Effects of Comprehensive Technologies on the Improvement of Acidified Vineyard Soils

Hongguo Jiang1,2, Qinan Wang3, Feng Xu4, Jun Jin2, Guoyu Wang1, Jianguo Liu1,a

1School of Environmental & Safety Engineering, Changzhou University, Changzhou 213164, China
2Changzhou Station for Horticultural Technology Spread, Changzhou 213001, China
3Wujin Station for Horticultural Technology Guidance, Changzhou 213161, China
4Changzhou Center for Agricultural Technology Spread, Changzhou 213001, China
E-mail: liujianguo@cczu.edu.cn

Abstract. Soil acidification is an important factor that restricts the yield and quality of fruits. In this study, the comprehensive improving technologies were applied on the vineyards in which the soil pH is below 5.5. The technologies include application of soil conditioner, organic fertilizer and bacterial manure, and growth of green manure and natural grass. The results show that the comprehensive improving technologies can raise the pH of 0-15 cm soil layer by 0.5-0.8 unit and the pH of 15-30 cm soil layer by 0.3-0.6 unit. The soil bulk densities are decreased by 0.77-10.42%. The contents of organic matter, total N, available P and K in the soils are all increased. Therefore, the soil fertilities are improved. The yields of grape fruits are increased by 12.77-14.94%, and the contents of soluble solid in the grapes are raised by 7.01-9.55%, by the comprehensive measure of seaweed liquid silicon plus sheep manure plus growth of green manure. The comprehensive measure of soil conditioner Naduoli No. 1 plus bacterial manure plus natural grass increases the yields of grape by 7.67%, raises the content of soluble solid in the grape by 8.6%. But the effect of the comprehensive measure of unslaked lime plus sheep manure plus growth of green manure is not clear.

1. Introduction
According to some surveys, soil acidification in vineyard is common because of the application of compound fertilizer of nitrogen and phosphorus [1]. The soil pH is below 5.5 in many vineyards, and even under 4.5 in some vineyards [2]. The soil acidification will lead to soil hardening, decrease of the ratio C/N, and wash away of many mineral nutrients (Ca, Mg, P, etc.) [3]. Soil acidification can also increase release of some toxic metals (Cd, Cr, Pb, Mn, Al, etc.). In acid condition, the soil fixed Al will become soluble Al3+ and Al(OH)2+ that are toxic to plant root. As a result, the abilities of plant root in absorbing water and nutrients are restricted, and the growth and development of plant is inhibited [4]. Soil acidification will also cause unbalance of nutrients in the soils. Excessive supply of nitrogen and phosphorus fertilizers will results in the accumulation of H+ in the soils. Alkaline ion, such as Ca2+, Mg2+, K+, etc., adsorbed by soil colloidal particles will be displaced by H+ [5]. The accumulation of H+ in soil will accelerate soil acidification, which can damage the plasmalemma of root cell, and cause the runoff of nutrients from root cell and decomposing of plant root [6]. Therefore, soil acidification in vineyard will result in decrease of grape yield, and the decline of grape qualities, such as single fruit weight, content of soluble solid, hardness, color and luster, and taste [7]. In some places of China, Soil acidification has become an important threat to the growth, yield and quality of grape, and the sustainable development of grape industry.
In this study, the experiments were designed according to the relevant standard of China (NY/T2271-2012), and locational experiments were applied in some vineyard in Changzhou, China. The effects of different comprehensive technologies on improving acidified vineyard soils, and on the yield and qualities of grape fruit, were studied. The technologies include application of different soil conditioner, organic fertilizer and bacterial manure, and growth of green manure and natural grass. The results will provide scientific basis to the improvement of acidified vineyard soils, and to the elevation of grape yield and quality, in the middle and lower reaches of Changjiang River in China.

2. Materials and methods

2.1. Experimental location and period
The experiments were carried out in two vineyards, e.g. the vineyard of Chaoqun Fruit Co. Ltd. and the vineyard of Ruiyuanyuan Grape Specialized Cooperative. The experimental period was from August 2016 to September 2017.

2.2. Grape varieties for experiment
Grape varieties for this experiment are two-year-old Sunshine Rose Grape in Chaoqun Fruit Co. Ltd., and fourteen-year old Summer Black Grape in Ruiyuanyuan Grape Specialized Cooperative.

2.3. Soil additives
The soil additives are: (1) seaweed liquid silicon (pH 9.5-11.0, containing Si, K, humic acid and alginic acid), (2) soil conditioner Naduoli No. 1 (containing glutamic acid), (3) unslaked lime, (4) sheep manure, (5) bacterial manure, (6) growth of green manure, broad bean or hairy vetch.

2.4. Experimental design
The experiment treatments are shown in Table 2.1.

| Location                  | Code Name of Measure | Treatments                                                                 |
|---------------------------|----------------------|---------------------------------------------------------------------------|
| Chaoqun Fruit Co. Ltd.    | A                    | Seaweed liquid silicon 30 L/hm² + sheep manure 15 ton/ hm² + growth of hairy vetch |
|                           | B                    | Seaweed liquid silicon 30 L/hm² + sheep manure 15 ton/ hm² + growth of broad bean |
|                           | C                    | Unslaked lime 750 kg/hm² + sheep manure 15ton/ hm² + growth of hairy vetch |
|                           | D                    | Unslaked lime 750 kg/hm² + sheep manure 15ton/ hm² + growth of broad bean |
| Ruiyuanyuan Grape Specialized Cooperative | E                  | Soil conditioner Naduoli No. 1 30 L/hm² + bacterial manure 1050 kg/hm² + natural grass |
|                           | Control 1            | Sheep manure 15ton/ hm²                                                   |
|                           | Control 2            | Natural grass                                                              |

2.5. Determination of soils and fruits
The soils were sampled at 0-15 cm and 15-30 cm before and after the treatments, and ten soil samples were taken for each treatment at each sampling time. The following properties were tested: pH, bulk density, and contents of organic matter, total N, available P and available K. Grape fruits were harvested at maturity. Fruit yields were weighted, and contents of soluble solid of the fruits were tested with Digital Refractometer (PR-101α, Japan) [8].
3. Results and discussion

3.1. Effects of different comprehensive measures on physical and chemical properties of acidified vineyard soils

3.1.1. Soil pH. It can be seen from Table 3.1 that the comprehensive measures are effective in improving soil pH of the acidified vineyards, and the soil pH is raised by 0.3-0.8 unit. But the effects vary with the measures and soil layers.

Table 3.1. Effects of Comprehensive Measures on the pH of Acidified Vineyard Soils

| Comprehensive Measure | 0-15 cm Soil Layer | 15-30 cm Soil Layer | Change | \( \text{Before Treatment} \) | \( \text{After Treatment} \) | ± (%) |
|-----------------------|-------------------|---------------------|--------|-----------------------------|-----------------------------|------|
| A                     | 5.5               | 6.0                 | 0.5    | 5.6                         | 5.9                         | 0.3  |
| B                     | 5.6               | 6.1                 | 0.5    | 5.7                         | 6.0                         | 0.3  |
| C                     | 5.4               | 6.1                 | 0.7    | 5.3                         | 5.9                         | 0.6  |
| D                     | 5.4               | 6.2                 | 0.8    | 5.4                         | 6.1                         | 0.7  |
| Control 1             | 5.4               | 5.5                 | 0.1    | 5.6                         | 5.7                         | 0.1  |
| E                     | 5.3               | 6.1                 | 0.8    | 5.9                         | 6.5                         | 0.6  |
| Control 2             | 5.3               | 5.4                 | 0.1    | 5.6                         | 5.6                         | 0    |

The soil pH is increased by 0.6-0.8 unit by the measure C (Unslaked lime + sheep manure + growth of hairy vetch), measure D (Unslaked lime + sheep manure + growth of broad bean) and measure E (Soil conditioner Naduoli No. 1 + bacterial manure + natural grass), but it is only raised by 0.3-0.5 unit by the measure A (Seaweed liquid silicon + sheep manure + growth of hairy vetch) and measure B (Seaweed liquid silicon + sheep manure + growth of broad bean). The effects are higher in 0-15 cm soil layer than in 15-30 cm soil layer. The soil pH of the controls changes little.

3.1.2. Organic matter content. Table 3.2 shows that the contents of organic matter in the vineyard soils are increased by the comprehensive measures, but the effects differ with the measures and soil layers.

In 0-15 cm soil layer, the contents of organic matter are raised by 5.70-10.55%, and the effects of different measures are in the order: measure B > measure E > measure A > measure D > measure C. In 15-30 cm soil layer, the effects are smaller than in 0-15 cm soil layer, and vary little among the comprehensive measures (from 4.78% to 5.01%). For the controls, organic matter contents of the vineyard soils change small during the experiments.

The results also show that natural grass can increase organic matter contents of vineyard soil largely.

Table 3.2. Effects of Comprehensive Measures on Organic Matter Contents of the Vineyard Soils (g/kg)

| Comprehensive Measure | 0-15 cm Soil Layer | 15-30 cm Soil Layer | ± (%) | Before Treatment | After Treatment | ± (%) |
|-----------------------|-------------------|---------------------|-------|-----------------|----------------|------|
| A                     | 14.88             | 16.36               | 9.95  | 13.57           | 14.22          | 4.79 |
| B                     | 17.73             | 19.60               | 10.55 | 16.02           | 16.79          | 4.81 |
| C                     | 20.17             | 21.32               | 5.70  | 19.38           | 20.17          | 4.08 |
| D                     | 19.38             | 20.55               | 6.04  | 16.97           | 17.82          | 5.01 |
| Control 1             | 15.68             | 16.37               | 4.42  | 14.65           | 14.69          | 0.27 |
| E                     | 22.17             | 24.36               | 9.88  | 17.59           | 18.43          | 4.78 |
| Control 2             | 21.97             | 21.98               | 0.05  | 17.48           | 17.50          | 0.11 |

3.1.3. Total N content. The comprehensive measures are effective in increasing total N contents of the soil (Table 3.3). The effects differ with the measures and soil layers. In 0-15 cm soil layer, total N contents of the soils are raised by 8.27-16.39%, and the effects of different measures are in the order: measure B > measure A > measure D > measure C > measure E. In 15-30 cm soil layer, the effects are
also smaller than in 0-15 cm soil layer, and the increasing rates range from 7.07% to 11.00%. The effects of different measures are in the order: measure B > measure D > measure C > measure E > measure A.

Table.3-3. Effects of Comprehensive Measures on Total N Contents of the Vineyard Soils (g/kg)

| Comprehensive Measure | 0-15 cm Soil Layer | 15-30 cm Soil Layer |
|-----------------------|--------------------|---------------------|
|                       | Before Treatment   | After Treatment ± (%) | Before Treatment   | After Treatment ± (%) |
| A                     | 1.14               | 1.27                | 11.40              | 0.99                | 1.06                | 7.07                |
| B                     | 1.22               | 1.42                | 16.39              | 1.00                | 1.11                | 11.00               |
| C                     | 1.32               | 1.45                | 9.85               | 1.15                | 1.24                | 7.83                |
| D                     | 1.06               | 1.18                | 11.32              | 0.94                | 1.04                | 10.64               |
| Control 1             | 0.99               | 1.05                | 6.06               | 0.93                | 0.95                | 2.15                |
| E                     | 1.33               | 1.44                | 8.27               | 0.97                | 1.04                | 7.22                |
| Control 2             | 1.33               | 1.35                | 1.50               | 0.97                | 0.98                | 1.03                |

3.1.4. Available P contents. Among the comprehensive measures, most measures (measure A, B, C and D) have no obvious effect on soil available P contents, and the increasing rates are below 5% (Table.3-4). But the effect of measure E is high, and increasing rate is 22.68% in 0-15 cm soil layer, and 16.79% in 15-30 cm soil layer.

Table.3-4. Effects of Comprehensive Measures on Available P Contents of the Vineyard Soils (mg/kg)

| Comprehensive Measure | 0-15 cm Soil Layer | 15-30 cm Soil Layer |
|-----------------------|--------------------|---------------------|
|                       | Before Treatment   | After Treatment ± (%) | Before Treatment   | After Treatment ± (%) |
| A                     | 49.98              | 52.08                | 4.20               | 36.80                | 38.12                | 3.59                |
| B                     | 50.14              | 52.22                | 4.15               | 43.56                | 44.99                | 3.28                |
| C                     | 65.46              | 67.67                | 3.38               | 49.57                | 50.58                | 2.04                |
| D                     | 60.53              | 62.79                | 3.73               | 40.26                | 41.84                | 3.92                |
| Control 1             | 38.56              | 40.33                | 4.59               | 28.80                | 29.72                | 3.19                |
| E                     | 36.28              | 44.51                | 22.68              | 24.90                | 29.08                | 16.79               |
| Control 2             | 36.28              | 37.45                | 3.22               | 24.90                | 25.72                | 3.29                |

Table.3-5. Effects of Comprehensive Measures on Available K Contents of the Vineyard Soils (mg/kg)

| Comprehensive Measure | 0-15 cm Soil Layer | 15-30 cm Soil Layer |
|-----------------------|--------------------|---------------------|
|                       | Before Treatment   | After Treatment ± (%) | Before Treatment   | After Treatment ± (%) |
| A                     | 210.60             | 238.45               | 13.22              | 234.20                | 256.25                | 9.42                |
| B                     | 166.90             | 191.32               | 14.63              | 156.00                | 175.26                | 12.35               |
| C                     | 203.10             | 221.07               | 8.85               | 190.10                | 205.15                | 7.92                |
| D                     | 210.50             | 221.36               | 5.16               | 204.90                | 213.92                | 4.40                |
| Control 1             | 167.30             | 175.32               | 4.79               | 154.50                | 159.45                | 3.20                |
| E                     | 176.63             | 194.40               | 10.06              | 124.74                | 135.12                | 8.32                |
| Control 2             | 176.63             | 188.66               | 6.81               | 124.74                | 128.94                | 3.37                |

3.1.6. Bulk densities. The effects of different comprehensive measures on bulk densities of the vineyard soils differ largely among the measures, and the decreasing rates on soil bulk densities range
from -10.42% to -0.77% (Table 3-6). The effects of different measures are in the order: measure E > measure A > measure B > measure D > measure C. For the controls, the soil bulk densities change small during the experiments.

**Table 3-6. Effects of comprehensive measures on bulk densities of the vineyard soils (g/cm³)**

| Comprehensive Measures | A | B   | C | D   | Control 1 | E  | Control 2 |
|------------------------|---|-----|---|-----|-----------|----|-----------|
| Before treatment       | 1.43 | 1.39 | 1.3 | 1.38 | 1.45      | 1.44 | 1.46      |
| After treatment        | 1.34 | 1.32 | 1.29 | 1.33 | 1.44      | 1.29 | 1.47      |
| ± (%)                  | -6.29 | -5.04 | -0.77 | -3.62 | -0.69     | 0.69 | 0.68      |

The results indicate that the soils become loose and have more pores after the application of the comprehensive measures, which will benefit the exchange of water, fertilizer, gas and heat, the activities of microorganism, the transfer of nutrients from soil to plant, and the growth of plants [9]. Some researches also presented that soil bulk densities decreased, soil total porosities increased, and gas permeability of the soils was improved after application of soil conditioners [10-12].

4. Effects of different comprehensive measures on the yields and soluble solid contents of grape fruits

4.1. Yield

Compared to the controls, the comprehensive measures can increase the yields of grape fruits, but the increasing rates differ largely among the measures (Figure 4-1). The yields of grape fruits are raised by 3.30-14.94% by the measures, and the increasing effects are in the order: measure B > measure A > measure E > measure D > measure C.

![Figure 4-1. Effects of different comprehensive measures on the yields of grape fruit](image1)

4.2. Contents of soluble solid.

Effects of the comprehensive measures on the contents of soluble solid in grape fruits also vary among the measures, and the increasing rates range from 0.64% to 9.55% (Figure 4-2). The effects are in the order: measure A > measure E > measure B > measure C > measure D.

![Figure 4-2. Effects of different comprehensive measures on contents of soluble solid in grape fruit](image2)

5. Conclusions

(1) The comprehensive improving measures can effectively raise the pH of acidified vineyard soils. The effects of measure C (Unslaked lime + sheep manure + growth of hairy vetch), measure D (Unslaked lime + sheep manure + growth of broad bean) and measure E (Soil conditioner Nduoli No. 1 + bacterial manure + natural grass) are better than that of measure A (Seaweed liquid silicon + sheep
manure + growth of hairy vetch) and measure B (Seaweed liquid silicon + sheep manure + growth of broad bean).

(2) The comprehensive measures can obviously decrease soil bulk density, and the effects are in the order: measure E > measure A > measure B > measure D > measure C.

(3) The comprehensive measures can largely increase the organic matter contents of 0-15 cm soil layer. The effects of measures B, E and A are better than that of measures D and C.

(4) The comprehensive measures can effectively increase total N and available K contents in the soils. The total N contents are raised by 7.01-16.39%, and available K contents by 4.40-14.63%, by the measures. For increasing available P contents, only measure E is highly effective.

(5) As a result of soil quality improvement, the yields and quality of grape fruits are largely increased by three comprehensive measures (measure A, B and E). The yields are raised by 7.67-14.94%, and the soluble solid contents by 7.01-9.55%, by the three measures.

6. Acknowledgment

This research was financially supported by the Agricultural “Three New Projects” of Jiangsu Province (SXGC [2016]076)

7. References

[1] J. Y. Wang, Q. H. Liu, J. L. Li, S. A. Jin, and Y. B. Yuan, “Analysis on the Characteristic and Cause of Orchard Soil Acidification in the Area of Shandong Peninsula,” Chinese Agricultural Science Bulletin, vol. 26, Oct. 2010, pp. 164-169.

[2] R. Q. Zhang, J. C. Yang, X. Sun, L. L. Zhao, Y. X. Sun, W. H. Xu, and Z. W. Jiang, “Research on Melioration Effect of Two Kinds of Biochars on Orchard Acidified Soil,” Shandong Agricultural Sciences, vol. 48, Feb. 2016, pp. 74-79, doi: 10.14083/j.cnki.1001-4942.

[3] Y. P. Li, H. Y. Hu, Z. J. Li, Q. B. Kong, C. S. Dai, and Y. Q. Zhang, “Effects of soil conditioner on red soil pH and yield and quality of water spinach,” Soils and Fertilizers Sciences in China, vol. 6, Dec. 2014, pp. 21-26, doi: 10.11838/sfsc.20140604.

[4] J. X. Yi, L. X. Lü, and G. D. Liu, “Research on soil acidification and acidic soil's melioration,” Journal of South China University of Tropical Agriculture, vol. 12, Jan. 2006, pp. 23-27, doi: 10.3969/j.issn.1674-7054.

[5] H. L. Chen, “Reason and harm of soil acidification in solar greenhouse and its comprehensive prevention technology,” Tianjin Agriculture and Forestry Technology, vol. 4, Apr. 2009, pp. 37, doi: 10.16013/j.cnki.1002-0659.

[6] K. Z. Xie, P. Z. Xu, C. Yan, F. B. Zhang, J. S. Chen, S. H. Tang, X. Huang, and W. J. Gu, “Study the effects of soil improvement on acid soil in the south of China,” Chinese Agricultural Science Bulletin, vol. 25, Nov. 2009, pp. 160-165.

[7] S. C. Lu, Quality status and improvement of orchard soil, Beijing: Chemical Industry Press, 2013.

[8] L. Xu, J. Yang, Y. X. Wang, J. T. Ye, B. X. Ma, and C. Lu, “Detection of Soluble Solids Content of Postharvest Grape Based on Hyperspectral Imaging.” Journal of Henan Agricultural Sciences, vol. 46, Mar. 2017, pp. 143-147, doi: 10.15933/j.cnki.1004-3268.

[9] H. W. Zhang, M. J. Long, and F. S. Zeng, “Study of amelioration to lateritic red soil by copolymer of humic acids grafted vinyl monomer,” Research of Soil and Water Conservation, vol. 2, Feb. 2001, pp. 115-118, doi: 10.3969/j.issn.1005-3409.

[10] D. G. Fan, Z. H. Yuan, and Z. Q. Song, “Primary report on the application of soil conditioner in dryland orchard,” Jiangxi Horticulture, vol. 5, May. 2004, pp. 12-13, doi: 10.3969/j.issn.1006-4958.

[11] D. L. Li, C. L. He, and X. M. Men, “Effect of different soil conditioners applied on Shajiang black soil,” Soil, vol. 4, Apr. 2000, pp. 210-214, doi: 10.3321/j.issn:0253-9829.

[12] X. B. Wang, and D. X. Cai, “Research and application of soil conditioner in agriculture,” Plant Nutrition and Fertilizer Science, vol. 6, Apr. 2000, pp. 457-463, doi: 10.11674/zwyf.