Advance Journal of Food Science and Technology 11(1): 33-39, 2016
DOI:10.19026/ajfst.11.2350
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: May 7, 2015 Accepted: August 30, 2015 Published: May 05, 2016

Research Article

Effects of Long-term Fertilization on Grain Quality of Summer Maize

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Abstract: To study the effect of non-calcareous fluvo-aquic soil long-term fertilization on grain quality of summer maize to improve the nutritional grain quality of summer maize. The use of began in 1978 Laiyang non-calcareous fluvo-aquic soil long-term experiment in 2003, 2013 summer maize grain and determination of the grain quality of summer maize in the main indicators of protein, starch, crude fat, etc. and the necessary of summer maize grain under different fertilizer amino acids in hierarchical clustering analysis. The study have shown that different long-term fertilization experiment, The M2N2 of grain protein content was the highest, in 2003 and 2013 respectively is 9.01 and 10.21%; the M2N2 of crude fat content was the highest, respectively is 4.95 and 5.35%; In fertilization treatment, the M2 of starch content was the highest, respectively 68.55 and 69.58%; amino acid content of grain between 5.45-9.57% in 2013,the content of amino acid in the grain between 4.81-8.65% in 2003, all M2N2 of amino acid content was the highest. In 17 kinds of amino acids, glutamic acid content was the highest, in 2003 and 2013 the average content of glutamic acid were respectively 1.32 and 1.57%; the variation degree of tyrosine was the biggest, the coefficient of variation were 54.48, 50.60%; analysis of seed of 17 kinds of amino acids in hierarchical clustering, the 2013 can be grouped into 3 categories, 2003 was grouped into 4 categories. The results showed that long-term different organic fertilizer and their treatment with nitrogen on different effects on grain quality of summer maize; organic fertilizer can help to improve grain quality of summer maize and nitrogen is an effective method to improve the maize grain protein, amino acid content.

Keywords: Grain quality, long-term fertilization, summer maize

INTRODUCTION

Compared with the conventional experiment, long-term fertilization experiment have advantages in lasting and climate representative, the data provided an important role for solve many problems both in theory and practice (Zhao and Zhang, 2002). The maize is a kind of important food crop, with high quality in feed and industrial raw materials (Lin and Zhou, 2014). The maize's quality refers to the comprehensive characters, the generalized quality including nutritional quality, edible quality, processing quality and safety quality. The quality of narrow sense only refers to the nutritional quality. The grain nutritional quality include nutrient components of itself and nutritive value for human and animal. Maize grain contain 8-10% protein, 4-5% fat, 70-75% starch, 1-2% sugar and amount of cellulose, mineral and vitamin. The main quality characters is protein, amino acid, the crude fat, starch. The quality of Maize also has very big relations with the harvest time besides influenced by varieties, environment, cultivation technology and other factors (Ma *et al*., 2007; Wu *et al*., 2008). The harvest time of maize is generally during the period of the maize largest output and the best quality (Herrmann *et al*., 2005). But the application of the current production of varieties are often grain filling has yet to stop and bracts yellow, early white phenomenon, corn has been ahead of the harvest, which resulting reduction of output (Bai *et al*., 2007; Meng *et al*., 2007). The research shows that summer maize delayed harvest, yield increased, significantly affected the grain quality of maize at the same time (Zhang *et al*., 2010; Liu *et al*., 2010).

Long term fertilization is one of the main measures to improve maize yield and nutritive quality of maize grains. Study on Liu *et al*. (2010) and Shen *et al*. (2008) pointed out that the different levels of fertilization on corn is not significant to influence of lysine content, interaction of fertilization level and maize varieties determine the protein content. Shen *et al*. (2008) and Feng and Chen (2006) research shows, regulation of nitrogen fertilizer on grain yield of individual plants was more obvious and the grain number per spike is mainly affected by fertilization. Appropriate amount of nitrogen can make maize leaves maintained higher photosynthetic performance, which provide sufficient amount of photosynthetic carbon. Based on corn autumn which is staging sowing experiment, Feng and Chen (2006) found sowing time changen't obvious the variation trends of main quality components of refined

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Table 1: Rates of the added manure and inorganic N fertilizer in the selected treatments from year of 1978 (kg/hm^2)

Treatment	Manure (M)	Nitrogen Fertilizer (N)
CK	0	0
M_1	30000	0
M_1N_1	30000	138
M_1N_2	30000	276
M_2	60000	0
M_2N_1	60000	138
M_2N_2	60000	276

maize grain filling period of rebellion, but it has great influence on content of the main quality components. In general, there are a lot of research about the effects of Huang *et al*. (2010) fertilization on maize quality, but the effect of long term fertilization on summer maize quality on the no-calcareous fluro aquic soil have not been reported. Therefore, this study used by long-term fertilization experiment at 1978 in Laiyang, Shandong Province, based on a long-term no-calcareous fluro aquic soil fertilization, respectively, discussed the effect of the organic fertilizer and nitrogen fertilizer on grain quality of summer maize, respectively at 2003 and 2013. This research aims to provide theoretical basis for scientific and reasonable fertilization for summer maize plant.

MATERIALS AND METHODS

Design of experiment: The experiment from the autumn of 1978, set 12 treatments and 3 repeats which totally 36 districts, randomized block design, each of them is 33.3 m^2. Each district separated by a 1.0 m glass pane, can not be independent of irrigation and drainage. The test implement summer corn rotation/winter wheat rotation system, 2 times a year. The winter wheat is Yanyou 361, summer maize is Luyu 16.

The treatments including control (CK), single application of low dose (M_1) and high dose (M_2) of organic fertilizer, low dose of organic fertilizer and low dose (M_1N1) and high dose (M_1N_2) of nitrogen fertilizer combined application and high organic fertilizer and low dose (M_2N_1) and high dose (M_2N_2) of nitrogen fertilizer combined application of 7 treatments, N_1 and M_1, N_2 and M_2 have equal nitrogen respectively. The nitrogen is urea, organic fertilizer application amount of pig manure (Table 1). The basal fertilizer is organic fertilizer, nitrogen for seed manure and stood up of winter wheat, jointing stage topdressing and maize jointing stage, heading stage topdressing; other management measures for the same.

Method of assay: In the summer maize harvest, in each district were randomly collected 30 samples of grain and dry preservation. The study of grain samples were taken in 2003 and 2013, high-speed multifunctional disintegrator treatment through 0.25 mm sieve, tested.

Starch content was determined by sulfuric acid anthrone method (Bao 2000); the protein content was determined by semi micro Kjeldahl method using residual method (Chen and Zhao, 2006); Determination of fat content; amino acid content was determined by Hitachi according to GB-T18246-2000, 8900 speed automatic amino acid analyzer. The test data were analyzed using DPS 7.05, SPSS 19 software.

RESULTS AND ANALYSIS

Effects of summer maize grain protein and amino acid content through long-term fertilization of organic manure and nitrogen fertilizer:

Effect on summer maize grain protein content: The difference is significantly between different treatment in summer maize grain protein content (Fig. 1). Compared with the control, single organic fertilizer to make summer maize grain protein significantly increased from 25.5 to 45.9%; compared with single organic fertilizer, the same amount of organic chemical nitrogen fertilizers to make summer maize grain protein content increased significantly in 2003 and 2013 an increase of 11.8~26.4% and 7.7~17.8%; at the same level of inputs of organic fertilizer, high-volume processing of chemical nitrogen into protein content is higher than the amount of chemical fertilizer inputs low processing, improving from 4.3 to 10.6%; in nitrogen, etc. Under the investment case (M_1N_1 and M_2), organic

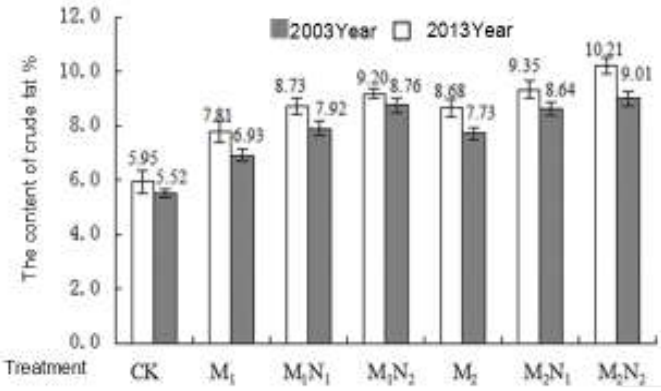
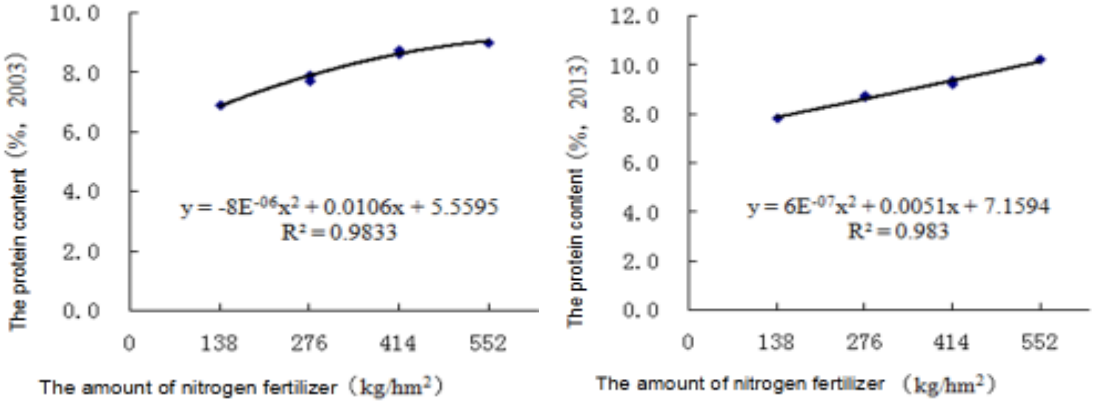


Fig. 1: Effect of long-term fertilization on summer maize grain protein content

and inorganic fertilizers compared with single application of organic fertilizer to make 2003 and 2013 to increase the protein content. Within a certain range, the increasing amount of nitrogen, protein content increased, but the increase was reduced, in line with certain rules (Fig. 2).



(a) (b)

Fig. 2: Relationship between nitrogen input and summer maize grain protein content

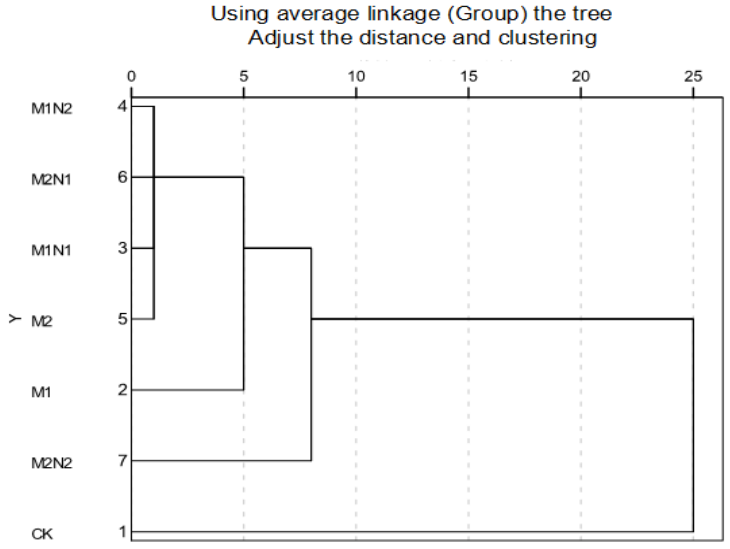
Table 2: Effect of long-term fertilization on summer maize grain amino acid content (%)

	2003									
Treatment	CK	M_1	M_1N_1	M_1N_2	M_2	M_2N_1	M_2N_2	S.D.	AV	C.V (%)
Asp	0.31	0.41	0.44	0.48	0.48	0.49	0.53	0.31	0.41	16.18
Thp	0.19	0.25	0.27	0.29	0.28	0.29	0.31	0.19	0.25	14.86
Ser	0.23	0.31	0.35	0.37	0.37	0.37	0.42	0.23	0.31	17.67
Glu	0.91	1.32	1.46	1.62	1.47	1.71	1.90	0.91	1.32	21.35
Gly	0.22	0.25	0.30	0.30	0.29	0.31	0.33	0.22	0.25	13.46
Ala	0.34	0.46	0.51	0.54	0.55	0.56	0.64	0.34	0.46	18.43
Cys	0.16	0.17	0.20	0.21	0.19	0.19	0.21	0.16	0.17	10.29
Val	0.23	0.29	0.32	0.34	0.34	0.35	0.38	0.23	0.29	15.38
Met	0.15	0.15	0.19	0.19	0.18	0.16	0.19	0.15	0.15	10.96
Ile	0.15	0.19	0.23	0.24	0.23	0.24	0.27	0.15	0.19	18.03
Leu	0.52	0.74	0.81	0.86	0.91	0.98	1.06	0.52	0.74	20.29
Tyr	0.10	0.09	0.12	0.32	0.12	0.12	0.14	0.10	0.09	54.48
Phe	0.24	0.31	0.34	0.37	0.36	0.37	0.42	0.24	0.31	16.69
Lys	0.24	0.28	0.32	0.26	0.32	0.34	0.36	0.24	0.28	14.75
His	0.15	0.19	0.22	0.23	0.22	0.22	0.25	0.15	0.19	15.55
Arg	0.24	0.29	0.34	0.36	0.34	0.36	0.39	0.24	0.29	15.42
Pro	0.43	0.59	0.64	0.70	0.72	0.69	0.81	0.43	0.59	18.44
Amino acid content AA	4.81	6.29	7.06	7.68	7.37	7.79	8.65	4.81	6.29	17.37
2013										
Asp	0.38	0.42	0.51	0.53	0.49	0.57	0.62	0.08	0.50	16.47
Thp	0.23	0.25	0.30	0.32	0.29	0.34	0.36	0.05	0.30	15.64
Ser	0.28	0.32	0.41	0.43	0.38	0.46	0.49	0.08	0.40	18.96
Glu	0.99	1.39	1.57	1.69	1.61	1.77	1.95	0.31	1.57	19.65
Gly	0.25	0.26	0.31	0.32	0.30	0.31	0.34	0.03	0.30	10.84
Ala	0.40	0.47	0.61	0.66	0.61	0.67	0.73	0.12	0.59	19.74
Cys	0.16	0.17	0.20	0.20	0.18	0.19	0.21	0.02	0.19	9.62
Val	0.26	0.29	0.36	0.37	0.33	0.38	0.43	0.06	0.35	16.60
Met	0.15	0.15	0.19	0.17	0.17	0.19	0.19	0.02	0.17	10.41
Ile	0.17	0.20	0.26	0.28	0.24	0.29	0.32	0.05	0.25	20.85
Leu	0.61	0.75	1.04	1.10	1.02	1.15	1.27	0.23	0.99	23.35
Tyr	0.08	0.12	0.34	0.15	0.15	0.15	0.15	0.08	0.16	50.60
Phe	0.25	0.30	0.41	0.40	0.39	0.43	0.47	0.08	0.38	20.26
Lys	0.28	0.29	0.28	0.33	0.32	0.34	0.37	0.03	0.32	10.80
His	0.17	0.19	0.24	0.25	0.22	0.25	0.29	0.04	0.23	17.57
Arg	0.28	0.31	0.38	0.38	0.36	0.40	0.44	0.05	0.36	14.86
Pro	0.51	0.59	0.77	0.83	0.81	0.84	0.94	0.15	0.76	20.04
Amino acid content AA	5.45	6.47	8.18	8.41	7.87	8.73	9.57	1.40	7.81	17.96

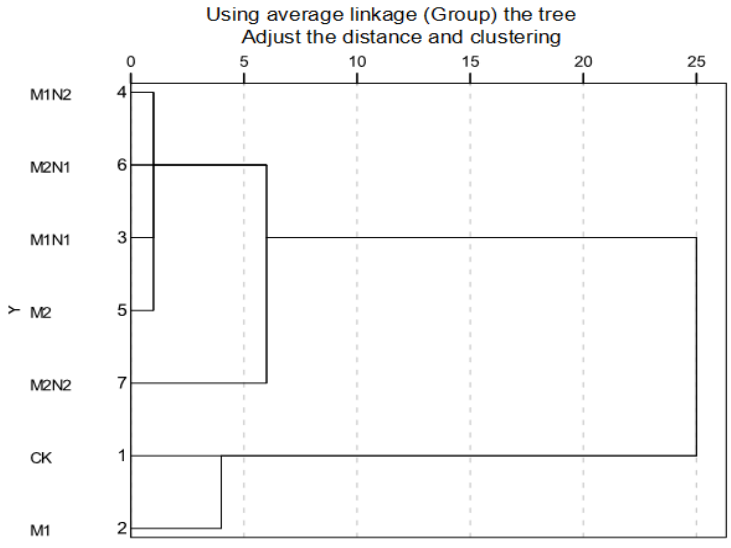
S.D.: Standard Deviation

Effect of amino acid content of summer maize grain: The effects of Long-term different fertilization on grain amino acid content of summer maize have same effect on the protein. Compared with CK, single organic fertilizer to have significantly improve in the amino acid content of summer corn and have a single amino acid content of organic fertilizer to make 18.7~53.2% increase (Table 2). Compared with single organic fertilizer, organic manure and chemical fertilizer distribution make amino acid content increased respectively in 2003 and 2013, have an increase of 5.7 to 22.1% and 10.9~30.6%. At the same level of inputs at organic fertilizer, also have high volume chemical fertilizer inputs summer corn amino acid content than the low amount of chemical fertilizer into treatment. Each component in the amino acid, glutamic acid content and between 0.91 to 1.95%. The lowest content of tyrosine and the most affected. Minimal impact on cystine, but other types of amino acid and cystine was no significant difference.

The use of SPPS Q type clustering hierarchical clustering of amino acid content analysis in 2003, 2013. Individual distances using squared euclidean distance, using the average distance between the class joins from cluster analysis generated tree diagram, the results are different (Fig. 3). As can be seen that in



(a) 2003



(b) 2013

Fig. 3: Long-term fertilization experiment on summer maize grain amino acid composition of hierarchical cluster analysis results

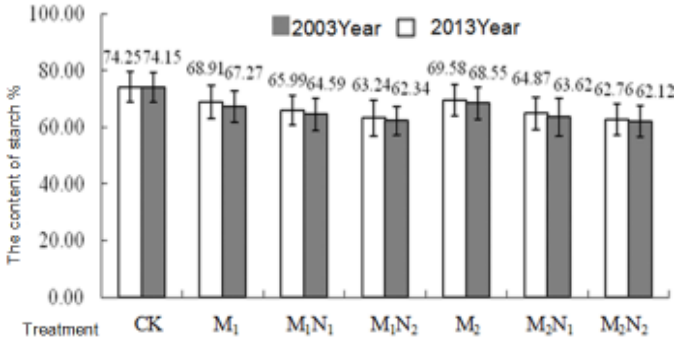


Fig. 4: Effect of long-term fertilization on summer maize grain starch content

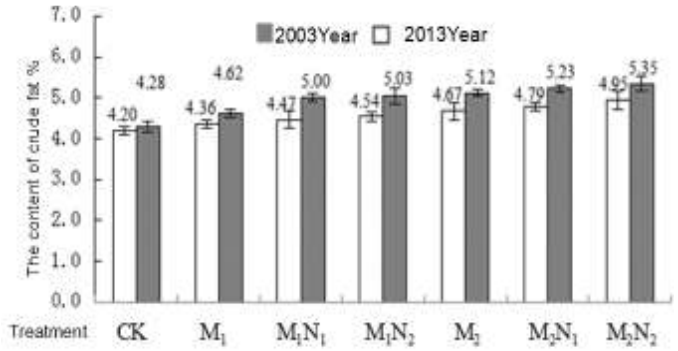


Fig. 5: Effect of long-term fertilization on summer maize grain crude fat content

2003 amino acid content, amino acid content M_1N_2, M_2N_1, M_1N_1, M_2 is high similarity, clustered together (category 1); M_1 as for Class 2; M_2N_2 highest content of amino acids alone as a class (Section Class 3); CK minimum content of the 4th class. 2013 and 2003 in the same category 1; and M_2N_2 highest content of amino acids alone as a Class 2; amino acid content of CK high similarity with the M_1, clustered into category 3.

Effect of long-term positioning with organic fertilizer and nitrogen fertilizer on summer maize starch content: The different treatments of summer maize grain starch content was the highest (Fig. 4). Compared with the control group, in 2003, 2013, all treatments were made of summer maize starch content reduced 7.6~16.2% and 8.3~15.5%. Compared with single organic fertilizer, organic chemical nitrogen fertilizers make starch content decreased respectively 4.0~9.4%, from 4.2 to 9.8% in 2003 and 2013; the same level of inputs of organic manure, low chemical nitrogen fertilizer inputs make starch content is higher than the highest chemical fertilizer input, the starch content of M_1N_1 treatment higher than M_1N_2 treatment increased by 3.6~4.4%, M_2N_1% than M_2N_2 treatment increased 2.4~3.4%. In the case of nitrogen inputs (M_1N_1 and M_2), single application of organic fertilizer compare with organic and inorganic fertilizer in 2003 and 2013 respectively, the starch content was significantly increased by 6.1 and 5.4%; in the treatment of organic and inorganic nitrogen (M_1N_2 and M_2N_1), organic manure have a large proportion of the more conducive is good for the increase of starch content of summer maize.

Effect of long-term positioning with organic fertilizer and nitrogen fertilizer on summer maize grain crude fat content: There are differences between different fertilization treatments on summer maize grain crude fat content (Fig. 5). Compared with the CK, at 2003 and 2013 single organic fertilizer to make summer maize fat increased 3.8~11.2% and 7.9~19.6%, while applying a low amount of organic fertilizer to make lower fat content at 2003, making crude fat content increased at 2013.

Compared with single organic fertilizer, equal amounts of organic manure combined with chemical nitrogen fertilizer increased the content of crude fat of summer maize, increased to 2.6~6.0% in 2003 and 2.2~4.5% in 2013. In the same organic fertilizer input levels, low chemical nitrogen fertilizer input crude fat content less than high chemical nitrogen fertilizer treatment of investment; in equal organic and inorganic nitrogen in treatment (M_1N_2 and M_2N_1), The greater the proportion of organic fertilizer, the more help to improve the content of crude fat in summer maize.

DISCUSSION AND CONCLUSION

Organic fertilizer and the combined application of nitrogen fertilizer in different, different effects on grain

quality of summer maize. Application of organic fertilizer can improve the quality of summer maize, nitrogen is the effective means to improve the maize grain protein content, amino acid. Improvement of crop nitrogen nutrition is beneficial to the improvement of protein and amino acid content of agricultural products.

The results shows that compared with no fertilization, organic manure and nitrogen fertilizer application can significantly improve the quality of various indicators of the content of maize grain. Long term application of organic manure and N fertilizer to improve the effect of summer maize grain protein content significantly, organic manure and nitrogen fertilizer effect is more apparent; and in applying the same amount of organic fertilizer (nitrogen fertilizer) conditions, the summer maize grain protein content increased with nitrogen fertilizer (organic fertilizer) application rates increased.

The research (Zhang *et al*., 2010) shows that with the nitrogen conditions, after the application of organic compound inorganic fertilizer, grain protein content of corn was higher than that of the single application of nitrogen. The amount of organic fertilizer is higher, the effect is better. Chen and Zhao (2006) Studies have shown that, in a certain range of nitrogen, the content of starch increased with adding nitrogen. Li *et al*. (2013) has a similar study. Compared with conventional fertilization, nitrogen fertilizer and organic manure use can significantly improve grain quality.

In nitrogen condition, the organic fertilizer contains a lot of useful trace elements and active substances. These elements and active substances can greatly promote nitrogen absorption and transformation of nitrogen in crops. Improving the utilization rate of nitrogen fertilizer, protein content increased significantly. The change law of the contents of total amino acid was positively correlated with the change law of protein content in summer maize. Application of nitrogen fertilizer could increase the content of amino acid, in all kind of amino acids, the biggest influence on tyrosine and minimal impact on cystine, but other kinds of amino acid and cystine were not significantly different. About clustering analysis of amino acid contents in summer maize grain on long-term different fertilization levels, overall variation test in 2013 are basically the same as 2003. Associated with amino acid contents of summer maize grain were positive correlation. But there are differences between the corresponding treatment. The amino acid content of summer maize in test of 2003 can be grouped into 4 categories. The experiment in 2013 have low amount of organic fertilizer and no fertilizer high similarity can be clustered into one category. The amino acid content of corn in summer 2003 test can be grouped into 4 categories. The test of mid-low organic fertilizer treatment in 2013 is the same as long-term no fertilization. It can be clustered into one category. This may be related to some factors, such as climate, cultivation techniques and maize variety (Wu *et al*., 2008), also related to the different between the soil nutrient content because of long-term different fertilization in two years. Although cluster analysis has made progress, but the related report was less, we need further analysis and discussion. Tarch grain in the form of carbohydrate, accounting for the proportion of corn grain is larger. The result shows that different long-term fertilization had little effect on summer maize grain starch content. However, based on the application of a certain amount of organic fertilizer, with the increasing of nitrogen fertilizer in maize grain starch content decreased.

Research is different from Wei *et al*. (2008), this may be related to maize varieties, climate, cultivation techniques of Liu *et al*. (2005) factors. The same amount of nitrogen conditions, with the increase of organic fertilizer, summer maize grain crude fat content increased; and equal application of organic fertilizer, with the increase of nitrogen, reduce the content of crude fat of summer maize. Liu *et al*. (2004) view is basically on the same, long-term application of organic manure with chemical fertilizer can increase the total protein, amino acid in grains, but also improve the content of crude fat in the grain; long term fertilizer, reduce the content of starch and crude fat in the grain, although the increased protein content, but because of its low yield, protein yield is low.

ACKNOWLEDGMENT

The study was supported by the National Special Research Fund for Non-Profit Sector (Agriculture)" Research and demonstration of the main producing areas of soil fertility evolution and cultivation of grain fertilizer technology "(201203030); Shandong Province, modern agricultural industry technology system construction funds (SDAIT-01-022-06); "Comprehensive technology integration and demonstration of high efficient utilization of eastern Shandong hilly area of wheat and maize water natural resources" (2013BAD07B06-03); Major Innovation Project for Applied Technology of Shandong Province (middle and low yield fields of wheat and corn two crops yield key technology research and demonstration of shandong province); Scientific Research Innovation Team in Colleges and Universities of Shandong Province “Dryland crop water efficiency use of innovation team".

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