

## Impact of long-term application fertilizer on soil total sulphur and valid sulphur

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**Abstract.** The object of this study was to investigate the effect of the long-term application fertilizer on soil total sulphur and valid sulphur. The results showed that applying fertilizer can improve total sulphur and valid sulphur. In comparison with the low level of nitrogen fertilization treatment, the high one total sulphur and valid sulphur were obviously increased by 29.41% and 19.0%, respectively. Compared with in application of different levels nitrogen and the low level of organic fertilizer, the high level treatment total sulphur and valid sulphur contents were significantly increased by 10.73% and 23.47% than the low one. In application of organic fertilization can also improve total sulphur and valid sulphur The total sulphur and valid sulphur content were higher than organic fertilization only treatment 34.14% and 455.89% in comparison with high levels of organic fertilization mix with nitrogen, phosphorous and potassium fertilization treatment.

### 1. Introduction

Sulphur is of the essential element for plant growth and development. The organic carbon content, the type of fertilizer and soil pH are the main factors to influence the distribution of soil sulphur element forms. Especially the application of organic fertilizer plays an important role which can improve soil properties, increase soil organic sulphur content and potential sulphur [1]. In recent years, the sulphur content in the soil declined year by year with crops multiple cropping index enhanced, yield increased and atmospheric sulphur emissions reduced [2,3]. The soil sulphur has become limit factor to improve agricultural crops yield, quality and the utilization ratio of fertilizer[4]. It is very important to know soil sulphur condition so that we can ensure the sustainable development of agriculture and improve soil sulphur biological effectiveness. There were many researches about it such as Zhong [5] found that the contents of soil total sulphur was increased by 65.42 mg/kg in NPK plus organic manures treatment compared with the origin samples, while the ratio of available sulphur in NPK plus organic manures treatment was lower than that in NPK. The content of soil adsorbed sulphur were improved by 177.4% and 93.3% in NPK plus organic manures treatment compared with the origin samples. Gao's [6] research showed that the contents of soil total sulphur was improved in the treatment which application of inorganic nitrogen fertilizer, organic fertilizer and combined application of organic fertilizer and inorganic nitrogen fertilizer and combined application of nitrogen and phosphorus and



potassium fertilizer. But the more organic fertilizer and inorganic nitrogen fertilizer was used, the more contents of soil total sulphur was increased.

As a result, this study was based on a thirty seven-year long-term fertilization experiment and employed the impact on soil total sulphur and valid sulphur.

## 2. Materials and methods

The long-term experiment was located in Liaoning Province at the Shenyang Agricultural University Peanut Scientific Research Center (40°48'N, 123°33' E). The soil at the experimental site was a brown soil classified as an alfisol, with hydromica as a dominant clay mineral. This experiment began in 1977 and the basic physical and chemical properties are detailed in Table 1.

**Table 1** Basic properties of soil at the beginning of the experiment

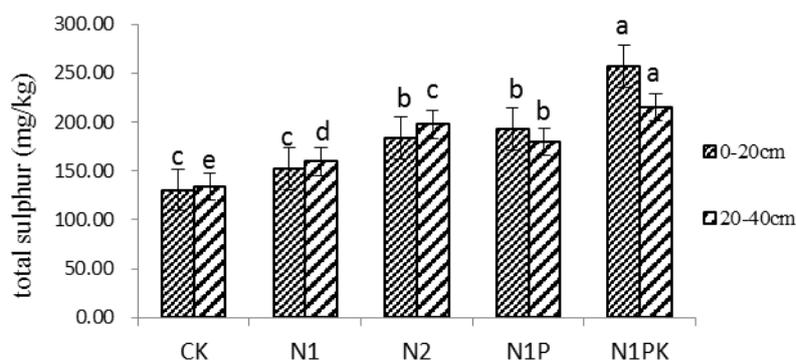
Soil layer (cm)	Organic matter (g/kg)	Total N (g/kg)	Total P (g/kg)	Total K (g/kg)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	pH
0–20	13.1	0.53	0.67	18.8	56.2	12.5	89.6	6.81

There three split-plot designs, chemical plot, low levels of organic fertilizer, high levels of organic fertilizer. Fifteen treatments were established in 1979 and end in 2014: nitrogen and phosphorous fertilization (N<sub>1</sub>P), nitrogen, phosphorous and potassium fertilization (N<sub>1</sub>PK), low levels of nitrogen fertilization (N<sub>1</sub>), high levels of high levels of nitrogen fertilization (N<sub>2</sub>), no fertilization (CK), low levels of organic fertilization mix with nitrogen and phosphorous fertilization (M<sub>1</sub>N<sub>1</sub>P), low levels of organic fertilization mix with nitrogen, phosphorous and potassium fertilization (M<sub>1</sub>N<sub>1</sub>PK), low levels of organic fertilization and nitrogen fertilization (M<sub>1</sub>N<sub>1</sub>) low levels of organic fertilization and high levels of nitrogen fertilization (M<sub>1</sub>N<sub>2</sub>), low levels of organic fertilization (M<sub>1</sub>), high levels of organic fertilization mix with nitrogen, phosphorous and potassium fertilization (M<sub>2</sub>N<sub>1</sub>PK), high levels of organic fertilization and nitrogen fertilization (M<sub>2</sub>N<sub>1</sub>), high levels of organic fertilization and high levels of nitrogen fertilization (M<sub>2</sub>N<sub>2</sub>), high levels of organic fertilization (M<sub>2</sub>). The experimental field cropping system consisted of maize- maize- peanut rotation cropping. Soil samples at depths of 0–20 cm and 20–40 cm were collected randomly in 2014.

The total and valid sulphur were determined by ICP-AES method. Microsoft Excel 2010 and SPSS 19.0 were used for the statistical analysis of the experimental data.

## 3. Results and discussion

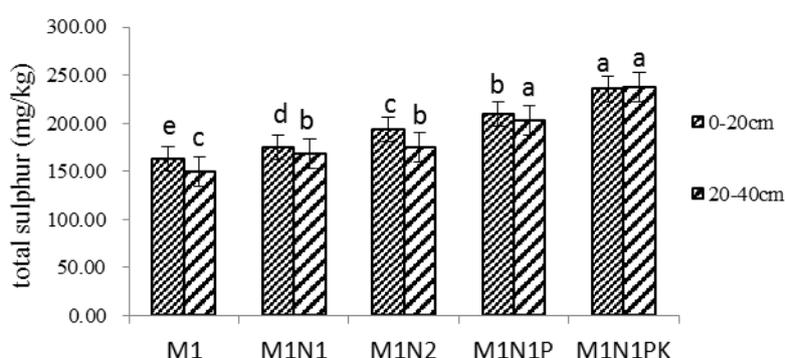
### 3.1. Effect of different fertilization on soil total sulphur



**Fig. 1** the content of total sulphur in chemical fertilization plot

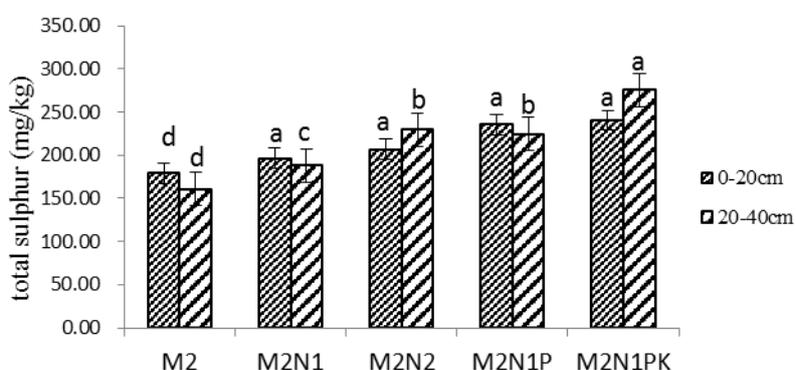
Different letters represent significant differences between different treatments ( $p < 0.05$ ; Duncan's test)

In the depth of 0-20cm, the contents of soil total sulphur with chemical fertilizations treatments were all higher than no fertilization treatment. The application of low high level of nitrogen significantly increased 29.41% in comparison with the high one. Compared between N1PK, N1P and N1 treatments, the N1PK treatment had the highest total sulphur content that was 499.73mg/kg and significantly higher than N1 treatment 1.91 times. It showed that applied in more abundant chemical fertilizations can improve the content of total sulphur. The result was as same as Xu's [7]. The total sulphur content of every treatment in 20-40cm depth was lower than that in 0-20cm depth. Ren's result [8] had the same result. In comparison with no fertilization applied, the total sulphur content was improved when chemical fertilizations were used. The content of sulphur in low levels of nitrogen treatment was increased significantly 28.71% compared to the high level treatment. It was different with the result in 0-20cm depth. The N1PK treatment total sulphur was the highest in comparison with N1P and N1 treatment and that significantly higher than nitrogen fertilization treatment 0.55 times.



**Fig. 2** the content of total sulphur in low levels of organic fertilization plot

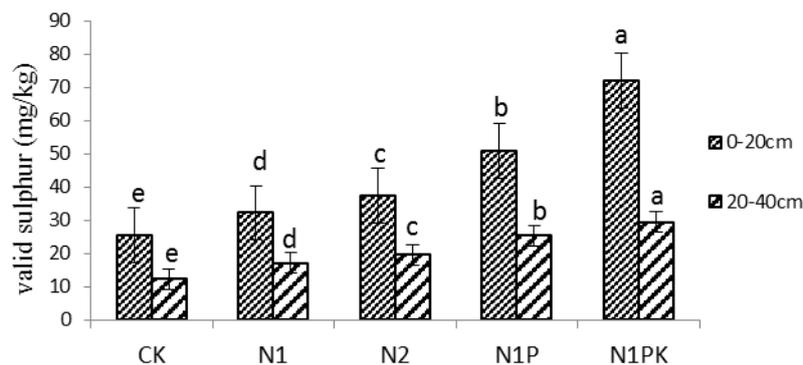
In the low levels of organic fertilization plot, the contents of total sulphur were obviously higher in application of chemical fertilizations than organic fertilization only in the depth of 0-20cm. Obviously, the effect was better when organic and chemical fertilizations applied together. In comparison with different levels of nitrogen fertilizers, the high level treatment total sulphur content was significantly increased to 10.73% than the low one. The content of total sulphur with low levels of organic fertilization and nitrogen and phosphorous fertilization applied was the highest 235.33mg/kg and it obviously higher than M1N1P treatment 12.36% and M1 treatment 21.82%. respectively. It showed that the more kinds of fertilizations were used the higher total sulphur content was. In the depth of 20-40cm, the regulars were similar as 0-20cm depth but the total sulphur contents were lower than that. The content of total sulphur of M1N1PK treatment was significantly increased to 58.36% compared with no chemical fertilizers were used.



**Fig. 3** the content of total sulphur in high level of organic fertilization plot

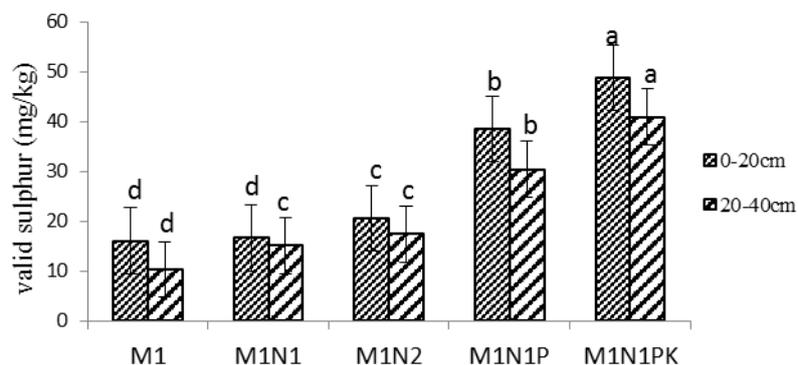
In the high levels of organic fertilization plot, the total sulphur content of chemical fertilization mixed with organic fertilization treatments were higher than organic fertilization only treatment. It same as Gao's [6] result. In comparison with high level of organic fertilizer only treatment, total sulphur content was significantly increased by 34.14% in M1N1PK treatment. The total sulphur content of high level of nitrogen treatment was higher than the low one 5.29%. However, there was no significant difference. There were similar regulars in 20-40cm depth. The total sulphur content of high level of nitrogen treatment was significantly higher than the low one 22.00%.The nitrogen fertilization was helpful to increased total sulphur content in deeper soil depth.

### 3.2. Effect of different fertilization on soil valid sulphur



**Fig. 4** the content of valid sulphur in chemical fertilization plot

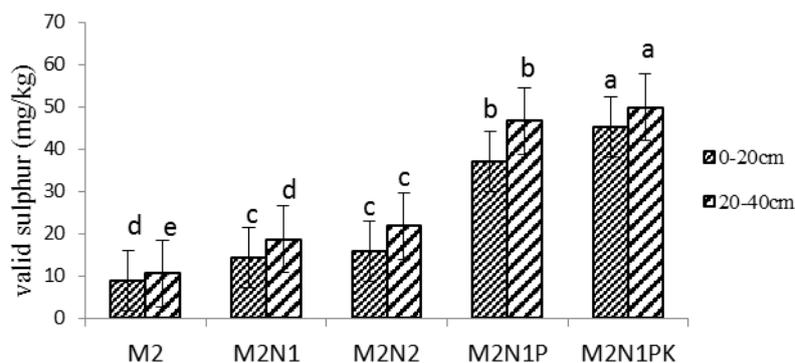
In chemical fertilization plot, no matter what kinds of fertilizations were applied, the contents of valid sulphur were improved compared with in application of no fertilizer. N1PK treatment had the highest valid sulphur and it higher than CK treatment 1.38 times. In comparison with different levels nitrogen fertilization treatments, the valid sulphur in N2 treatment was significantly increased by 16.05%. The result confirmed that more chemical fertilization can improve valid sulphur content. The chemical fertilizers were helpful to improve soil valid sulphur. The reason was that soil pH significantly reduced when chemical fertilizer applied in soil. There were more positive charges at soil surface increased so that it can absorb more  $\text{SO}_4^{2-}$  [9].The regulars in the depth of 20-40cm as same as in 0-20cm depth.



**Fig. 5** the content of valid sulphur in low levels of organic fertilization plot

In 0-20cm depth of low level organic fertilization plot, the valid sulphur content was the highest in M1N1PK treatment and it significantly higher than M1N1 treatment 26.49% ,M1N1% treatment 192.61%, respectively. In comparison with low level of nitrogen treatment, valid sulphur content was significantly increased by 23.47% in M1N2 treatment. However, there was no significant difference

between M1N1 and M1 treatment. The content of valid sulphur was higher than only organic fertilization treatment 0.60mg/kg compared with chemical fertilizer mixed with organic fertilization treatment. There were similar regulars in 20-40cm depth but no obvious difference between different levels of nitrogen treatments. Organic fertilizer application brought a lot of anion groups and inhibited  $\text{SO}_4^{2-}$  by competing adsorption sites in the soil adsorption cumulative [10].



**Fig. 6** the content of valid sulphur in high levels of organic fertilization plot

In high levels of organic fertilization plot, every chemical mixed organic fertilization treatments had more valid sulphur in comparison with organic fertilization only treatment in 0-20 cm depth of soil. It in M2N1PK treatment was higher than in M2 treatment 4.14 times. There was no significant difference between different levels nitrogen treatments and valid sulphur content in M2N2 treatment was higher than that in M2N1 treatment 10.28%. However, in 20-40cm depth, there was significant difference. Except that, the regulars in different depths were same. In application of organic fertilizer can improve soil carbon. Carbon bonds sulphur is the main source of organic sulphur mineralization. This part of the organic sulphur can be converted into valid sulphur effectively when drying or microorganisms acting [11].

#### 4. Results

1) After long-term fertilization for 37 years, in comparison with in application of no fertilizer, after other only chemical fertilization treatments the soil total sulphur and valid sulphur content were increased.

2) Compared with organic only fertilization treatment, in application of organic fertilization mixed with chemical fertilization can improve total sulphur and valid sulphur better. The effect of high levels of organic fertilization mix with nitrogen, phosphorous and potassium fertilization was significantly greater.

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