Effect of agricultural practices on soil acidification in acid precipitation area

Dingyong Wang[A,B], Shixing Li[A] and Xiaojun Shi[A,C]

[A]Eco-environments in Three Gorges Reservoir Region (Ministry of Education), College of Resources and Environment, Southwest University, Chongqing 400715, China, Email dywang@swu.edu.cn
[B]Agricultural Resources and Environment, Chongqing 400716, China, Email dywang@swu.edu.cn
[C]National Monitoring Station of Soil Fertility and Fertilizer Efficiency on Purple Soils, Chongqing 400716, China, Email shixj@swu.edu.cn

Abstract
Both acid precipitation and unreasonable agricultural practice are notorious artificial factors resulting in soil acidification. To sort out reasonable agricultural practices favorable to abating soil acidification, the task of this study was directed to a long-term field trial from 1991 to 2007 in Chongqing, China during which chemical fertilizer were applied to the rice-wheat-rotated field and the soil pH value was measured. The result indicated that all treatments decreased pH in the 0 to 20 cm soil layer after ten years, especially when chlorine-containing fertilizer, excessive chemical fertilizer and mixed fertilizer were applied. It is demonstrated that balance rates of N, P and K fertilizers and application of muck in field are advantageous to abating soil acidification.

Key Words
Soil acidification, agricultural practices, acid precipitation.

Introduction

Soil acidification is one of the major causes of soil degeneration, which leads to decrease in the pH value, loss of base and nutrient content, consequently results in deforestations and decrease of crop yield. Once acidified leaching water enters into water bodies like lakes, rivers, etc, it causes water acidification and death of fish. Therefore, soil acidification is one of the serious environment problems in the world. Soil acidification is originally a slow natural process. However, human activities have dramatically accelerated the process in recent decades. Two artificial factors, including acid precipitation caused by air pollution and unreasonable agricultural measures such as abusing chemical fertilizer, considerably aggravate soil acidification. Therefore, these two factors were a hot topic and were studied by many researchers through field or simulated experiments in recent years. Their results indicated that acid precipitation could acidify the soil in a short time and the soil pH decrease caused by unreasonable agricultural measures presented in a few years, especially when N-fertilizer was applied to the field. However, the effects of agricultural measures on soil acidification in China have been less studied. The object of this work was to find reasonable agricultural measures to buffer and inhibit soil acidification in acid precipitation areas.

Materials and methods

Site and experimental design

A long-term fix fertilizer application experiment was carried out from 1991 at the National Monitoring Station of Soil Fertility and Fertilizer Efficiency on Purple Soils, located at Beibei(29°39′N, 106°18′E, 1208.3 mm annual precipitation), Chongqing, China. The soil was classified as Typic Purpli-Udic Cambosols wherein purple sandy and silt rocks of the Shaximiao formed in Jurassic period. Soil properties such as pH (7.45), exchangeable acidity (0 g/kg), oganic matter (16.61 g/kg) and cation exchange capacity (20.05 cmol /kg) were measured at the beginning of the experiment in 1990.

The experiment was conducted in rice-wheat-rotated field with nitrogenous ($CO(NH_2)_2$), potash (K_2SO_4), phosphorus (CaH_2PO_3) fertilizers and organic manure. Different chemical fertilizer and organic manure were applied to rice-wheat-rotated field to compare their effect on soil acidification. The chemical fertilizers were converted into N, P_2O_5 and K_2O respectively. No N, P_2O_5, K_2O or organic manure were applied to the CK. In the chemical fertilizer treatments, N (15.0 g/m^2/yr) for N, N (15.0 g/m^2/yr) and P_2O_5 (7.5 g/m^2/yr) for NP, N (15.0 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for NK, P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for PK, N (15.0 g/m^2/yr), P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for NPK treatments respectively were applied to the rice-wheat-rotated field. In the organic manure and chemical fertilizers treatments, pig dung (150.0 g/m^2/yr) but no chemical fertilizer for M_1, pig dung (150.0 g/m^2/yr), N (15.0 g/m^2/yr), P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for M_1+NPK, pig dung (150.0 g/m^2/yr), N (22.5 g/m^2/yr), P_2O_5 (10.3 g/m^2/yr) and K_2O (10.3

g/m^2/yr) for M_1+NPKadd, straw (50.0 g/m^2/yr), N (15.0 g/m^2/yr), P_2O_5 (7.5 g/m^2/yr) and K_2O (7.5 g/m^2/yr) for M_2+NPK, were applied to the rice-wheat-rotated field. In the M_1+P(NK)Cl treatment, $CO(NH_2)_2$ and K_2SO_4 were replaced by NH_4Cl and KCl.

Soil analyses
Soil samples from each plot in the experiment were colleted at the depth of 20 cm and homogenized in 1991, 1996, 2001 and 2007. The pH value was measured in slurry of soil and water at the ratio of 1:2.5 by a glass electrode pH meter.

Results and discussion
Effect of chemical fertilizer on soil acidification
A significant effect of the application of chemistry fertilizer on soil acidification was observed at the long-term fertility trial (Figure 1). In 1996, 2001 and 2007, the soil pH was obviously decreased more by all fertilizer treatments than that in control treatment (CK). It showed that chemical fertilizer accelerated soil acidification. The soil pH value of NP, NP and PK treatments decreased more than that of N and NPK treatments in 1997 and 2001. From 1991 to 2007, the soil pH values of NP, NK and PK treatments decreased by 0.66, 0.64 and 0.61, respectively. During the same time, the soil pH values of N and NPK treatments decreased by 0.08 and 0.23, respectively. The soil pH value changed discontinuously in the time from 1991 to 2001. In 1996, the soil pH values of all treatments increased together but those applied chemistry fertilizer increased less than that of the comparisons. In 2001, the soil pH values of all treatment decreased together and those applied chemistry fertilizer dropped more than that of the comparisons. In 2007, the soil pH values of NP, NK and PK treatments went down further and those of all kinds of chemistry fertilizer kept below that of comparisons.

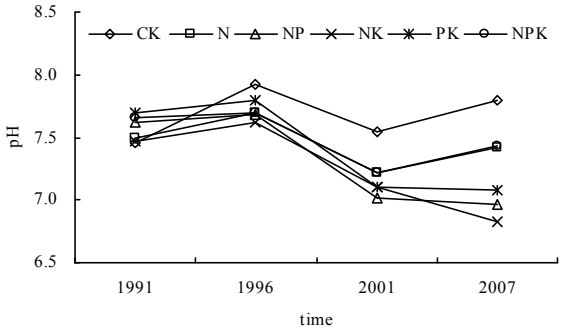

Figure 1. Soil pH value influenced by application of chemical fertilizer.

The results suggested that application of chemistry fertilizer accelerated soil acidification and balance rates of N, P and K fertilizer had less effect on soil acidification.

Effect of organic fertilizer in soil acidification
The application of organic manure affected the soil acidification process differently, as can be seen in Figure 2. The soil pH values of adopting organic manure decreased after ten years. The order of soil pH value decrease was: M_2+NPK>M_1+NPK>NPK or M_1. From 1991 to 2001, the soil pH values of M_2+NPK and M_1+NPK treatments decreased by 0.55 and 0.46, respectively; and those of NPK and M_1 treatments by 0.23 and 0.07. M1 treatment decreased the soil pH value less than M_1+NPK and M_2+NPK did. It indicated that muck had less effect on soil acidification. But mixed manure and fertilizer in field could accelerate soil acidification. N input was greater than that need by biota in M_1+NPK treatments and the excessive was oxidized into more nitric acid by microorganisms in soil. M_2+NPK decreased the soil pH value from 7.58 to 7.03 during ten years. Though part of negative ion returned to soil increased the soil pH values, the putrefaction of straw increased organic nitrogen that would take into reaction and result in soil pH values decrease. The soil pH value depended upon the balance of the two effects. In this experiment, the straw returned to the soil accelerated soil acidification.

Effect of different element and quantity of fertilizer on soil acidification
To study the effect of chlorine-containing fertilizer on soil acidification, NH_4Cl and KCl was used in treatment M_1+$P(NK)_{Cl}$ to replace urea and K_2SO_4. The soil pH values of M_1+$P(NK)_{Cl}$ and M_1+NPK_{add} treatments were lower than of M_1+NPK treatment. From 1991 to 2001, the soil pH values of M_1+NPK_{add}

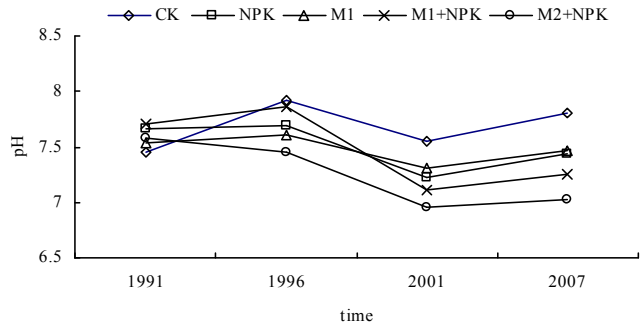

Figure 2. Soil pH value influenced by application of organic manure.

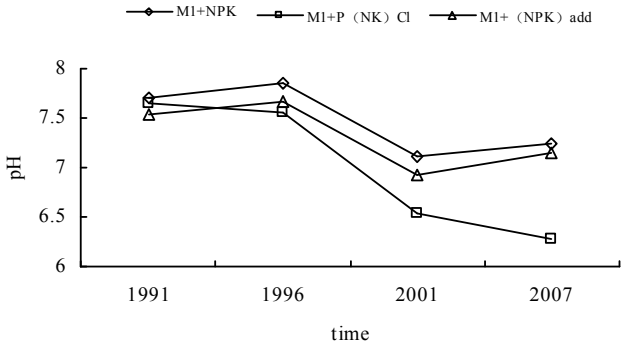

Figure 3. Soil pH value influenced by application of chlorine-containing fertilizer.

treatment dropped from 7.64 to 6.27, decreased by 1.37, the most in all treatments (Figure 3). It indicated that application of chlorine-containing fertilizer or excessive chemical fertilizer accelerated soil acidification. There have been some reports about chlorine-containing fertilizer resulting in soil acidification. When chlorine-containing fertilizer is applied, crop absorbs more ammonia nitrogen than nitrified nitrate. In the process, roots of crop release H^+ that directly causes soil acidification. It is not wisdom to apply excessive chemical fertilizer to farming for yield growth. Replacing chemical fertilizer with organic fertilizer of appropriate amount according to the need of the crop is a good measure to buffer soil acidification. Chlorine-containing fertilizer should be avoided. However, some study indicated that addition of chlorine-containing fertilizer at intervals could buffer soil pH values decrease rapidly.

Conclusion

Soil pH value decreases in the 0 to 20 cm soil layer with application of chemical fertilizer and organic fertilizer, and is influenced by crop rotations after 15 years in acid precipitation areas. Problems are more serious when chlorine-containing fertilizer and excessive chemical fertilizer are applied. But the balance rates of N, P and K fertilizer in field can abate soil acidification. It is shown that soil pH value decreases significantly with application of mixed fertilizer and organic manure. So, application of a reasonable amount of organic manure is a necessary measure in farming.

Acknowledgements

This study was financially supported by the “211” Ecology National Key Discipline of Southwest.

References

Barak P, Jobe BO, Krueger AR (1997) Effect of long-term soil acidification due to nitrogen fertilizer inputs in Wisconsin. *Plant and Soil* **197,** 61-69.

Burle ML, Mielniczuk J, Mielniczuk SF (1997) Effect of cropping systems on soil chemical characteristics, which emphasis on soil acidification. *Plant and Soil* **190,** 309-316.

Cui Y Z (1989) Study about effect of NH_4Cl on production and soil character. *Acta Pedologica Sinica* **20,** 38-40. (in Chinese with English abstract).

He ZL, Alva AK, Calvert DV (1998) Effects of nitrogen fertilization of grapefruit trees on soil acidification

and nutrient availability in a Riviera fine sand. *Plant and Soil* **206,** 11-19.

Lrich B, Mayer R, Khanna PK (1980) Chemical changes due to acid precipitation in a losse-derired soil in central Europe. *Soil Sci* **130,** 193-199.

Peng JL, Yan GA, Sheng XG (2001) Effect of acid rain aquatic ecosystem. *Hydrobioloicaly Sinica* **25,** 282-288. (in Chinese with English abstract).

Tian RS, Liu HT (1990) Aluminum and toxicity to biology in acidified soil. *Environment Science* **11,** 41-48. (in Chinese with English abstract).

Wu JG, Lou DR, Ning YW (1990) Evaluation on efficiency of choride-bearing fertilizer applied in farmland. *Acta Pedologica Sinica* **32,** 321-325. (in Chinese with English abstract).

Xu RK, Coventry DR (2002) Soil acidification as influenced by some agricultural practices. *Agro-environmental Protection* **21,** 385-388. (in Chinese with English abstract).

Zhang AQ (1998) Effect of NH_4Cl on crop character and soil properties. *Gansu Agr Sci and Techn.* **98,** 36-40. (in Chinese with English abstract).

Zhong Z (1988) Effects of soil acidification on trees growth in forest. *Agrology Evolving*. **2,** 51-56. (in Chinese with English abstract).