Effects of Chemical Fertilizer Replaced with Functional Organic Fertilizer on Yield of Seed-producing Maize in Hexi Irrigation Area

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Abstract. This experiment was conducted in order to study the effects of commodity functional organic fertilizers on maize yield, soil fertility and economic benefits, and to provide a feasibility basis for the application of functional organic fertilizers instead of chemical fertilizers in maize production. Using seed-producing maize as experimental crop, drip irrigation under the mulch as water supply mode, and different fertilization treatments CK (no fertilization treatment), T1 (3000kg hm⁻²), T2 (2250kg hm⁻²), T3 (local method), T4 (Local conventional reduction) in a total of 5 treatments. Research shows that maize yields have different responses under different organic fertilizer conditions. Compared with T3, the plant yield of CK is reduced by 26.4%. The remaining CK, T1, and T3 are increased by 7.8%, 3.4%, and -5.6% respectively compared with T2. Compared with CK, T1, T2, T3 and T4 significantly increased by 31.7%, 28.8%, 26.4%, 22.0%. The difference was significant. The economic shape of fruit spike was also different in response to different modes of functional organic fertilizer application. T1 treatment plants were the highest, reaching 139.8 cm, followed by T3, T4, T2 and CK, which were 11.2%, 4.5%, 8.3%, 6.4% higher than CK compared with T1, T2, T3 and T4, and the difference was significant. T1, T2, T3 and T4 increased by 11.2%, 4.5%, 8.3%, 6.4% compared with the spike length of CK, the difference was significant. Ear diameter increased respectively by 20.5%, 21.6%, 20.6%, 14.0%, the difference is significant; compared with CK, the ear rows of T1, T2, T3 and T4 are increased by 5.5% overall. The number of ear rows in the remaining treatments remains between 0.7% and 3.4%. The difference is not significant; the bald tip after each treatment was generally shortened, compared with CK, T1, T2, T3 and T4 are shortened by 44.6%, 28.6%, 12.5%, and 60.4%, respectively. the difference was significant; the number of rows after treatment Compared with CK, T1, T2, T3, and T4 increased by 18.1% overall. The number of ear rows in the remaining treatments remained between 0.3% and 4.7%, with no significant difference. The Spike grain after each treatment increased significantly. Compared with CK, T1, T2, T3, and T4 are increased by 30.1%, 29.5%, 27.6%, and 26.4% respectively. The difference is significant; the 100-seed weight of T1 was the largest, compared with CK, the 100-seed weight of T1, T2, T3 and T4 are increased by 27.7%, 15.6%, 11.1% and 6.1% respectively. the difference was significant. After two years of experiments, the soil fertility of T1 was improved, in which alkaline-hydrolysis nitrogen Basically remain unchanged, the content of rapidly-available potassium and alkaline-
hydrolysis nitrogen was slightly increased. The content of available phosphorus was nearly four times higher than before the experiment. The soil is more weakly-alkaline. The comprehensive soil evaluation index is 40% before the test. The comprehensive evaluation was index increased by 54 after the test. The evaluation index was medium. Applying functional organic fertilizer 3000kg·hm⁻², additional fertilizer is based on the total nutrients of soil nutrients and chemical fertilizers. It can significantly increase the cluster length, panicle diameter, kernel number per row, and grain number per spike of seed-producing maize. while effectively reducing the invalid spike length, providing a guarantee for increasing production at the late stage. The application of functional organic fertilizer is 3000kg·hm⁻² has a significant increase in yield, which is 7.5% higher than the habitual fertilization of local farmers (average of two-year data).

1. Introduction
The great contribution of chemical fertilizers to the development of agricultural production and crop income is undeniable. On the other hand, the impact of chemical fertilizers on the environment cannot be ignored. The application of chemical fertilizers can increase and improve the yield and quality of maize. Excessive and long-term application of chemical fertilizers may cause the problem of environmental pollution and soil degradation. Many scholars have conducted deeper studies on the pollution caused by excessive and inappropriate application of chemical fertilizers. They pointed out that excessive and unreasonable application of chemical fertilizers has caused more and more serious safety problems on groundwater resources and agricultural products[1-2]. Therefore, in agricultural production, how to reduce the amount of chemical fertilizer used, increase the utilization rate, and effectively control pollution has become a research topic for scholars[3-4]. On the basis of ensuring crop yield and food security, reducing the amount of chemical fertilizer used is a fertilization measure to improve soil fertility and to reduce environmental pollution. In recent years, some domestic and foreign research has shown that replacing some chemical fertilizers with organic fertilizers can coordinate the balanced supply of organic and inorganic nutrients, increase soil nutrient content, meet the nutrient requirements of crop growth and development, it reduces the number of chemical fertilizers while ensuring stable and increased production of crops [5]. The replacement of some chemical fertilizers by organic fertilizers can contribute to maize absorb and utilize nutrients and store soil nutrients, which can increase soil nutrients content and maize yield.

2. Materials and Methods
2.1. Overview of the test area
The test field is located in Tianjiazha Village, Dangzhai Town, Ganzhou District, Zhangye City, Gansu Province. It is located at 100°6′-100°52′ E, 38°32′-39°24′ N, and 1474 m above sea level. The area is temperate continental climate. In the climate zone, the perennial mean temperature is 7.25℃, July is the hottest, the monthly mean temperature is 23.9℃, January is the coldest and its mean temperature is -10.1 ℃. The mean annual precipitation is 97.6 mm. In 2018, the rainfall and evaporation were 118.2 mm and 1898.5 mm. In 2019, the rainfall and evaporation were 207.5 mm and 1736.9 mm. The rainfall, temperature and evaporation conditions during the experiment are shown in Figure 1. The experimental area is sandy loam soil, the terrain is flat, and one crop per annum. The basic physical and chemical properties of the 0-20 cm soil layer in the experimental area are shown in Table 1.
Figure 1. Rainfall, average Temperature and Evaporation during crop growth in 2018 and 2019

Table 1. Soil analysis results of the experimental demonstration site

| Year | Soil type  | Layer (cm) | Soil pH | Soil organic matter (g kg⁻¹) | Alkali hydrolyzed nitrogen (mg kg⁻¹) | Available phosphorus (mg kg⁻¹) | Available potassium (mg kg⁻¹) | Soil bulk density (g cm⁻³) |
|------|------------|------------|---------|------------------------------|-------------------------------------|-------------------------------|-------------------------------|-----------------------------|
| 2018 | sandy loam | 0-20       | 8.33    | 16.3                         | 42.35                               | 4.45                          | 118.59                       | 1.38                        |
| 2019 | sandy loam | 0-20       | 8.35    | 18.5                         | 45.32                               | 15.8                          | 125.36                       | 1.35                        |

2.2. Test material
Top dressing: Urea 600kg/ha. Test crops: seed-producing maize, the variety is seed-producing maize: NC236.
Test fertilizers: urea (containing 46% pure N), superphosphate (containing 46% P₂O₅), potassium sulfate (containing 50% K₂O).
2.3. Experimental design
The experiment has 5 treatments, each treatment is repeated 3 times in a total of 15 plots, and a random block design is adopted. The plot area is 35 m² (length 8.7m×width 4m), separated by a ridge with a base width of 25cm and a height of 20cm, surrounded by a protection zone with a width of 1m. Base fertilizer is applied to the soil at one time in combination with site preparation before sowing. Use mulching film to cover row ratio planting (1:5). The test fertilizer is a functional organic fertilizer, provided by Gansu Laonongtou Fertilizer Development Co., Ltd. (N+P₂O₅+K₂O³5%, organic matter content³45%); traditional fertilizer: diammonium phosphate (N: P₂O₅: K₂O=18-46-0 ), provided by Gansu Weng fu Chemical; Urine (N³46.4%) was provided by Talimu Petrochemical; Potassium sulfate (K₂O³50%) was provided by Yantai Hua hai Trading Co., Ltd. The experiment adopts 50×50cm equi-row mulching and hole-seeding cultivation method, and the parents are arranged with gypsophila. Fertilization and management are the same as farmers’ habits. The female parent was sown on April 15 and the male parent was sown 9 days later.

Table 2. Functional organic fertilizer instead of fertilizer test treatment

| Code | Treatments                          | Fertilization method                                      |
|------|------------------------------------|----------------------------------------------------------|
| CK   | Contrast                           | No fertilization.                                         |
| T1   | Functional organic fertilizer      | Apply functional organic fertilizer 3000kg.hm⁻². Additional fertilizer N 399 kg hm⁻², P₂O₅ 138 kg hm⁻², K₂O 60 kg hm⁻². Two topdressings in jointing stage and Tasseling period is 56%. 44%. |
| T2   | Functional organic fertilizer      | Application of functional organic fertilizer is 2250kg hm⁻². Additional fertilizer N 399kg hm⁻², P₂O₅ 138kg hm⁻², K₂O 60kg hm⁻². Two topdressings in jointing stage and tasseling period is 56%. 44%. |
| T3   | Conventional fertilization         | Local routine level diammonium phosphate (N-P₂O₅-K₂O 18-46-0, total nutrient content ³64%) 20kg, urea (³46%) 5kg, K₂SO₄ (K₂O 50%) 8kg. Additional fertilizer N 399kg hm⁻², P₂O₅ 138kg hm⁻²,K₂O60kg hm⁻². Two topdressings in jointing stage and Tasseling period is 56%. 44%. |
| T4   | Conventional fertilization reduction 50% | Local conventional fertilization reduction is 50% diammonium phosphate (N-P₂O₅-K₂O 18-46-0, total nutrient content ³64%) 10kg, urea (³46%) 2.5kg, K₂SO₄ (K₂O 50%) 4kg. Additional fertilizer N 399kg hm⁻², P₂O₅ 138kg hm⁻²,K₂O 60kg hm⁻². Two topdressings in jointing stage and Tasseling period is 56%. 44%. |

2.4. Determination items and methods

2.4.1. Crop biomass and yields. The plant height, ear diameter, bald tip length and ear length were measured at different growth stages of corn. Twenty female fruit ears were randomly selected from each plot and harvested respectively and the economic characters such as ear length, ear diameter, ear row number, ear grain number, row grain number, single ear weight, single ear grain weight, bare tip length, seed yield, thousand seed weight and so on were determined in the laboratory. Cutting the plants, 108 °C for 30 minutes, and then 75 °C drying to constant weight determination of straw biomass. The index includes ear length, row grain number and ear grain number. At the end of waxing, 2 films (4 rows) were harvested in each plot, after natural drying, the ears of the mother fruit were threshed and weighed, and the yield of the plot was calculated and converted.

2.4.2. Evaluation of soil fertility. Soil fertility as an important index to release crop high yield potential and improve soil productivity, soil fertility was used to evaluate the tested soil using the soil nutrient grading and grading evaluation system. The soil nutrient index scoring rules, index weight and grading rules were shown in Table 3 and 4^[6]. Soil nutrient index by using the additive model calculation, as shown in the following equation.
\[ I = \sum F_i \times W_i (i = 1, 2, 3, \ldots, n) \]

where \( I \) is Soil nutrient synthesis index; \( F_i \) is The \( i \) index score values; \( W_i \) is the \( i \) index of weight.

### Table 3. Evaluation and weight of soil nutrient index

| Nutrient index         | \( F_i \) | High  | Medium | Low   | Extremely low | Weight |
|------------------------|----------|-------|--------|-------|---------------|--------|
| Organic matter         | g kg\(^{-1}\) | 25~20 | 20~15  | 15~10 | <10           | 0.30   |
|                        | score    | 80    | 60     | 40    | 20            |        |
| Alkaline hydrolysis    | g kg\(^{-1}\) | 100~90| 90~60  | 60~45 | <45           | 0.25   |
| nitrogen               | score    | 80    | 60     | 40    | 20            |        |
| Available phosphorus   | g kg\(^{-1}\) | 90~60 | 60~30  | 30~15 | <15           | 0.25   |
| score                  | 80       | 60    | 40     | 20    |               |        |
| Available potassium    | g kg\(^{-1}\) | 155~125| 125~100| 100~70| <70           | 0.20   |
| score                  | 80       | 60    | 40     | 20    |               |        |

### Table 4. Rules for classification of soil nutrients.

| Grade                  | Composite index (1) |
|------------------------|---------------------|
| Extremely high         | 100~95              |
| High                   | 95~75               |
| Medium                 | 75~50               |
| Low                    | 50~30               |
| Extremely low          | 30~0                |

2.5. Data analysis method

Using EXCEL 2010 software for data processing; SPSS 25 was used for data analysis.

3. Results and Analysis

3.1 Seed corn production situation in functional organic fertilizer application situation

In 2018, corn yield had different responses under different organic fertilizer conditions. Compared with production of T3 (normal planting conditions of farmers), the plant yield decreased by 26.4% compared with CK, while that of T1, T2, T4 increased by 7.8%, 3.4% and -5.6% respectively compared with T3 (P > 0.05), compared with CK, T1, T2, T3, T4 increased by 31.7%, 28.8%, 26.4% and 22.0%, respectively, with significant differences (P < 0.05); In 2019, the corn yield responded differently under different organic fertilizer conditions, which basically maintained similar rules with more obvious rules in 2018. Compared with T3 (normal planting condition of farmers), the plant yield decreased by 28.6% compared with CK, while that of T1, T2, T4 increased by 9.2%, 2.9% and -4.3% respectively compared with T3 (P > 0.05), compared with CK, T1, T2, T3 and T4 increased by 53%, 44%, 40% and 34%, respectively, with significant differences.

3.2 Different treatment of corn economic shape

It can be seen from Table 5 that in 2018, the economic shape of ear of corn also has different responses under different modes of functional organic fertilizer application. T1 had the highest concentration of 139.8cm, followed by T3, T4, T2 and CK, compared with CK, T1, T2, T3 and T4 Plant height increased by 11.2%, 4.5%, 8.3% and 6.4%, respectively, with significant differences (P < 0.05); Compared with T1, T2, T3 and T4, The ear length of CK increased by 11.2%, 4.5%, 8.3% and 6.4%, with significant differences (P < 0.05). ear diameter increased by 20.5%, 21.6%, 20.6% and 14.0%, respectively, with significant differences (P < 0.05). Compared with CK, the number of ear row number in T1, T2, T3 and T4 increased by 5.5%,and the number of ear rows in other treatments
remained between 0.7% and 3.4%, with no significant difference (P > 0.05). After treatment, bald tips were generally shortened, compared with CK, T1, T2, T3 and T4 are 44.6%, 28.6%, 12.5% and 60.4% shorter, respectively, with significant differences (P < 0.05). After treatment, the number of grain rows in T1, T2, T3 and T4 increased by 18.1% overall compared with that in CK. The number of grain row number in other treatments remained between 0.3% and 4.7%, with no significant difference (P > 0.05); Compared with CK, T1, T2, T3 and T4 increased by 30.1%, 29.5%, 27.6% and 26.4%, respectively, with significant differences (P < 0.05). Compared with CK, T1, T1, T3, and T4 had the highest hundred-grain weights, which were 27.7%, 15.6%, 11.1%, and 6.1% higher, respectively, with significant differences (P < 0.05).

In 2019 tests, T1 plants were still the highest, reaching 135.4 cm, followed by T3, T4, T2 and CK. Compared with CK, T1, T2, T3 and T4 Plant height increased by 14.4%, 4.2%, 8.0% and 4.8%, respectively, with significant differences. T1, T2, T3 and T4 increased ear length by 18.0%, 8.7%, 14.1% and 11.6% compared with CK, with significant differences (P < 0.05). Ear diameter increased by 26.6%, 29.2%, 24.2% and 19.3%, respectively, with significant differences (P < 0.05). Compared with CK, the total number of ear rows T1, T2, T3 and T4 increased by 5.5%, the number of ear rows in other treatments remained between 0.9% to 3.1%, with no significant difference (P > 0.05). Ear length increased by 26.6%, 29.2%, 24.2% and 19.3%, respectively, with significant differences (P < 0.05). After treatment, bald tips were generally shortened, compared with CK, T1, T2, T3 and T4 are 80.4%, 38.3%, 31.7% and 59.6% shorter, respectively, with significant differences (P < 0.05). After treatment, the number of row grain number in T1, T2, T3 and T4 increased by 19.4% overall compared with that in CK. The number of grain rows in other treatments remained between 0.3% and 5% with no significant difference (P > 0.05). Compared with CK, T1, T2, T3 and T4 increased by 40.3%, 38.0%, 32.7% and 28.0%, respectively, with significant differences (P < 0.05). Compared with CK, T1, T2, T3 and T4 have the highest hundred-grain weights, which are increased by 31.4%, 23.1%, 12.2% and 7.3% respectively, with significant differences (P < 0.05).

After the determination of production and indoor analysis, application of functional organic fertilizer 3000 kg·hm$^{-2}$, fertilizer to soil nutrient, fertilizer nutrient content of total nutrient. Can significantly improve the seed corn ear length, ear diameter row grain number and ear grain number, at the same time effectively reduce the invalid Ear length, provide guarantee for the late production. Application of functional organic fertilizer 3000 kg·hm$^{-2}$, increase yield significantly, local farmers used fertilizer significantly increase 7.5%.

| Year | Treatments | Plant height (cm) | Ear length (cm) | Ear diameter (cm) | Bald tip (cm) | Ear rows (line) | Row grain number (grain) | Ear grain number (grain) | Hundred grain weight (g) |
|------|------------|------------------|----------------|------------------|--------------|----------------|-------------------------|-------------------------|------------------------|
| 2018 | CK         | 124.1b           | 11.95b         | 30.5c            | 1.62a        | 10.9b          | 16.8b                   | 183.1c                  | 24.83d                 |
|      | T1         | 139.8a           | 13.64a         | 38.4a            | 1.12cd       | 12.6a          | 20.6a                   | 262.1a                  | 34.34a                 |
|      | T2         | 130.0ab          | 13.58a         | 38.9a            | 1.26c        | 12.8a          | 20.3a                   | 259.8ab                 | 29.42b                 |
|      | T3         | 135.4ab          | 13.50a         | 38.4a            | 1.44b        | 12.2ab         | 20.4a                   | 252.9ab                 | 27.92bc                |
|      | T4         | 132.6ab          | 13.52a         | 35.4b            | 1.01d        | 12.5a          | 19.9a                   | 248.7b                  | 26.45cd                |
| 2019 | CK         | 123.2b           | 11.95c         | 30.1c            | 1.66a        | 10.3c          | 16.3c                   | 178.3d                  | 22.63d                 |
|      | T1         | 141.9a           | 14.09a         | 41.1a            | 0.92c        | 12.8ab         | 21.7a                   | 335.8a                  | 37.62a                 |
|      | T2         | 132.7ab          | 13.99ab        | 39.9a            | 1.20b        | 13.0a          | 20.8ab                  | 330.3a                  | 35.25a                 |
|      | T3         | 134.7ab          | 13.64ab        | 38.4ab           | 1.26b        | 12.3ab         | 20.3ab                  | 263.6b                  | 28.12b                 |
|      | T4         | 130.5ab          | 12.34b         | 34.9b            | 1.04c        | 11.7bc         | 19.8b                   | 237.4c                  | 25.73c                 |
3.3 T1 treatment soil indexes and evaluation before and after the experiment

It can be seen from Table 6 that after two years of experiment, T1 soil fertility has been improved, in which the alkaline hydrolysis nitrogen basically remains unchanged, available potassium and alkali hydrolyzed nitrogen content increased slightly, available phosphorus content than promoted about four times before the test, more alkaline soil. The comprehensive evaluation index of soil increased from 40 before the test to 54 after the test from low to medium.

Table 6. soil indexes and evaluation before and after the experiment.

| Analyze project                  | PH   | Organic matter (g kg⁻¹) | Alkali hydrolyzed nitrogen (mg kg⁻¹) | Available phosphorus (mg kg⁻¹) | Available potassium (mg kg⁻¹) | Comprehensive evaluation index |
|----------------------------------|------|-------------------------|--------------------------------------|-------------------------------|------------------------------|--------------------------------|
| Before a test                    | 8.33 | 16.3                    | 42.35                                | 4.45                          | 118.59                       | Low (40)                       |
| Before the test evaluation (score) | Medium (60) | Extremely low (20) | Extremely low (20) | Medium (60) | Low (40) |                                |
| After test to determine          | 8.70 | 18.5                    | 45.32                                | 16.2                          | 125.36                       | Medium (54)                    |
| After test evaluation (score)    | Medium (60) | Low (40)      | Low (40)                            | High (80)                     |                              |

4. Discussion

After the determination of production and indoor analysis, application of functional organic fertilizer 3000 kg hm⁻², according to soil nutrient, fertilizer nutrient content of total nutrient. Can significantly improve the seed corn ear length, ear diameter, row grain number and ear grain number, at the same time effectively reduce the invalid ear length, provide guarantee for the late production. Application of functional organic fertilizer 3000 kg hm⁻², increase yield significantly, local farmers used fertilizer significantly increase 7.5% (two years of data on average), and the predecessor study, obvious effects to increase production

Comprehensive comparing the processing plant height, ear length, ear diameter, bald tip, ear rows, row grain number and ear grain number and hundred grain weight knowable, T1 than T3 in multiple index has more significant promotion, ear rows and row grain number two indicators of no obvious ascension, with conventional fertilization were little changed, may be because the function of organic fertilizer index promoting effect is not strong, organic fertilizer or function does not affect flower pollinate plants when the final number of pistil. T2 in plant height, ear diameter, bald tip three aspects are weaker than conventional fertilization, combined with the T1 and T2 in this three indicators are stronger than the conventional fertilization, so guess probably because organic fertilizer usage is insufficient, food as a result of the restrictions. The number of ear rows did not change significantly in multiple treatments, while T2 was the largest in this index, probably because a certain amount of functional organic fertilizer could change the proportion of one or more nutrients in the soil, which could promote this index. Organic fertilizer can promote the growth of soil microbes, and promote crops to absorb using organic fertilizer in organic matter, accelerate the formation of soil aggregate, improve soil physical properties.

5. Conclusion

Applying functional organic fertilizer 3000 kg hm⁻², additional fertilizer is based on the total nutrients of soil nutrients and chemical fertilizers. It can significantly increase the cluster length, panicle diameter, kernel number per row, and grain number per spike of seed-producing maize, while effectively reducing the invalid spike length, providing a guarantee for increasing production at the late stage. The application of functional organic fertilizer is 3000 kg hm⁻² has a significant increase in yield, which is 7.5% higher than the habitual fertilization of local farmers (average of two-year data).
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