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RELATIONSHIP BETWEEN THE N_{min} CONTENT OF THE SOIL AND THE QUALITY OF MAIZE (*ZEA MAYS* L.) KERNELS

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Abstract: *In a long-term mineral fertilisation experiment with 64 treatments representing all possible combinations of four rates each of N, P and K, set up on chernozem meadow soil in Szarvas in 1989. The following N fertiliser rates were applied: 0, 80, 160, 240 kgha^{-1}year^{-1}. The protein and oil contents and the amino acid and fatty acid compositions of the maize grain yield were analysed between 1997 and 2004. The protein content of the maize kernels increased by 1.1–1.5 percentage points up to a NO_3-N level of 80–100 kg ha^{-1} in the 0–60 cm soil layer prior to sowing. The year had a greater influence on the protein content than the N supplies. In the present experiment it was found that in years with high yields (8,5 tha^{-1}<) the protein content, averaged over the N treatments, was lower (8.3-10.0 %) than in years with poorer yields (7.5 tha^{-1}>), when it ranged from 11.2-12.3 %. No consistent effect of N on the amino acid composition, detectable as a change in the ratio of any amino acid in the majority of experimental years, was observed. The N supplies had no effect on the ratio of isoleucine, theonine, alanine, cysteine, glutamic acid or proline in the protein. Of the seven years investigated, the leucine ratio increased in three years, while that of lysine declined at higher N suppli levels. In two experimental years there was a significant increase in phenylalanine, but a decrease in the glycine ratio as the result of increasing N supplies. Arginine, methionine, valine, aspartic acid, serine acid and tyrosine exhibited significant but inconsistent increases or decreases in two or three years as a function of N supplies. The ratio of essential amino acids exhibited a slight increase in most years up to the 80-100 kgha^{-1} NO_3-N supply level. The oil content and fatty acid composition of maize kernels was extremely stable, and was very little affected by the nutrient supplies or the year. During the experimental period excessive N supplies were only found to reduce the oil content and modify the fatty acid composition on one occasion.*

Key words*: maize, protein and oil content, amino and fatty acid composition, N fertiliser response*

INTRODUCTION

The biological value of maize fodder is fundamentally determined by the protein and oil content of the kernels and by the amino acid and fatty acid composition. The protein content of the normal maize varieties in general cultivation is around 8–12%. The feed value of maize kernel protein is relatively poor, as it consists mainly of zein (50–55%) and glutelin (30–45%), which are poor in tryptophan, lysine and methionine (LÁSZTITY 1981, LARKINS et al. 1993, GYŐRI and MILE 2002). Considerable differences can be observed between the protein contents and amino acid compositions in the various morphological parts of the kernel. The germ contains 17–20% protein, the endosperm 7–10% and the seedcoat 3–4%, but if the mass ratio is considered, 70–75% of the total protein is concentrated in the endosperm and 20–25% in the germ. As regards the amino acid composition, the proteins in the germ and the aleuron layer are richer in lysine. The storage proteins in the endosperm are particularly poor in lysine and tryptophan, but they have high glutamic acid, proline and leucine contents (LÁSZTITY 1999). Maize kernels have an oil content of 3–6% and the fatty acid composition is dominated by unsaturated linoleic acid (C 18:2) and oleic acid (C 18:1), which make up 40–60% and 25–40%, respectively. The germ has the highest oil content (30–35%), compared with only 0.7–1.0% in the endosperm. In terms of mass ratio, 80–85% of the total lipid is found in the germ (PATEL and SANGHI 1990, LÁSZTITY 1999, GYŐRI and MILE 2002). As the protein and oil are unevenly distributed in the kernels, any factors that cause a change in the kernel mass and in the mass ratio of kernel parts may influence the contents and composition of the protein and oil.

The protein content and amino acid composition of maize kernels are mainly determined genetically, but they may be modified by ecological and agronomic factors. Among the latter, the effect of nutrient supplies on quality is the most pronounced. It has been widely proved that better N supplies improve the protein content (VERESS 1973, PROKSZÁNÉ et al. 1995, IZSÁKI 1999). The correlation between N supplies and the amino acid composition of the protein is less consistent. The effect of fertilisation on protein content and the amino acid composition may be modified by the year, especially the water supplies. Results published by PROKSZÁNÉ et al. (1995) showed that the protein content of maize was smaller in wet years than in dry years, both without N fertilisation and at various N fertiliser levels. Irrigation also caused a decrease in the protein content, particularly at high stand densities (PROKSZÁNÉ et al. 1988). In dry years mineral fertilisation resulted in a greater increase in the crude protein content (GYŐRI and MILE 2002, PROKSZÁNÉ et al. 1995). The year may influence the quantity of certain amino acids, but others have stable values over the years (PÁSZTOR et al. 1997).

Over the last decade, the need for precise, environment-friendly, quality-oriented plant nutrition for maize has made it imperative to place N fertilisation on new foundations, by elaborating and implementing a fertilisation system based on the measurement of soil mineral N contents. In connection with this N fertilisation system, few research results are available on the correlation between the N_{min} reserves of the soil prior to sowing and the quality of maize. The present paper provides further results that can be used for the development of quality-oriented N fertiliser recommendations.

MATERIAL AND METHODS

Long-term mineral fertilisation experiments were set up at the Experimental Station of the Crop Production Department, Faculty of Agricultural Water and Environmental Management, Szent István University, Szarvas, in 1989. The soil of the experimental area had the following parameters: chernozem meadow soil, calcareous in the deeper layers, 85–100 cm humus layer, $pH_{(KCl)}$ 5.0–5.2, humus content 3.0–3.2%, upper limit of plasticity according to Arany (K_A) 50, clay content 32%. Prior to the setting up of the experiment the soil contained the following nutrient supplies: AL-P_2O_5 156 mg kg^{-1}, AL-K_2O 322 mg kg^{-1}, AL-Na 212 mg kg^{-1}, KCl-Mg 765 mg kg^{-1}, EDTA-Mn 386 mg kg^{-1}, EDTA-Cu 5.4 mg kg^{-1} and EDTA-Zn 3.0 mg kg^{-1}.

Fertilisation was carried out in all possible combinations of four levels each of N, P and K, giving a total of 64 treatments, set up in a split-split plot design with three replications, with K fertilisation as the “A” factor, P fertilisation as the “B” factor and N fertilisation as the “C” factor. The following fertiliser rates were applied: nitrogen: $N_0 = 0$, $N_1 = 80$, $N_2 = 160$, $N_3 = 240$ kg N ha^{-1} year^{-1}; phosphorus (P_2O_5): $P_0 = 100$ kg ha^{-1} year^{-1}, $P_2 = 500$ kg ha^{-1} in 1989, 1993 and 2001, $P_3 = 1000$ kg ha^{-1} in 1989, 1993 and 2001; potassium (K_2O): $K_0 = 0$, $K_1 = 300$ kg ha^{-1} year^{-1} between 1989 and 1992, 100 kg ha^{-1} year^{-1} from 1993, $K_2 = 600$ kg ha^{-1} in 1989 and 2001, 1000 kg ha^{-1} in 1993, $K_3 = 1200$ kg ha^{-1} in 1989 and 2001, 1500 kg ha^{-1} in 1993. The high rates of P and K replenishment fertilisation were used to create clearly distinct supply levels in the soil in order to investigate plant responses to nutrient status. The nitrogen was applied as ammonium nitrate, the phosphorus as superphosphate and the potassium as potassium chloride in autumn. In each year of the experiment, four crops were included in the crop rotation on 4 × 192 plots, where the plot size of the sub-sub-plots was 4 × 5 = 20 m^2.

In order to determine the level of soil nutrient supplies, soil samples were taken from the 0–60 cm soil level each year in autumn after harvesting the forecrop to analyse the P and K contents with the AL (0.1 M NH_4-lactate + 0.4 M acetic acid) method. When evaluating the results the soil P and K supply levels are given as the AL-P_2O_5 and K_2O contents of the ploughed layer. The mineral nitrogen content of the soil in the 0–60 cm soil layer was determined in spring, prior to sowing. The NO_3-N + NH_4-N content determined using the 1 N KCl method is given in the paper as an estimation of the N supply level. The nitrogen supplies of the soil during the experimental period are presented in Table 1.

Table 1.

Nitrogen supplies of the soil during the experimental period
(SZARVAS, 1997-2004)

Year	NO_3+NH_4-N kg ha^{-1} in 0-60 cm soil layer			
	N_0	N_1	N_2	N_3
1997	58+36	100+41	138+40	205+53
1999	31+17	40+20	80+18	86+18
2000	21+28	20+30+80$^+$	22+32+160$^+$	22+28+240$^+$
2001	38+5	80+6	131+8	148+11
2002	60+18	85+19	180+20	205+21
2003	39+40	55+51	61+46	77+61
2004	64+22	96+22	133+23	191+22

+ Ammonium nitrate applied in spring

For the calculation of crude protein content (N×6.25) the total N was measured by the macro-Kjeldahl method. The amino acids were measured after acidic (6 N HCl) hydrolysis by ion exchange column chromatography (HPLC, Aminochrom II. Labor, MIM Hungary). The total fatty acids were extracted, methyl-esterified and analysed by gas-liquid chromatography (GLC, UNICAM PRO-GC).

Table 2.

Rainfall quantities and distribution during the experimental years, mm
(SZARVAS, 1997–2004)

Year	Up to the beginning of tasselling (Apr.–Jun.)	During the growing eason (Apr.–Aug.)	Outside the growing season (Sep.–Mar.)	Annual total
1996	170	386	348	663
1997	174	309	231	489
1998	151	330	193	606
1999	296	446	330	847
2000	80	152	341	339
2001	204	337	254	612
2002	124	303	196	489
2003	29	77	262	350
2004	164	356	271	659
Long-term average 1901–1975	171	274	264	538

The maize experiments have been underway since 1994. The present paper presents the results of trials carried out on the hybrid Clarica (FAO 310, Pioneer) between 1997 and 2004. The forecrop was fibre hemp from 1997–1999 and silage sorghum between 2000 and 2004. Sowing was carried out with a row distance of 75 cm and 75,000 germs ha^{-1}.

Data on the rainfall supplies in the various years, characterised by the quantity of rain up to the beginning of tasselling and over the whole vegetation period, demonstrate that the years with the best rainfall distribution and supplies were 1997, 1999 and 2001. In 1998, 2002 and 2004 the rainfall distribution was less favourable, but total rainfall over the growing season exceeded the many years' mean, while 2000 and 2003 were dry or droughty years (Table 2). The mean temperature during the growing season was 18.5, 19.5, 20.4 and 18.0°C, while the many years' mean was 18.0°C.

RESULTS AND DISCUSSIONS

Protein content

The protein content of maize kernels ranged from 7.3–12.9% during the experimental years, as a function of N supplies and year. An evaluation of the N effect shows that in most years the protein content rose significantly by 1.1–1.5 percentage points compared to the N control (given no N fertiliser) as the NO_3-N level in the 0–60 cm soil layer prior to sowing increased to 80–100 kg ha^{-1}, achieved with N fertilisation of 80 kg ha^{-1}. A further slight increase in the protein content was detected when the NO_3-N reserves in the soil prior to sowing reached 120–140 kg ha^{-1}. At higher N supply levels no further change in the protein content was observed (Table 3, Fig. 1).

Table 3.

Effect of N supplies on the protein content of maize kernels, g 100 g^{-1} dry matter (SZARVAS, 1997–2004)

Year	N supplies in the 0-60 cm soil layer				$LSD_{5\%}$	Average
	N_0	N_1	N_2	N_3		
	Protein content g $100g^{-1}$ dry matter					
1997	7.30	8.40	8.60	8.80	0.30	8.24
1999	7.70	7.99	8.73	8.97	0.62	8.34
2000	9.37	10.10	10.41	10.25	0.51	10.03
2001	8.44	9.65	10.02	10.18	0.67	9.57
2002	11.17	12.43	12.74	12.87	0.54	12.30
2003	10.22	11.39	11.54	11.76	0.76	11.22
2004	10.05	11.57	12.02	11.91	0.62	11.39
$LSD_{5\%}$ between years	0.75	0.46	0,38	0.56	-	1.05
Range of protein content	7.30-11.17	7.99-12.43	8.60-12.74	8.80-12.87	-	8.27-12.30

The year had a greater effect on the protein content of maize kernels than the N supplies. While N fertilisation increased the protein content by a maximum of 1.3–2.0 percentage points, the effect of the year was 2–3 times as great. When the year effect was analysed for various N supply levels, the fluctuation in the protein content over the experimental period was found to be 3.9% in the N control and 4.1–4.4% in the N treatments, indicating that better N supplies did not reduce the changes in protein content resulting from the year effect. When the effect of N supplies was evaluated for each year it could be seen that in years with poor rainfall supplies N fertilisation resulted in a slightly (0.2–0.3 percentage points) higher protein content compared with years with good water supplies (Table 3).

As the year had a greater modifying effect on protein content than the N supplies, the experimental years were grouped according to yield level when evaluating the year effect.

Years were considered to have a high yield when the grain yield achieved on soil with an 80–100 kg ha^{-1} NO_3-N content in the 0–60 cm layer prior to sowing exceeded 8.5 t ha^{-1}. Years when the grain yield at this N supply level was less than 7.5 t ha^{-1} were considered to have low yields. The close correlation between rainfall distribution, the water supplies during the vegetation period and the yield has been confirmed by many authors (Nagy and Huzsvai 1996, Berzsenyi and Lap 2002). Under the present experimental conditions too, years with high yields had more favourable rainfall distribution and water supplies than those giving lower yields. A negative correlation between yield and protein content was reported by Kralovánszky (1975) and Bálint (1977). In our experiment was found that in years with high yields the protein content, averaged over the N treatments, was lower (8.3–10%) than in years with poorer yields, when it ranged from 11.2–12.3%. However, even in this grouping a smaller, but significant year effect could be detected. The correlation between soil NO_3-N supplies and grain protein content was weak to medium (r=0.41) if years with different weather conditions were analysed together. When the years were grouped according to yield level, however, the correlation between N supplies and protein content was closer, with values of r=0.70 in high-yielding years and r=0.79 in years with lower yields (Table 3, Figs. 1, 2).

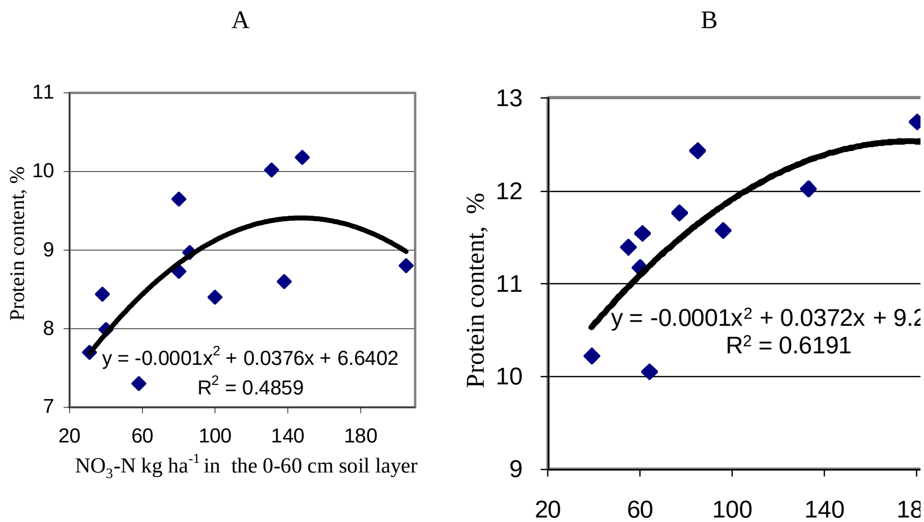

Fig. 1. Relationship between the NO_3-N content of the soil prior to sowing and the protein content of maize kernels (A= in years with high grain yields 2000, 2002, 2003, 2004 B= in years with low grain yields 1997, 1999, 2001)

Amino acid composition

As regards the amino acid composition of the protein (g 100 g^{-1} protein), none of the amino acids exhibited a consistent change in ratio in all the experimental years as the result of N treatment. Of the 17 amino acids examined, Table 4 lists only those that responded to N supplies with a significant change. The N supplies had no effect on the ratio of isoleucine, threonine, alanine, cysteine, glutamic acid or proline in the protein. Of the seven years investigated, the leucine ratio increased in three years, while that of lysine declined at higher N supply levels. In two experimental years there was a significant increase in phenylalanine, but a decrease in the glycine ratio as the result of increasing N supplies. Arginine, methionine, valine, aspartic acid, serine and tyrosine exhibited significant but inconsistent increases or decreases in two or three years as a function of N supplies. The ratio of essential amino acids exhibited a slight increase in most years up to the 80–100 kg ha^{-1} NO_3-N supply level.

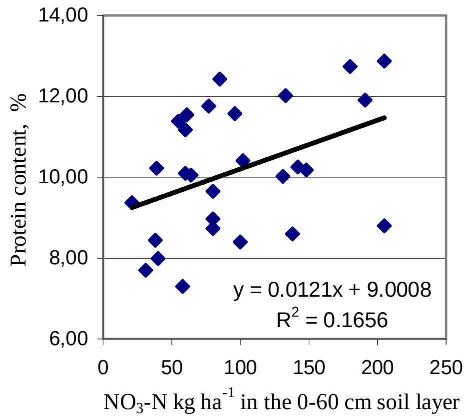

Fig. 2. Relationship between the NO_3-N content of the soil prior to sowing and the protein content of maize kernels (SZARVAS, 1997–2004)

It can be concluded from the data that on this chernozem meadow soil, which had a humus content of almost 3% and which, according to previous studies (IZSÁKI and IVÁNYI 2005), was able to provide around 100 kg ha^{-1} N each year without N fertilisation, the application of an 80 kg ha^{-1} rate of N fertilisation, resulting in 80–100 kg ha^{-1} NO_3-N content in the upper 0–60 cm soil layer prior to sowing, produced a near maximum grain yield (IZSÁKI 1999, 2003) and favourable protein content and amino acid composition, which could not be significantly improved by higher N supply levels.

Effect of the year

The trends in the amino acid composition of maize kernel protein in the experimental years, averaged over the fertiliser treatments, can be seen in Table 5.

In most years the ratio of individual amino acids in the protein was not influenced by N supplies. By contrast, the effect of the year on the amino acid composition was very pronounced. Over the seven experimental years the ratio of individual amino acids fluctuated over a fairly wide range, and significant differences could be demonstrated between the years for all the amino acids in most cases. The ratio of lysine, methionine and cysteine, the group of amino acids that is limiting for the fodder value of maize, also varied greatly, from 5.64–8.37%. The ratio of essential amino acids ranged from 41–45% over the experimental period. The annual changes experienced in the amino acid composition were not consistently correlated either with the protein content or with the yield. The explanation of the year effect will require further analysis.

Depending on the N supplies, the oil content of the maize kernels varied over a narrow range (4.21–4.76%) during the experimental period. Only in one of the four years (2004) was there a significant, but still not large reduction in oil content at the highest N supply level. The year had a slight modifying effect on the oil content, averaged over the N treatments, which was occasionally significant. However, this change in the oil content could not be explained by either the water supplies or the temperature during the grain-filling period or over the whole vegetation period. The results did not confirm the findings of Veneni (1971) who reported a decline in the kernel oil content in cooler than average years (Table 6).

These results suggest that the oil content of the kernel is extremely stable, being only slightly influenced by nutrient supplies and the year.

Table 4.

Effect of N supplies on the amino acid composition of maize protein, g 100 g^{-1} protein (SZARVAS, 1997–2004)

Amino acid	N-supplies in the 0-60 cm soil layer				$LSD_{5\%}$
	N_0	N_1	N_2	N_3	
	Amino acid g $100g^{-1}$ protein				
	1997				
Phenylalanine	3.85	4.40	4.44	4.33	0.42
Leucine	9.90	10.71	10.52	11.17	0.82
Methionine	1.78	1.54	1.40	1.59	0.21
Glutamine	16.23	16.42	17.19	18.24	1.34
Serine	4.95	5.11	5.14	5.47	0.31
	1999				
Lysine	5.83	5.02	4.68	4.89	0.97
Methionine	1.68	1.87	1.48	1.55	0.25
Glycine	4.73	4.66	4.23	4.21	0.47
Tyrosine	1.95	1.93	1.71	2.47	0.41
	2000				
Glycine	3.97	3.86	3.64	3.77	0.26
	2001				
Leucine	10.90	11.60	12.37	12.08	1.18
Lysine	4.02	3.62	3.29	3.33	0.65
Valine	4.38	4.14	4.19	3.73	0.58
Aspartic acid	8.17	6.83	7.48	7.17	0.65
Serine	5.09	4.76	4.89	4.42	0.46
Tyrosine	2.84	2.38	2.59	2.45	0.23
	2002				
Leucine	12.71	13.43	13.26	13.59	0.45
Lysine	3.84	3.53	3.29	3.65	0.32
	2003				
Arginine	4.28	4.73	5.16	4.23	0.75
Phenylalanine	5.16	5.22	5.52	5.72	0.53
Histidine	2.74	2.73	3.04	3.17	0.42
Methionine	2.30	2.43	2.48	2.04	0.14
Valine	4.55	4.93	4.97	5.05	0.45
Tyrosine	2.89	3.79	3.83	2.54	0.61
	2004				
Arginine	4.40	3.31	3.06	3.69	0.53
Aspartic acid	7.60	7.23	8.17	7.21	0.82
Serine	4.71	4.88	5.40	4.70	0.68

The fatty acid composition was only significantly influenced by the N supplies in one year (2004), when the oleic acid content dropped and that of linoleic acid rose when the NO_3-N level in the 0–60 cm soil layer prior to sowing was 96 kg ha^{-1}. However, these changes were relatively slight. At higher N supply levels no further significant changes could be detected (Table 6).

Oil content and fatty acid composition

It has long been known that the composition of plant oils changes as a function of the temperature during the growing period. In cooler years there is an increase in the degree of unsaturation of the fatty acids (HITCHCOCK and NICHOLS, 1971). According to HILDITCH and WILLIAMS (1964) these changes primarily affect the oleic, linoleic and linolenic acids, with a greater accumulation of oleic acid under warmer conditions at the expense of linoleic and linolenic acids.

Table 5.

Amino acid composition of maize kernels during the experimental years, g 100 g^{-1} protein (SZARVAS, 1997–2004)

Amino acid (AA)	Years with high grain yield (HGY)			Years with low grain yield (LGY)				$LSD_{5\%}$	Average	Average		Range
	1997	1999	2001	2000	2002	2003	2004			HGY	LGY	
Essential AA												
Arginine	3.87	4.71	4.93	4.22	3.83	4.60	3.62	0.52	4.25	4.50	4.06	3.62-4.93
Phenylalanine	4.26	5.13	5.38	5.09	5.01	5.40	4.92	0.34	5.02	4.92	5.10	4.26-5.40
Histidine	2.65	3.45	3.64	2.87	3.16	2.92	3.12	0.34	3.12	3.24	3.01	2.65-3.64
Isoleucine	2.90	3.31	3.09	3.50	3.26	3.49	3.97	0.21	3.36	3.10	3.55	2.90-3.97
Leucine	10.58	10.89	11.73	11.43	13.24	11.92	11.30	0.65	11.58	11.06	11.97	10.58-13.24
Lysine	3.79	5.10	3.56	4.01	3.57	3.61	2.30	0.44	3.71	4.15	3.57	2.30-5.10
Methionine	1.57	1.65	0.99	0.93	2.15	2.31	2.16	0.19	1.68	1.40	1.88	0.93-2.31
Threonine	3.84	3.91	3.79	3.63	3.77	3.29	3.79	0.20	3.72	3.84	3.62	3.29-3.91
Valine	5.25	4.85	4.11	4.98	3.73	4.87	4.90	0.39	4.67	4.73	4.62	3.73-5.25
Total EAA	**38.71**	**43.00**	**41.22**	**40.66**	**41.72**	**42.41**	**40.08**	**-**	**41.11**	**40.94**	**41.18**	**38.71-43.00**
Non-essential AA												
Alanine	7.02	7.72	7.09	7.55	7.97	7.77	9.33	0.37	7.78	7.23	8.16	7.02-9.33
Aspartic acid	6.69	7.96	7.41	8.25	7.02	6.72	7.55	0.45	7.37	7.35	7.39	6.69-8.25
Cysteine	1.82	1.62	1.09	1.22	2.09	1.96	2.27	0.16	1.72	1.51	1.88	1.09-2.27
Glycine	4.70	4.45	4.47	3.81	4.50	3.40	3.99	0.29	4.19	4.54	3.93	3.40-4.70
Glutamic acid	17.02	17.47	17.44	17.22	20.58	17.56	17.90	0.98	17.88	17.31	18.32	17.02-20.58
Proline	9.03	9.31	7.01	8.53	8.61	6.86	9.47	0.75	8.40	8.45	8.37	6.86-9.47
Serine	5.17	4.81	4.79	4.88	5.13	4.59	4.92	0.29	4.90	4.92	4.88	4.59-5.17
Tyrosine	2.15	2.01	2.56	2.95	0.83	3.26	2.48	0.43	2.32	2.24	2.38	0.83-3.26
Total NEAA	**53.60**	**55.35**	**51.86**	**54.41**	**56.73**	**52.12**	**57.91**	**-**	**54.56**	**53.55**	**55.31**	**51.86-57.91**
Total EAA+NEAA	**92.31**	**98.35**	**93.08**	**95.07**	**98.45**	**94.53**	**97.99**	**-**	**95.67**	**94.49**	**96.49**	**92.31-98.35**
EAA/NEAA	**42/58**	**44/56**	**44/56**	**43/57**	**42/58**	**45/55**	**41/59**	**-**	**43/57**	**43/57**	**43/57**	**41/59-45/55**

The present results for maize did not confirm these findings, since the oleic acid content was significantly higher and the linoleic acid content significantly lower in 2001, when the mean temperature during the vegetation period was 18.5°C, than in 2002 and 2003, when the mean temperature was 19.5 and 20.4°C, respectively. The joint ratio of oleic and linoleic acid within the total lipids was practically unchanged, at 84.4–85% over the experimental period (Table 6). A negative correlation was found between the relative quantities of linoleic and oleic acid (CHEESBROUGH et al. 1997, SEO et al. 1998).

CONCLUSIONS

1. The protein content of maize kernels rose substantially, by 1.1–1.5 percentage

points when the NO_3-N level in the 0–60 cm soil layer rose to 80–100 kg ha^{-1} prior to sowing. The year had a greater influence on the protein content than the N supplies.

2. A consistent N effect, detected as a change in the ratio of any amino acid in the majority of the experimental years, was not observed in the amino acid composition of the protein.

3. The oil content and fatty acid composition of the maize kernels was extremely stable, being only influenced to a slight extent by nutrient supplies and the year. During the experimental period excessive N supplies only reduced the oil content and modified the fatty acid composition on one occasion.

Table 6.

Effect of N supplies on the oil content and fatty acid composition of maize kernels, %
(SZARVAS, 2001–2004)

Components	N supplies in 0–60 cm soil layer				$LSD_{5\%}$	Average
	N_0	N_1	N_2	N_3		
		2001				
Oil content, %	4.21	4.26	4.36	4.34	NS	4.29
Palmitic (C 16:0)	11.72	11.60	11.46	11.67	NS	11.61
Stearic (C 18:0)	2.21	2.08	2.00	1.95	NS	2.06
Oleic (C 18:1)	37.39	37.10	36.99	37.12	NS	37.15
Linoleic (C 18:2)	47.14	47.63	47.94	47.89	NS	47.65
Alpha-linolenic (C 18:3)	1.07	1.09	1.15	0.89	NS	1.05
Arachidic (C 20:0)	0.49	0.47	0.47	0.41	NS	0.46
		2002				
Oil content, %	4.45	4.27	4.37	4.29	NS	4.35
Palmitic (C 16:0)	11.53	11.58	11.60	11.61	NS	11.58
Stearic (C 18:0)	1.85	1.82	1.81	1.79	NS	1.82
Oleic (C 18:1)	33.94	33.33	33.60	33.52	NS	33.60
Linoleic (C 18:2)	50.92	51.69	51.56	51.44	NS	51.40
Alpha-linolenic (C 18:3)	1.06	1.11	1.11	1.09	NS	1.09
Arachidic (C 20:0)	0.45	0.39	0.31	0.53	NS	0.42
		2003				
Oil content, %	4.58	4.60	4.54	4.55	NS	4.57
Palmitic (C 16:0)	11.94	11.91	11.74	11.97	NS	11.89
Stearic (C 18:0)	2.13	2.16	2.11	2.20	NS	2.15
Oleic (C 18:1)	34.57	34.75	34.53	34.76	NS	34.65
Linoleic (C 18:2)	49.75	49.62	50.05	49.49	NS	49.73
Alpha-linolenic (C 18:3)	1.05	1.04	1.05	1.05	NS	1.05
Arachidic (C 20:0)	0.56	0.52	0.52	0.53	NS	0.53
		2004				
Oil content, %	4.76	4.60	4.57	4.54	0.22	4.61
Palmitic (C 16:0)	11.45	11.63	11.59	11.42	NS	11.52
Stearic (C 18:0)	2.04	2.07	2.01	1.99	NS	2.03
Oleic (C 18:1)	35.52	34.52	34.34	34.34	0.91	34.68
Linoleic (C 18:2)	49.47	50.29	50.55	50.75	0.86	50.26
Alpha-linolenic (C 18:3)	1.02	0.99	1.00	1.02	NS	1.01
Arachidic (C 20:0)	0.49	0.49	0.51	0.48	NS	0.49

$LSD_{5\%}$ between years: Oil content: 0.11; Oleic acid: 0.50; Linoleic acid: 0.60
Stearic acid: 0.09;Palmitic acid: 0.15

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