared to treatments without a fertilizer. These variations could be statistically demonstrated.

As concerns the ratio of essential to non-essential amino acids within the complex of amino acids, slight variations (± 3 to 4%) were found in dependence on fertilizing. About one quarter was the share of essential amino acids within the overall amino acid complex, the others were non-essentials.

Chemical indices (*Table 12*) changed differently, but significantly. The optimum effect was due to nitrogen in itself, as well as to high doses of all three macro elements (NPK). NP and NK_1 treatments partly deficient in nutrient abruptly reduced indices. Nitrogen deficient P_1K_1 fertilizing was favourable to the chemical index.

Winter Wheat (Grown on Tchernoziom Soil)

The grain yield of the tested wheat (*Table 9*) was significantly increased by nitrogen given in itself or in PK combinations, compared to the control and to PK treatment. Also in NPK treatments the yield significantly exceeded yields from N and NK combinations.

Table 9
Effect of fertilizers on the grain yield, nitrogen content and raw protein yield of winter wheat
Winter wheat cultivar MV-8 (Nagyhörcsök, 1982)

Treatment	Grain yield t/ha	N %	Raw protein %	Raw protein yield kg/ha
Ø	2.98	1.94	12.12	361
N	4.20	2.21	13.81	580
P_1K	3.60	1.85	11.56	416
NP_1	5.07	2.34	14.62	741
NK_1	4.31	2.26	14.12	630
NP_1K_1	5.60	2.25	14.06	787
NP_2K_2	5.29	2.22	13.87	734
AVERAGE:	4.44	2.15	13.44	597

N=200 kg/ha P_1= 500 kg P_2O_5/ha K_1= 500 kg K_2O/ha
P_2=1000 kg P_2O_5/ha K_2=1000 kg K_2O/ha

Nitrogen and raw protein contents in the grain showed a statistically significant increase upon nitrogen treatments. The calculated yield in raw protein became over two-fold upon fertilizing. Further significant yield increases were due over that of the control by NK, NP, NPK treatments; compared to PK by NP and NPK combinations. The non-essential amino acid content of winter wheat grain is shown in *Table 10*. Fertilizing caused significant changes in all amino acid contents except arginine (ARG). Treatment by N caused significant increasee in alanine (ALA); NP in proline (PRO); NK in alanine; while N_1K_1 in histidine (HIS), serine (SER), glycine (GLY), glutamic acid (GLU) and aspartic acid (ASP) contents compared to unfertilized cereals. At the same time, PK treatment significantly reduced the glutamic acid content. Considering the relation between the sum of non-essential amino acid contents and the fertilizer, it appears that while NP and NP_1K_1 treatments entrain significant increases, PK treatment involves reduction.

Table 10
The effect of fertilizers on the non essential amino acid content of winter wheat grains (mg/g)
Winter wheat cultivar MV-8 (Nagyhörcsök, 1982.)

Treatment	ARG	HIS	SER	GLY	ALA	GLU	PRO	ASP	Total
1	7.45	3.10	6.00	5.85	3.95	56.8	16.5	8.65	108.3
2	6.90	3.85	6.70	5.80	4.80	63.9	18.0	9.25	119.2
3	6.10	2.15	6.25	5.80	4.00	47.5	12.9	7.35	92.1
4	6.95	3.80	5.90	6.05	4.25	67.2	25.7	9.60	129.5
5	7.15	3.65	5.95	6.85	5.20	60.2	21.5	10.05	120.6
6	7.25	4.00	8.70	8.30	4.80	87.6	18.7	10.40	149.7
7	6.55	3.15	4.95	6.40	4.30	55.5	21.1	8.00	110.0
AVERAGE:	6.91	3.39	6.35	6.44	4.47	62.7	19.2	9.04	118.5

As to the fertilizer effectivity, NP_1K_1 treatment produced an increase by about one third, NP combination by about one fifth, and other N, P and K combinations by about 10% while PK treatment induced an about 15% decrease.

Essential amino acid contents are presented in *Table 11*. From the data it appears that fertilizing caused significant variations in the concentration of all of the amino acids. Compared to the control treatment, treatment by N caused statistically significant excesses in leucine (LEU), lysine (LYS), triptophan (TRP), phenylalanine (PHE) + tyrosine (TYR); by PK in LYS and TRY; by NP in valine (VAL) and LYS; by NK in LEU; by NP_1K_1 in threonine (THR), LEU, TRY and methionine (MET) + cystine (CYS) contents. At the same time, NK treatment caused a negative change in the ILE content. In NP_2K_2 treatment the amount of all amino acids except LYS proved to be lower than in NP_1K_1 treatment. Maximum LEU, LYS, PHE+TYR contents were found for N treatment; maximum ILE and TRP contents for PK treatment; maximum VAL in NP treatment; while THR and MET+CYS maxima in NP_1K_1 treatment.

Table 11

Effect of fertilizers on the essential amino acid content of winter wheat grains (mg/g)

Winter wheat cultivar MV-8 (Nagyhörcsök, 1982)

Treatment	THR	VAL	ILE	LEU	LYS	TRY	MET + CYS	PHE + TYR	Total	Essential + non-essential amino acids (Total)
1	4.60	4.95	3.55	8.20	4.15	0.23	2.00	9.15	36.83	145.1
2	4.15	5.65	4.00	9.85	5.40	0.37	2.26	14.00	45.68	164.9
3	3.95	4.85	4.35	6.75	5.40	0.42	1.80	9.85	37.37	129.5
4	5.15	7.00	3.15	9.15	5.00	0.30	2.12	10.00	41.87	171.4
5	4.70	5.70	2.80	9.80	3.65	0.28	2.10	12.80	41.83	162.4
6	6.95	6.20	3.95	9.60	4.35	0.33	2.48	10.80	44.66	194.4
7	5.75	5.20	3.05	8.65	4.50	0.30	2.21	10.40	40.06	150.1
AVERAGE:	5.04	5.65	3.55	8.86	4.64	0.32	2.14	10.70	40.90	159.4

As to the sum of essential amino acids, N, NP, NK and NP_1K_1 treatments gave rise to a significant increase compared to the unfertilized case and PK treatments, and so did N treatment in itself, compared to all other but NP_1K_1 treatments.

As to the effectiveness, compared to the control, the percentage of essential amino acids was increased by N by one fourth, by NP_1K_1 by one fifth, the other treatments except PK by about 10% compared to the control, while PK left it practically unaltered.

As to the complex of (essential + non-essential) amino acids, N, NP and NP_1K_1 treatments were found to increase, while PK treatment — mainly because of the formation of non essentials — tended to reduce the total amount of amino acids. NP_1K_1 treatment was the most effective, causing about a one third increase over that of unfertilized control. Also here it appears that the effect of NP_2K_2 treatment lags behind that of NP and NPK treatments.

The analysis of fertilizer effects on the two amino acid groups shows that for the group of essential amino acids, the effects of N, NP_1K_1, NP_1 and NK treatments prevailed, in this order.

In the group of non essentials, the quantities were increased by NP_1K_1 and NP treatments, in this order. The amounts of essential amino acids obtained with different treatments were: 0; 25%; N 28%; PK 29%; NP_1 24%; NK_1 26%; NP_1K_1 23% and NP_2K 27%. The data testify that N, PK and NP_2K_2 treatments in themselves improved the ratio of essentials, in spite of the fact that they did not invariably increase the absolute quantities of essential amino acids.

Table 12
Effect of fertilizers on the in vitro biological value of the proteins of grains
(Transformed Gauss Index, %)
Winter wheat cultivar MV-8

Treatment	Őrbottyán, 1982	Nagyhörcsök, 1982	Rye (Cultivar Kecskemét)	Triticale (Variety KT-77)
Ø	60.01	76.31	77.34	98.13
N	67.75	79.57	82.37	94.85
P_1K	65.32	85.75	85.26	96.40
NP_1	50.32	77.73	89.73	88.77
NK_1	34.14	76.14	82.19	94.15
NP_1K_1	55.27	47.33	86.33	88.22
NP_2K_2	63.46	59.48	83.79	92.71
AVERAGE:	56.61	71.76	83.86	93.32

In a high-fertility tchernoziom soil, fertilizers caused a variation of chemical indices (*Table 12*), of different trends. An NPK fertilizers significantly reduced the index, while partly nutrient-deficient treatments (N_1, P_1K_1, NP_1, NK_1) increased the biological value of protein. The best results, with relatively outstanding values, were obtained with P_1K_1 treatments.

References

1. BAUER, F. (1964): Rozzsal végzett műtrágyaadag és arány kísérletek Duna-Tisza közti lepelhomok talajon. *Kísérletügyi Közlemények, Növénytermesz tés,* LVII/A. 19–50. (in Hungarian).
2. BAYZER, H. – MAYR, H. H. (1967): Beeinflüssung der Aminosäurezusammensetzung der Roggenproteine durch Stickstoffdüngung und Chlorcholinchlorid. *Z. Lebensmittel-Unters. u. Forsch.,* Vol. 133, pp. 215–219.
3. DAIGGER, L. A. – SANDER, D. H. – PETERSON, G. A. (1976): Nitrogen Content of Winter Wheat during Growth and Maturation, *Agron. J.* Vol. 68, pp. 815–818.
4. DEBRECZENI, B. (1981): A műtrágyázás hatása a szántóföldi növények termésének minőségére. *In: A növények ásványi táplálkozása és a műtrágyázás c. Tud. Tanácskozás.* Agrártud. Egy., Gödöllő, 280–290. (in Hungarian).
5. DZAMIC, M. – LEKOVIC, M. (1984): Amino Acid Composition of Grain in Some Sorts of Wheat in the Nis Region. *Agrohemija,* Vol. 3. pp. 145–163.
6. ELEK, É – BÁRTFAI, T. – KÁDÁR, I. (1976): Correlation between Fertilizer Application and Winter Wheat Crop Quality. *Moscow VIII. Intern. Fert. Congr. Sect. 3. 4. 5.* Vol. II. pp. 136–143.
7. ELEK, É – KÁDÁR, I. (1978): Műtrágyázás hatása az őszi búza tápanyaggazdálkodására. *A mezőgazdaság kemizálása. Ankét,* Keszthely, Vol. 1. 169–176, NEVIKI, Veszprém.
8. FILEP, GY. – BUKAI, J. (1969): Nitrogén ellátottság hatása a burgonyagumó kémiai összetételére, szabad aminosav és fehérje tartalmára. *Növénytermelés,* Vol. 18. pp. 23–32. (in Hungarian).
9. GASHOW, L. – HIGWIRA, L. N. (1981): Ammonium and Nitrate–N Effect on the Growth and Mineral Compositions of Triticale, Wheat and Rye. *Agron L.* Vol. 73. pp. 47–51.
10. HÍDVÉGI, M. – BÉKÉS, F. (1985): Mathematical Modelling of Protein Nutritional Quality from Amino Acid Composition. In: Amino Acid Composition and Biological Value of Cereal Proteins. LÁSZTITY, R. and HÍDVÉGI, M. (eds.) D. Reidel Publ. Co., Dordrecht, Boston, Akadémiai Kiadó, Budapest, pp. 205–286.
11. HOJJATI, S. M. – MALEKI, M. (1972): Effect of Potassium and Nitrogen Fertilization on Lysine, Metionine and Total Protein Contents of Wheat Grain. *Agr. J.* Vol. 64. pp. 46–48.
12. KÁDÁR, I. – LÁSZTITY, B. – SZEMES, I. (1982): Az őszi rozs ásványi tápanyag felvételének vizsgálata szabadföldi tartamkísérletben II. *Agrokémia és Talajtan,* Vol. 31, pp. 17–28. (in Hungarian).
13. KIRKBY, E. A. (1970): Nitrogen Nutrition of the Plants. The University of Leeds, Publ., Leeds.
14. KISS, Á (1968): Triticale a homok új gabonája. pp. 189. Mg. Kiadó, Budapest. (in Hungarian).
15. KISS, J. M. (1980): Nagy termőképességű, széles alkalmazkodóképességű kenyér- és takarmánygabona (triticale) előállítása. Kandidátusi értekezés, p. 151. (in Hungarian).
16. KLECSKOVSZKIJ, V. M. – PETERBURGSZKIJ, A. V. (1967): Dejsztvie udobrenij na szosztav i kacsesztvo urozsaja. In: *Agrohimija,* pp. 416–419. Izd. Kolosz. Moscow.
17. KODANEV, J. M. (1976): Povüsenie kacsesztva zerna. pp. 25–27, Izd. Kolosz, Moscow.
18. KOSTIC, M. – DJOKIC, D. (1976): The Influence of Method of Application of Nitrogen on Grain Yields and Quality of Winter Wheat. *VIII. Intern. Fert. Congr. Papers* Vol. II. 3, 4, 5. Sect. pp. 174–182.

19. KOZÁK, L. – TARKOWSKY, XZ. (1977): Zawartosc skladnikov mineralnich w ziarniach Triticale psenicy i zyta *Roczn. Nauk. Roln.* Ser. A. 102. pp. 65–73.
20. LÁSZTITY, B. (1982): Fertilization and Nutrient Relation in some Genotypes of Cereals. *Proc. Genetic Specificity of Mineral Nutrition of Plants.* pp. 285–288. Beograd.
21. LÁSZTITY, B. – KÁDÁR, I. (1978): Az őszi búza szárazanyag felhalmozódásának, valamint tápanyag felvételének tanulmányozása szabadföldi kísérletben. *Agrokémia és Talajtan,* Vol. 27, pp. 429–444. (in Hungarian).
22. LÁSZTITY, B. – SIMON-SARKADI, L. – HÍDVÉGI, M. (1984): Az NPK műtrágyázás hatása az őszi rozs és triticale szem beltartalmára. *Agrokémia és Talajtan,* Vol. 33. pp. 391–402. (in Hungarian).
23. LÁSZTITY, R. (1984): The Chemistry of Cereal Proteins CRC Press. Boca Raton, Florida.
24. MENGEL, K. (1976): A növények táplálkozása és anyagcseréje. Mg. Kiadó, Budapest, pp. 134–141. (in Hungarian).
25. MINEEV, V. G. – PAVLOV, A. N. (1979): Znacsenie osnovnih mineralnih elementov i ih sootnosenija dlja nakoplenija belkov v zerne zlakovih rastenii. *Agrohimija,* Vol. 8. pp. 117–130.
26. NÉMET, I. (1983): A búza és a kukorica nyersfehérje és aminosav tartalmának alakulása a nitrogén, foszfor és kálium műtrágyázás függvényében. *Növénytermelés,* Vol. 32. pp. 37–41. (in Hungarian).
27. PAVLOV, A. N. (1967): Nakoplenie belka v zerne psenici i kukuruzü. Akad. Nauk. SSSr. Izd. Nauka. Moscow, pp. 139–154.
28. PAVLOV, A. N. – CSERGINEC, B. I. – MIHALEV, N. N. – VAULINA, G. I. (1979): Uszlovija mineralnogo pitanija i formirovanija kacsesztva zerna triticale. *Agrohimija,* Vol. 10. pp. 55–59.
29. PECZNIK, J. – KOVÁCS, K. – KISS, T. M. (1971): Különböző mikroelemek hatása a búza terméshozamára és minőségére. In: *Búzatermesztési kísérletek* (ed.: I'so, I.) Akadémiai Kiadó, Budapest, pp. 407–419. (in Hungarian).
30. PEREIRA, A. (1966): Proteinas de trygo-Aminoacidos essencias de algunes trigos cultivades em Portugal. *Agron. lusitana,* Vol. 18. pp. 285–300.
31. PLESKOV, B. P. – SULÜNDDIN, A. F. – JEMELJANOVA, I. P. (1983): Szoderzsanije i szosztav belkov zerna triticale pri razlicsnüh urovnjah azotnogo pitanija. *Izv. TSzHA Vüp.* Vol. 2. pp. 74–79.
32. RUCKMAN, J. E. – ZSCHEILE, F. B. – QUALSET, C. O. (1973): Protein Lysine and Grain Yields of Triticale and Wheat as influenced by Genotype. *J. Agric. Food Chem.* Vol. 21. pp. 697–790.
33. SARKADI, J. (1966): Der Einfluß einiger bedeutsamer Faktoren auf den Nahrstoffgehalt des Weizens. *DAL. Tagungsber.* Vol. 85. pp. 67–75.
34. SARKADI, J. (1981): Főbb szántóföldi növényeink tápanyagfelvételi dinamikája és fajlagos tápanyagigénye. In: *A növények ásványi táplálkozása és a műtrágyázása.* (ed.: Debreczeni, B.) Gödöllő, pp. 169–184. (in Hungarian).
35. SCHEIBE, A. – SCHÖN, W. J. – ZOHSCHKE, M. – BAUER, R. (1968): Untersuchungen über die Eiweissfraktionen bei Füttergersten. *Z. Acker-u. Pflanzenbau,* Vol. 128. pp. 139–144.
36. SIKKA, K. C. (1978): Comparitive Nutritive Value and Amino Acid Content of Triticale Wheat and Rye. *J. Agric. Food Chem.* Vol. 26. pp. 788–791.
37. SZEMES, I. – KÁDÁR, I. – LÁSZTITY, B. (1982): Az őszi rozs ásványi tápanyag felvételének vizsgálata szabadföldi tartamkísérletben. I. *Agrokémia és Talajtan,* Vol. 31. pp. 5–16. (in Hungarian).

38. TABL, M. M. – KISS, A. (1983): Der Einfluß von N-Düngung und Pflanzendichte auf die Aminosäure Zusammensetzung bei Hexaploiden von Triticale und Weizen. *Arch. für Züchtungsforsch.* Vol. 13. (4.2.) pp. 95–101.
39. VINCZE, I. – SZŰCS, G. (1978): A búza és kukorica aminosav tartalom alapján számított biológiai értékének alakulása a nitrogén műtrágya adag változásának függvé nyében. XX. Georgikon Napok, Keszthely, pp. 380–397. (in Hungarian).
40. VÖLKER, L. (1960): Über den Einfluß zusätzlichen Stickstoffdüngung auf den Gehalt einiger Aminosäuren in Getreideiweiss. *Landw. Forsch.* Vol. 13. pp. 307–316.

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