

EFFECT OF NITROGEN SUPPLIES ON PROTEIN CONTENT AND AMINO ACID COMPOSITION IN MAIZE (*ZEA MAYS* L.) KERNELS

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Introduction

Normal maize varieties have a protein content of 8-12%, consisting mainly of zein (50-55%) and glutenin (30-45%) which are poor in lysine, methionine, cysteine and tryptophan (Lásztity 1981, Matuz et al. 2001, Györi and Mile 2002). Fundamentally, the protein content and amino acid composition of maize kernels are determined genetically, but ecological and agronomic factors may also modify them. Among the agronomic factors, the quality of the nutrient supplies has the greatest influence. Many authors have proved that better N supplies increase the protein content (Veress 1973, Prokszáné et al. 1995, Izsáki 1999), but the correlation between the N supplies and the amino acid composition is not so consistent (Veress 1973, Németh 1985, Kádár et al. 2000, Györi and Mile 2002). The effect of N fertilization on protein content and amino acid composition may be modified by the year, especially the water supply (Prokszáné et al. 1995, Pásztor et al. 1997, Tuba, 2005).

In order to develop precise, environment-friendly, quality-oriented plant nutrition techniques for maize, it has been essential over the last decade to place N fertilisation on a new basis, through the elaboration and application of a fertilisation system based on the measurement of soil mineral N contents (Németh 1996). In relation to this N fertilization system, few data are available on the correlation between the N_{min} reserves of the soil prior to sowing and the quality of maize. The aim of the paper is to provide new results for the development of quality-oriented N fertilisation for maize.

Methods

The long-term mineral fertilization experiments were set up at the Experimental Station of the Crop Production Department, TSC, Szarvas, in 1989, on chernozem meadow soil. Fertilization 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 fertilizations as the „A” factor, P fertilization as the „B” factor and N fertilization as the „C” factor. The following fertilizer 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): $P_0=0$, $P_1=100$ 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 Pioneer hybrid Clarica (FAO 310) was used in the maize experiment. The NO_3 -N+ NH_4 -N content of the soil were determined using 1 N KCl method. Estimation of N supply level the NO_3 -N content of 0-60 cm soil layer at prior to planting was used. For calculation of crude protein content ($N \times 6.25$) the total N was measured by the macro-Kjeldahl method. The amino acids were measured after acidic (6 M HCl) hydrolysis by HPLC ion exchange column chromatography. In this paper the main N effects results are presented during the experimental period of 1997-2004.

Results and discussion

The protein content of the maize kernels ranged from 7.3-12.9% during the experimental years, depending on the N supplies and the year. An evaluation of the N effect revealed that,

compared to the treatment without N fertilization, fertilization with 80 kg ha⁻¹, resulting in NO₃-N values 80-100 kg ha⁻¹ in the 0-60 cm soil layer prior to sowing, led to increases of 1.1-1.5% in the protein content in the majority of years. Higher NO₃-N levels of the soil generally did not result in any further significant increase in protein content. The year, particularly the water supplies, had a considerable modifying effect on the protein content than the N supplies.

Table 1. Protein content and amino acid composition of maize kernels during the growing seasons (Szarvas, 1997-2004)

Components	Average	Interval	Average	Interval
Protein content, %	10.15	7.3-12.9	10.15	7.3-12.9
Amino acids (AA)	g 100g ⁻¹ dry matter		g 100g ⁻¹ protein	
Essential AA				
Arginine	0.42	0.32-0.51	4.25	3.62-4.93
Phenylalanine	0.51	0.35-0.62	5.02	4.26-5.40
Histidine	0.32	0.22-0.35	3.12	2.65-3.64
Isoleucine	0.34	0.24-0.45	3.36	2.90-3.97
Leucine	1.19	0.88-1.63	11.58	10.58-13.24
Lysine	0.37	0.26-0.42	3.71	2.30-5.10
Methionine	0.18	0.10-0.27	1.68	0.93-2.31
Treonine	0.38	0.32-0.47	3.72	3.29-3.91
Valine	0.47	0.39-0.56	4.67	3.73-5.25
Total EAA	4.18	3.20-5.15	41.11	38.71-43.00
Non-essential AA				
Alanine	0.80	0.58-1.06	7.78	7.02-9.33
Aspartic acid	0.75	0.55-0.87	7.37	6.69-8.25
Cysteine	0.18	0.11-0.26	1.72	1.09-2.09
Glycine	0.42	0.37-0.56	4.19	3.40-4.70
Glutamic acid	1.83	1.41-2.54	17.88	17.02-20.58
Proline	0.85	0.67-1.08	8.40	6.86-9.47
Serine	0.50	0.40-0.63	4.90	4.81-5.17
Tyrosine	0.23	0.10-0.36	2.32	0.83-3.26
Total NEAA	5.56	4.42-7.00	54.56	51.86-57.91
Total EAA + NEAA	9.74	7.62-12.15	95.67	92.31-98.35
EAA/NEAA	43/57	41/59-45/55	43/57	41/59-45/55

The protein content was lower 8.3-10.0%, averaged over the N treatments, when the water supplies were favorable and the yield was above 8.5 t ha⁻¹. When the rainfall distribution was less favorable or the growing season dry the protein content was 11.2-12.3, accompanied by lower grain yield than 7.5 t ha⁻¹.

During the experimental years the amino acid composition of maize kernels and the essential and non-essential amino acid ratios changed relatively wide interval showing the significant influence of the years (Table 1.). A consistent N effect detectable as a change in the ratio of any amino acid in all experimental years could not be demonstrated in the amino acid composition of the protein. So, of the 17 amino acids examined, Table 2. only contains data on those which showed significant changes as a function of the N supplies. The N supplies did not influence the ratio of isoleucine, treonine, alanine, cysteine and glutamic acid. In three years from seven examined the ratio of leucine increased while the lysine decreased. In two years significant increase was observed in the quantities of phenylalanine while decrease in glycine in line with the better N supplies. The ratio of arginine, methionine, valine, aspartic acid, serine and tyrosine showed not consistent significant changes in two or three years according to the N supplies.

Table 2. Effect of N supplies on the amino acid composition of maize protein, g 100g⁻¹ protein (Szarvas, 1997-2004)

Year Amino acid	Amino acid g 100g ⁻¹ protein				LSD _{5%}
	N ₀	N ₁	N ₂	N ₃	
1997	NO ₃ +NH ₄ -N kg ha ⁻¹ , in 0-60 cm soil layer				0.42 0.82 0.21 1.34 0.31
	58+36	100+41	138+40	205+53	
Phenylalanine	3.85	4.40	4.44	4.33	
Leucine	9.90	10.71	10.52	11.17	
Methionine	1.78	1.54	1.40	1.59	
Glutamin acid	16.23	16.42	17.19	18.24	
Serine	4.95	5.11	5.14	5.47	
1999	NO ₃ +NH ₄ -N kg ha ⁻¹ , in 0-60 cm soil layer				0.97 0.25 0.47 0.41
	31+17	40+20	80+18	86+18	
Lisyne	5.83	5.02	4.68	4.89	
Methionine	1.68	1.87	1.48	1.55	
Glycine	4.73	4.66	4.23	4.21	
Tyrozine	1.95	1.93	1.71	2.47	
2000	NO ₃ +NH ₄ -N kg ha ⁻¹ , in 0-60 cm soil layer				
	21+28	60+70	102+112	142+148	
Glycine	3.97	3.86	3.64	3.77	
2001	NO ₃ +NH ₄ -N kg ha ⁻¹ , in 0-60 cm soil layer				1.18 0.65 0.58 0.65 0.46 0.23
	38+5	80+6	131+8	148+11	
Leucine	10.90	11.60	12.37	12.08	
Lisyne	4.02	3.62	3.29	3.33	
Valine	4.38	4.14	4.19	3.73	
Aspartic acid	8.17	6.83	7.48	7.17	
Serine	5.09	4.76	4.89	4.42	
Tyrozine	2.84	2.38	2.59	2.45	
2002	NO ₃ +NH ₄ -N kg ha ⁻¹ , in 0-60 cm soil layer				0.45 0.32
	60+18	85+19	180+20	205+21	
Leucine	12.71	13.43	13.26	13.59	
Lisyne	3.84	3.53	3.29	3.65	
2003	NO ₃ +NH ₄ -N kg ha ⁻¹ , in 0-60 cm soil layer				0.75 0.42 0.14 0.53 0.45 0.61
	39+53	55+52	61+53	77+68	
Arginine	4.28	4.73	5.16	4.23	
Phenylalanine	2.74	2.73	3.04	3.17	
Histidine	2.30	2.43	2.48	2.04	
Methionine	5.16	5.22	5.52	5.72	
Valine	4.55	4.93	4.97	5.05	
Tyrozine	2.89	3.79	3.83	2.54	
2004	NO ₃ +NH ₄ -N kg ha ⁻¹ , in 0-60 cm soil layer				0.53 0.82 0.68
	64+22	96+22	133+23	191+22	
Arginine	4.40	3.31	3.06	3.69	
Aspartic acid	7.60	7.23	8.17	7.21	
Serine	4.71	4.88	5.40	4.70	

Conclusions

It can be seen from the data that on chernozem meadow soil with a humus content of almost 3% shown by previous analyses to have an N-supplying ability of 100 kg ha⁻¹ without N fertilization, the application of 80 kg ha⁻¹ N fertilizer, leading to an NO₃-N level of 80-100 kg ha⁻¹ in the 0-60 cm soil layer prior to showing, resulted in a grain yield close to the maximum, with favorable protein content and amino acid composition. A further increase in the N supplies was unable to given significantly higher yield or better quality.

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