

Research Article

Effect of Long-term Application of Chemical Fertilizer on the Quality of Summer Maize

Mingzhang Yuan, Bin Liang, Shutang Liu, Yanling Chen, Jintao Liu, Zhenwu Nan and Guangkai Zhang
College of Resources and Environmental Sciences, Qingdao Agricultural University,
Qingdao 266109, China

Abstract: The study on the effect of fertilization on the quality of maize grain was conducted based on continue application of fertilizer for 26 and 36 years in gleyic cambisols. The amounts of protein, starch, fat and amino acid were determined and the amino acid was analyzed by cluster analysis. The results showed: Long-term fertilization 26 years showed that N₂K and N₂P processing protein content as high as 9.01, 9.01%, lowest comparing CK treatment is 5.52%; all fertilizer treatments reduced the summer maize starch content, including N₂PK deal with relatively high starch content is 57.55%; N₂K processing crude fat content as high as 5.95%; N₂P processing total amino acids and essential amino acid content is the highest, 8.13 and 3.22%, respectively. Long-term fertilization 36 years (2013) summer maize grain each nutrition indicators in line with 26 years change rule.

Keywords: Amino acid, fat, long term fertilization, protein, quality, starch, summer maize

INTRODUCTION

Compared to the long-term fertilization experiment with routine test, has for a long time and climate advantages, provided data to solve many theoretical and practical problems has an important role (Zhao and Zhang, 2002). Maize is an important food crop and its nutritional quality refers to the nutrient components in the grain and the nutritional value of human and livestock. Its main quality traits include protein, amino acid, fat, starch four aspects. Maize quality except for variety, environment and cultivation techniques factors (Ma *et al.*, 2007; Wu *et al.*, 2008) and harvest time also have great relationship; corn harvest time is generally in the largest output, the quality of the best period (Herrmann *et al.*, 2005). Some studies have indicated that summer maize delayed harvest and yield increase meanwhile significantly affected the quality of corn grain (Meng *et al.*, 2007; Wen *et al.*, 2007; Zhang *et al.*, 2010). Liu *et al.* (2010) indicated that the effect of different fertilization levels on the lysine content of maize was not significant. Shen *et al.* (2008) show that the regulation affects of nitrogen fertilizer on maize plant material production capacity is more obvious; nitrogen fertilizer had greater control of nitrogen fertilizer and corn on corn plant material production capacity and is mainly influenced by grain number per spike.

Chen and Zhao (2006) showed that spring maize grain amylose, amylopectin, the total starch accumulation in the filling period showed an upward trend, conform to the law of "S" curve. Within a certain

range, the content of starch increased with the increase of nitrogen application rate. Feng *et al.* (2006) of waxy corn in autumn sowing date tests found, there was no significant change of pure corn seeding time found during grain filling the changing trends of main quality components, but had a great influence on the content of main quality components. In general, there is a lot of research on the effects of fertilization on the quality of maize, however, the effect of long-term fertilization on the quality of summer maize in the fluvo-squic soil is not reported (Oikeh *et al.*, 1998; Belay *et al.*, 2002; Montemurro *et al.*, 2002; Huang *et al.*, 2010). Therefore, this study use began in 1978 the Laiyang non calcareous fluvo aquic soil, long-term fertilization, respectively, to study the effect of 2003 and 2013 nitrogen fertilizer and the combined application of phosphorus and potassium on grain quality of summer maize, aimed at for rational fertilization in maize, the production of high quality corn provides a theoretical basis.

MATERIALS AND METHODS

Experiment design: The experiment was built up in Qingdao Agricultural University long term location experiment base, in Laiyang (36.9°N, 120.7°E) since 1978. It is Warm temperate semi-humid monsoon climate. The mean annual rainfall and temperature are 779.1 mm and 11.2°C, it is non lime fluvo-aquic soil, separately. It is gleyic cambisols and the basic properties are as follows: 6.8 pH; 4.10 g/kg Soil Organic Matter (SOC); 0.50 g/kg Total Nitrogen (TN);

Corresponding Author: Shutang Liu, College of Resources and Environmental Sciences, Qingdao Agricultural University, Qingdao 266109, China

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Table 1: Experimental selected 6 fertilization treatments (kg/ha)

Treatments	Fertilizer type and amounts (kg/ha)	Treatments	Fertilizer type and amounts (kg/ha)
CK	0	N ₂ P	N: 276; P ₂ O ₅ :90
N ₁	N: 138	N ₂ K	N:276; K ₂ O:135
N ₂	N: 276	N ₂ PK	N:276; P ₂ O ₅ :90 K ₂ O:135

Footnotes 1 and 2 respectively represent the low and high volume fertilization

Table 2: Starch contents of maize grain in different fertilization treatments

Treatments (%)	Starch content (%)		
	26 years (2003)	36 years (2013)	Amplitude (%)
CK	62.15±0.52 a	66.25±0.47 a	6.60
N ₁	45.76±0.36 de	52.35±0.58 cd	14.41
N ₂	45.03±0.56 e	50.35±0.25 e	11.81
N ₂ PK	57.55±0.19 b	58.58±0.43 b	1.80
N ₂ P	46.12±0.51 d	52.87±0.49 c	14.63
N ₂ K	48.26±0.26 c	51.76±0.55 d	7.25

Different small letter indicate significantly different at 5% levels

0.46 g/kg total Phosphorus (total P); 15 mg/kg Olsen P; 38 mg/kg Available Potassium (AK) and 11.8 mol/kg Cation Exchange Capacity (CEC). The rotation of wheat and maize were in the autumn and summer every year, the types of maize was Luyu 16.

The experiment began in the autumn of 1978, total 12 processing, 3 repeat, randomized block arrangement design, 36 cells, each cell area 33.3 m², cell with 1.0 m glass plate separated, no leakage and independent irrigation. This thesis selects 6 of them to analyze the process. Respectively non fertilization control treatment (CK), single application low (N₁), high amount of nitrogen fertilizer (N₂), high nitrogen and phosphorus fertilizer (N₂P), potassium fertilizer treatment (N₂K), combined application of N, P and K (N₂PK). The urea was used for N fertilizer, the application of P₂O₅ and KCL for the P and K fertilizer, the P and K was used as basic fertilizer, as a kind of nitrogen fertilizer and wheat rose, fertilizer and Maize Jointing, heading fertilizer, other management measures are the same. There were six treatments in this study (Table 1).

Experiment method: The summer maize grain samples were protected by paper bags in the field and samples in 2003 and 2013 were used in this study. In each plot, 30 samples were random collected and kept 25% samples on average. All the samples were sieved to 0.25 mm. The content of protein of the wheat was investigated by Kjeldahl determination. The starch was determined by anthranone-H₂SO₄ and fat was tested by residue method, but automatic amino-acid analyzer analyzed the amino acid. All the data were analyzed by SPSS 19.0.

RESULTS

Effect of long-term fertilization on the starch of summer maize grain: The starch content of all fertilizer treatments than CK treatment are falling, fertilization affected maize grain starch content. 26 years long-term experiment, comparing CK treatment

compared to other fertilization starch content as high as 62.15%; N₂PK with higher 57.55%; N₁ and N₂ treatment at the same level, for low starch content processing, fell more than 26% compared with CK treatment. 36 years long-term experiment, besides comparing CK treatment, N₂PK processing content as high as 58.58%; N₂ deal with lowest amount is 50.35%; NP with two processing N₂PK, N₂P starch content increased significantly; each processing starch content decreased: CK> N₂PK> N₂P> N₁> N₂K> N₂ (Table 2). 26 years with 36 years of the test results show that with the increase of N application, maize grain starch content showed a trend of decrease, illustrate the N fertilizer in maize grain starch content decreased and with the increasing of application rate of N amount, drop increases accordingly; N₂PK processing compared with N₂K, N₂P processing, content increase rate is higher, that single P fertilizer or K fertilizer to improve the maize starch content effect is not obvious, N₂PK with can significantly improve the maize starch content.

Effect of long-term fertilization on the fat of summer maize grain: The starch content of all fertilizer treatments than CK treatment were increased, fertilizing influence crude fat content of maize kernels. 26 years long-term experiment shows that N₂K processing content up to 5.75%, compared with the CK treatment increased by 1.54%; N₂P processing second-highest is 5.09%; N₂ treatment adipose content is higher than N₁, both differ by 0.52%. A long-term experiment, 36 years N₂K processing crude fat content as high as 4.95%, the order from high to low is: between the groups: N₂K> N₂PK> N₂P >N₁> N₂> CK (Table 3). Illustrate the high amount of N fertilizer fertilizer can raise the content of the maize grain crude fat and K fertilizer, P fertilizer promote synthesis and accumulation of fat.

Effect of long term fertilization on the protein of summer maize grain: The fertilizer processing maize protein content CK have increased significantly than control, fertilization can significantly improve the

Table 3: Crude fat contents of maize grain in different fertilization treatments

Treatments	Crude fat content (%)		Amplitude
	2003	2013	
CK	4.21±0.16 d	4.26±0.33 b	1.12
N ₁	4.51±0.15 cd	4.14±0.30 b	-8.24
N ₂	5.03±0.25 bc	4.53±0.21 ab	-9.81
N ₂ PK	5.07±0.39 b	4.67±0.28 ab	-7.94
N ₂ P	5.09±0.29 b	4.59±0.29 ab	-9.85
N ₂ K	5.75±0.05 a	4.95±0.14 a	-13.99

Different small letter indicate significantly different at 5% levels

Table 4: 26 years (2003) Effect of different fertilizing on the content of amino acid (%)

Amino acid	Treatments					
	CK	N ₁	N ₂	N ₂ PK	N ₂ P	N ₂ K
THR*	0.23	0.26	0.29	0.28	0.35	0.3
VAL*	0.26	0.3	0.33	0.32	0.39	0.36
MET*	0.15	0.17	0.17	0.17	0.19	0.16
ILE*	0.17	0.2	0.24	0.23	0.29	0.26
LEU*	0.61	0.7	0.93	0.87	1.2	1.04
PHE*	0.25	0.29	0.32	0.34	0.44	0.39
LYS*	0.28	0.32	0.29	0.3	0.36	0.33
ASP*	0.38	0.44	0.49	0.47	0.58	0.51
SER*	0.28	0.29	0.38	0.36	0.47	0.41
GLU*	0.99	0.32	1.45	1.38	1.85	1.61
GLY*	0.25	1.14	0.29	0.27	0.31	0.28
ALA*	0.4	0.46	0.57	0.53	0.69	0.61
CYS*	0.16	0.18	0.17	0.19	0.21	0.19
TYR*	0.08	0.09	0.111	0.13	0.14	0.1
HIS*	0.17	0.19	0.21	0.22	0.26	0.23
ARG*	0.28	0.32	0.34	0.35	0.4	0.36
Essential Amino Acid*	1.95	2.24	2.57	2.51	3.22	2.84
Total Amino Acids	4.94	5.67	6.58	6.41	8.13	7.14

All data are repeated three times average; “*” must nutrition amino acids for human body

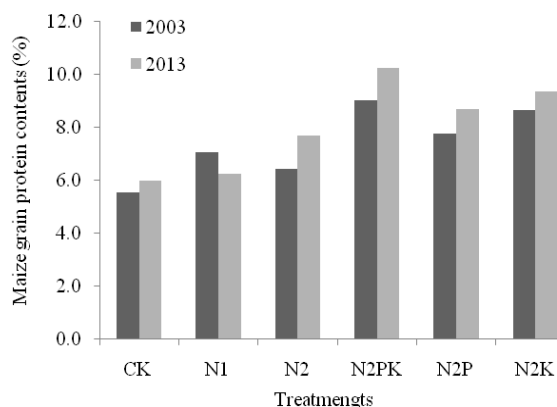


Fig. 1: Protein contents of maize grain in different fertilization treatments

maize grain protein content. 26 years long-term experiment, N₂K, N₂P treatment up to 9.01 and 8.64%, compared with CK treatment increased by 3.49, 3.12%, 36 years long-term experiment, N₂K as high as 10.21%, compared with CK treatment increased by 4.26%; the second is N₂P with 9.35%, compared with CK treatment increased by 3.4%, compared with N₂ and N₁ processing. Compared with 26 years, long-term N₂K fertilizer treatment by up to 13.32%; followed by long-term N₂PK fertilizer processing and the growth rate of 12.29%; long-term fertilization of 10.63% N₂ treatment,

N₁ handle is on the decline (Fig. 1). Shows the high amount of nitrogen fertilizer, K fertilizer can significantly improve and maize grain protein content, N₂PK with fertilization effect is stable and showed a trend of increased year by year, indicates that the main factors influencing the maize protein content is N, followed by K, the last is P, similar to previous results.

Effect of long-term fertilization on the amino acid of summer maize grain: 26 years long-term fertilization experiment, compared with CK treatment, all fertilizer treatments were significantly improve amino acid and essential amino acid content in maize grains, with N₂P treatment, among them the highest total amino acid and essential amino acid content, 8.13, 3.22%, respectively, compared with the CK treatment increased by 64.57, 65.13% (Table 4). That illustrate the impact of P fertilizer for amino acid, can promote the accumulation of amino acid; compared with N₁ and N₂, N₂ to deal with a high content of amino acids, that high amount of n fertilizer can raise the content of the maize grain amino acid; N₂K treatment just below N₂P amino acid content; the fertilizer processing amino acids in the order: N₂P> N₂K> N₂> N₂PK> N₁> CK.

Clustering analysis based on Q clustering of SPSS clustering in 6 processes into three categories (Fig. 2). It can be seen that, from 1 to 3 kind of amino acid content is lower, N₂, N₂PK and N₂K similarity of amino

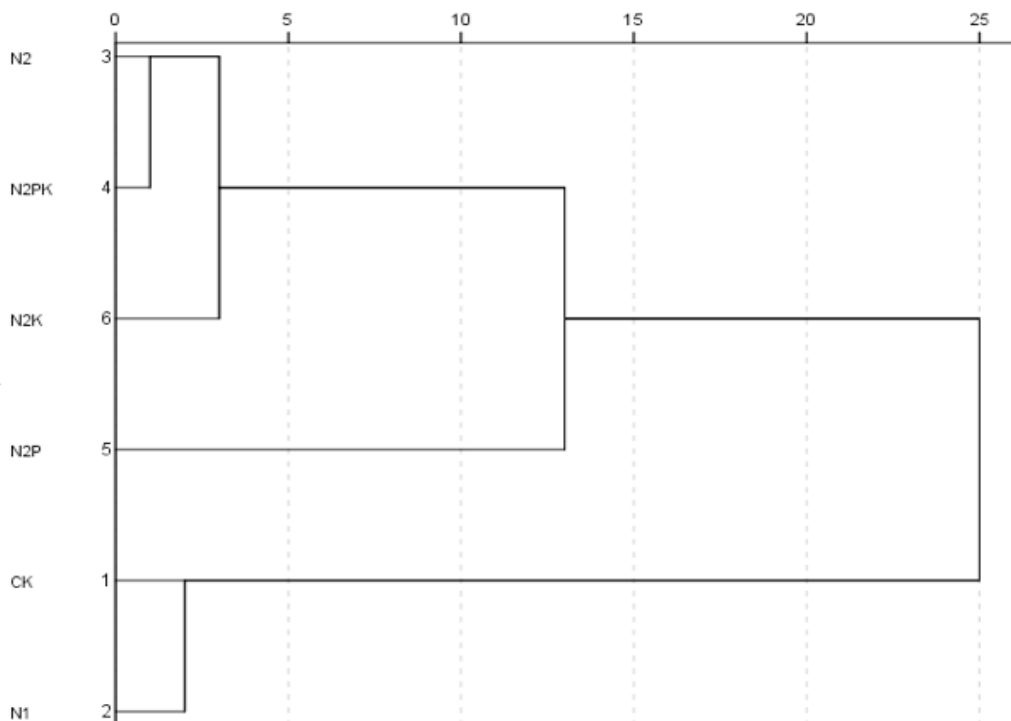


Fig. 2: Long-term fertilization experiment of maize grain amino acid composition of hierarchical cluster analysis results (26 years)

Table 5: 36 years (2013) Effect of different fertilizing on the content of amino acid (%)

Amino acid	Treatments					
	CK	N ₁	N ₂	N ₂ PK	N ₂ P	N ₂ K
THR*	0.19	0.25	0.25	0.26	0.28	0.27
VAL*	0.23	0.29	0.3	0.31	0.33	0.32
MET*	0.15	0.16	0.15	0.15	0.15	0.16
ILE*	0.15	0.2	0.2	0.22	0.23	0.23
LEU*	0.52	0.75	0.78	0.83	0.87	0.88
PHE*	0.24	0.32	0.33	0.35	0.36	0.35
LYS*	0.24	0.29	0.31	0.3	0.32	0.31
ASP*	0.31	0.42	0.41	0.44	0.46	0.45
SER*	0.23	0.32	0.32	0.34	0.35	0.35
GLU*	0.84	1.15	1.18	1.27	1.33	1.34
GLY*	0.22	0.26	0.26	0.27	0.29	0.28
ALA*	0.34	0.46	0.48	0.51	0.53	0.53
CYS*	0.16	0.17	0.17	0.17	0.18	0.18
TYR*	0.1	0.09	0.09	0.12	0.13	0.11
HIS*	0.15	0.19	0.19	0.2	0.22	0.21
ARG*	0.24	0.3	0.3	0.32	0.34	0.33
Essential Amino Acid*	1.72	2.26	2.57	2.51	2.54	2.52
Total Amino Acids	4.31	5.62	6.58	6.41	6.37	6.3

All data are repeated three times average; “*” must nutrition amino acids for human body

acid content is higher, together for the first class; N₂P treatment separately for class 2; CK, N₁ processing results similar to class 3. 2013 and 2003 compared to produce change, N₂, N₁ treatment for second categories, CK treatment alone is divided into third categories.

In Table 5, 36 years long-term fertilization experiment, compared with CK treatment, all fertilizer treatments can raise the content of the maize grain amino acids, of which N₂P deal with highest total amino acid content of 6.37%, which increased by

28.95% over CK, essential amino acid content is as high as 2.54%, increased by 30.26% than CK control treatments, this illustrates of P fertilizer influence on amino acids, can promote the accumulation of amino acids; N₂K treatment just below N₂P, N₂PK processing amino acid content than 26 years, the rest of the process change law is consistent, through long-term fertilization, N₂PK with treatment on the influence of amino acids gradually increase. The results showed that the factors influencing the summer maize protein

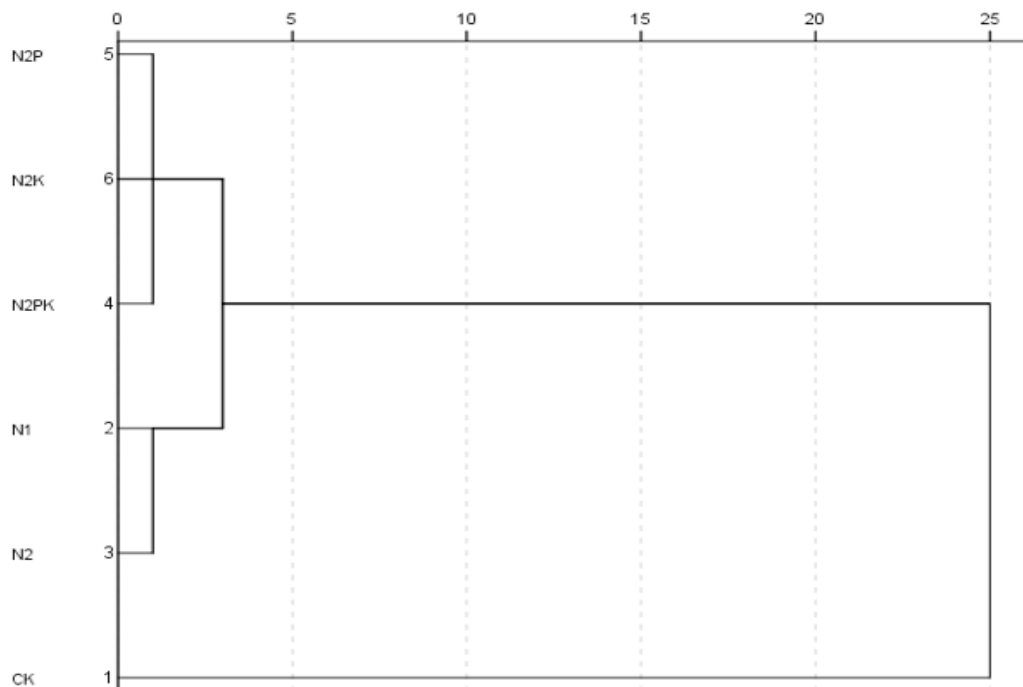


Fig. 3: Long-term fertilization experiment of maize grain amino acid composition of hierarchical cluster analysis results (36 years)

content of the main is N, followed by P element, the last is the K factor.

For six processing (36 years) clustering analysis, the generated clustering analysis tree diagram into three categories (Fig. 3). As you can see, from 1 to 3 kind of amino acid content is lower, N₂P, N₂K and N₂PK similarity of amino acid content is higher, together for the first class; N₁, N₂, processing into 2 classes; CK treatment alone together for class 3.

DISCUSSION

Show that it has been reported in nitrogen fertilizer can significantly improve the summer maize grain protein content, within a certain range protein content increased with the increase of amount of N application (Yang *et al.*, 2009; Li *et al.*, 2004). Jin *et al.* (2004) studies have shown that summer maize grain protein content increased with N application rate increased. Grain protein content is very significant positive correlation with N application rate, consistent with the test results. Which shows that nitrogen fertilizer on summer maize grain protein content in the enhancement effect is relatively stable; N₂P treatment significantly increased the amino acid and essential amino acids, which shows on the basis of high nitrogen with P fertilizer can significantly improve the content of amino acids in maize kernels, Zhang *et al.* (2004) study applied P effect on protein content and grain amino acid content is not obvious, do not agree with the test results. May be because the varieties tested, fertilizer and soil

environment. Wang and Ju (2012) and Yi *et al.* (2008) thinks that potassium can promote grain protein synthesis and can improve the summer maize grain protein content and amino acid content, with the same experimental results. Huang *et al.* (2004) research thinks, with the increase of n application maize grain crude fat content increased. Shi and Zhang (1994) suggested appropriate use of potash fertilizer can improve the fat content, but excessive K fertilizer can produce inhibition. Genter *et al.* (1956) and Wang *et al.* (2006) reported that P of fat did not make any difference, are the same as the experimental research results.

CONCLUSION

The test results show that the application of inorganic fertilizer can significantly improve the quality of summer maize kernels, especially on the basis of applying high amount of N fertilizer with P fertilizer and a moderate amount of increasing K fertilizer application could obviously increase the summer maize grain quality.

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