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Contents and Changes of Potassium in Plough Layers of Xuancheng, South Anhui Province

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Abstract

Xuancheng City is the dominant tobacco-planting area of Anhui province due to the high quality of the tobacco leaves. However, the potassium content in the tobacco leaves shows a gradual decreasing trend in recent years, which may be attributed partly to the possible low potassium content in topsoil of tobacco-planting farmland. Therefore, the content data in the year of 2005-2007 of rapidly available potassium (RA-K) of 7730 topsoil samples mainly under double rice rotation or wheat/rice-rice rotation at that time and the content data of slowly available potassium (SA-K) and RA-K of 124 typical topsoil samples in the year of 2015 under tobacco-rice rotation were used and compared in order to disclose the status of topsoil potassium and to provide a guidance for reasonable potassium fertilization in Xuancheng. The results showed that in 2005-2007 RA-K content ranged from 1 $mg \cdot kg^{-1}$ to 844 $mg \cdot kg^{-1}$ with an average of 68 $mg \cdot kg^{-1}$, and 82.7% of topsoil samples were insufficient in RA-K (<100 $mg \cdot kg^{-1}$). Comparatively in 2015 SA-K content ranged from 230 $mg \cdot kg^{-1}$ to 1340 $mg \cdot kg^{-1}$ with an average of 595 $mg \cdot kg^{-1}$, and 13.7% of soil samples were insufficient in SA-K (<400 $mg \cdot kg^{-1}$); RA-K content ranged from 46 $mg \cdot kg^{-1}$ to 352 $mg \cdot kg^{-1}$ with an average of 134 $mg \cdot kg^{-1}$, and 25.8% of soil samples were insufficient in RA-K (<100 $mg \cdot kg^{-1}$). The above data show that RA-K content has increased gradually in farmland topsoil mainly due to fertilization since 1980s, particularly to farmland under tobacco-rice rotation, but insufficient RA-K in topsoil is still widely and serious for farmland under double rice rotation or wheat/rice-rice rotation. Under tobacco-rice rotation, RA-K insufficiency usually occurred in the farmlands which plant tobacco less than 3 years, indicating more potassium fertilizer should be applied.

Keywords

Rapidly Available Potassium (RA-K), Slowly Available Potassium (SA-K), Topsoil, Tobacco-Rice Rotation, Xuancheng City

1. Introduction

The potassium content is an important index to evaluate the quality of flue-cured tobacco [1] [2]. Generally speaking, the potassium content in tobacco leaves with high quality should not be less than 2% [3]. The potassium content in tobacco leaves of the United States, Zimbabwe and Brazil and other countries ranges from 4% to 6% while it is only ranges from 1.5% to 2.0% in China, except for the Yunnan-Guizhou Plateau of southwest China and Sanming of Fujian province of southeast China [4] [5]. Thus, promoting the potassium content in tobacco leaves has been one of the key studies in China.

Xuancheng City (29˚57'N - 31˚19'N，117˚58'E - 119˚40'E), located in south Anhui Province, has been the dominant tobacco-planting region of this province since tobacco was initially planted in 2007 due to its well-known "burnt-sweet smelling" style [6] [7]. The tobacco-planting area is nearly 10,000 hm^2 with 10,000 tons of tobacco leaf yield [6]-[11]. However, according to the annual monitoring data, the average potassium content in tobacco leaves of Xuancheng City shows a decreasing trend, it alarmingly decreased from 2% in 2007 [6] to 1.5% in 2014.

The potassium in tobacco leaves mainly comes from soil and applied potassium fertilizer [12], and the rational potassium fertilization depends upon the background of soil potassium content [13]. Therefore, in this paper, we analyzed the potassium contents in the topsoil in 2005-2007 and in 2015 of Xuancheng City, disclosed the changes and mechanism of potassium status in order to instruct the reasonable potassium fertilization for producing tobacco leaves with high content of potassium.

2. Methods and Materials

2.1. The Sources of Soil Potassium Data

The contents of potassium in topsoil were from the following sources in this paper, one is the contents of rapidly available potassium (RA-K) of 7730 topsoil samples (0 - 20 cm) in 2005-2007 obtained from the programme of Soil Testing and Formula Fertilization (STFF), and the other is the contents of slowly available potassium (SA-K) and RA-K of 124 topsoil samples collected in 2015 from the farmlands of model tobacco-farmers.

The spatial distribution of topsoil samples in the two periods are shown in Figure 1 and Table 1. The contents of SA-K and RA-K were determined by the method of flame photometer after topsoil samples were digested by HNO_3 and extracted by acetamide for the content measurements of SA-K and RA-K, re

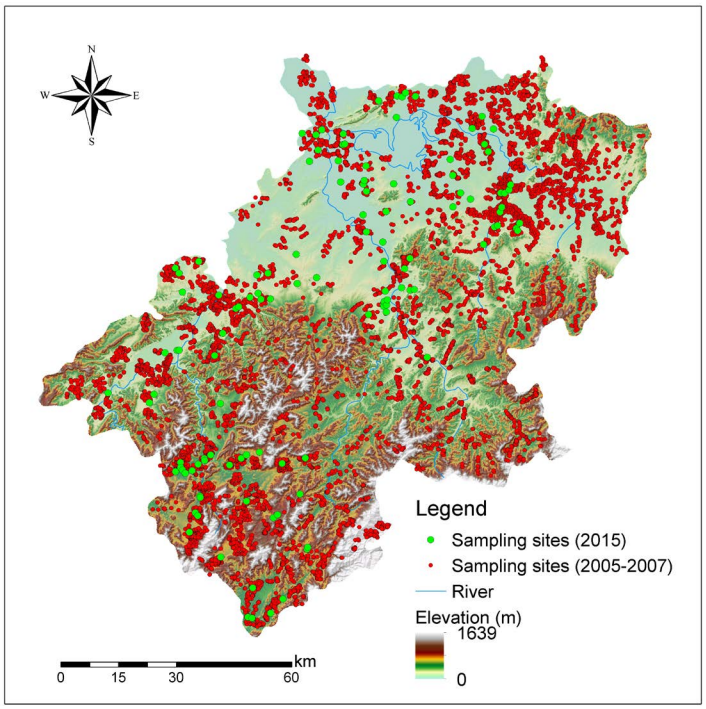

Figure 1. Spatial distribution of topsoil samples in Xuancheng City, South Anhui Province (7730 samples in 2005-2007, 124 samples in 2015).

Table 1. Regional distribution of topsoil samples in Xuancheng City.

Region	Xuanzhou (XZ)	Langxi (LX)	Guangde (GD)	Ningguo (NG)	Jingxian (JX)	Jixi (JXX)	Jingde (JD)	Total
2005-2007	923	1083	1308	930	1425	1073	988	7730
2015	42	11	13	8	19	10	21	124

spectively [14].

2.2. The Grading Standards of Soil Potassium Contents

Table 2 is the grading standards of SA-K and RA-K used in this study, which is simplified on the basis of grades of potassium contents adopted in the 2nd National Soil Survey (http://wenku.baidu.com/view/3f7f297e27284b73f242505c.html).

2.3. Methods of Data Statistics and Mapping

Data were analyzed with Microsoft Excel 2013 and IBM Statistics SPSS 20.0, the spatial distribution of topsoil samples was mapped on the platform of Esri ArcGIS 10.3.

3. Results

3.1. Rapidly Available Potassium Contents of Topsoil in 2005-2007

Table 3 shows the statistic information of RA-K contents of topsoil samples in

Table 2. Content grades of slowly available potassium and rapidly available potassium used in this study.

Index	Sufficient	Medium	Deficient	Severe deficient
SA-K ($mg \cdot kg^{-1}$)	>500	500 - 400	400 - 300	<300
RA-K ($mg \cdot kg^{-1}$)	>150	150 - 100	100 - 50	<50

Table 3. Statistics of rapidly available potassium contents in topsoil samples in 2005-2007, Xuancheng City.

Region		XZ	LX	GD	NG	JX	JXX	JD	Total
RA-K ($mg \cdot kg^{-1}$)	Range	1 - 826	9 - 420	6 - 310	15 - 470	2 - 611	11 - 844	8 - 371	1 - 844
	Average	57	71	68	94	66	77	47	68

2005-2007. To the whole Xuancheng City, RA-K content ranged from 1 $mg \cdot kg^{-1}$ to 844 $mg \cdot kg^{-1}$ with an average of 68 $mg \cdot kg^{-1}$, while the average RA-K contents in different administrative regions ranged from 47 $mg \cdot kg^{-1}$ to 94 $mg \cdot kg^{-1}$, generally in the deficient grade.

Table 4 shows the sample number distribution in different grades of RA-K contents in 2005-2007. To the whole Xuancheng City, 82.7% (6392 samples) of the total samples were in the deficient grade while 5.8% (9 samples) of the total samples were in sufficient grade, which indicate generally RA-K content of topsoil samples are insufficient. To various administrative regions, the deficiency of RA-K contents were most serious in Jingde and Xuanzhou, more than 90% of the corresponding total samples were in the deficient grade, followed by GuangDe, LangXi and Jixi, about 80% - 90% of the corresponding total samples were in the deficient grade, while 60% - 80% of the corresponding total samples in Jingxian and Ningguo were in the deficient grade.

3.2. Potassium Contents of Topsoil Samples in 2015

Table 5 shows the statistic information of the contents of SA-K and RA-K in topsoil samples from the model tobacco-farmers' farmlands of Xuancheng City in 2015.

To the whole region, SA-K content ranged from 230 $mg \cdot kg^{-1}$ to 1340 $mg \cdot kg^{-1}$ with an average of 595 $mg \cdot kg^{-1}$, in the sufficient grade; RA-K content ranged from 46 $mg \cdot kg^{-1}$ to 352 $mg \cdot kg^{-1}$ with an average of 134 $mg \cdot kg^{-1}$, in the medium grade.

To various administrative regions, 1) average SA-K content in Jingxian was 485 $mg \cdot kg^{-1}$, in the medium grade, average SA-K contents ranged from 545 $mg \cdot kg^{-1}$ to 810 $mg \cdot kg^{-1}$ in other region, in the sufficient grade. 2) average RA-K contents were 151 $mg \cdot kg^{-1}$ and 185 $mg \cdot kg^{-1}$ in Guangde and Ningguo, respectively, in the sufficient grade; average RA-K content ranged from 105 $mg \cdot kg^{-1}$ to 141 $mg \cdot kg^{-1}$ in other region, in the medium grade.

Table 6 shows the sample number distribution in various grades of SA-K contents of topsoil samples in 2015. To the whole region, 13.7% (17 samples) of

Table 4. Statistics of rapidly available potassium contents in different grades in topsoil samples in 2005-2007, Xuancheng City.

Region	Severe deficient		Deficient		Medium		Sufficient		Total	
	Sample No.	%	Sample No.	%	Sample No.	%	Sample No.	%	Sample No.	%
XZ	450	48.7	396	42.9	68	7.4	9	0.9	923	100
LX	317	29.2	593	54.8	129	11.9	44	4	1083	100
GD	409	31.2	722	55.2	134	10.2	43	3.3	1308	100
NG	98	10.5	509	54.7	225	24.2	98	10.6	930	100
JX	434	30.4	641	45	190	13.3	160	11.3	1425	100
JXX	379	35.4	508	47.3	106	9.9	80	7.4	1073	100
JD	674	68.2	262	26.5	36	3.6	16	1.6	988	100
Total	2761	35.7	3631	47	888	11.5	450	5.8	7730	100

Table 5. Statistics of slowly available potassium and rapidly available potassium contents in topsoil samples in 2015, Xuancheng City.

Region	Sample Number	S A-K ($mg \cdot kg^{-1}$)		R A-K ($mg \cdot kg^{-1}$)	
		Range	Average	Range	Average
XZ	42	230 - 1340	595	46 - 352	134
LX	11	340 - 730	545	106 - 200	141
GD	13	390 - 920	618	68 - 292	151
NG	8	390 - 800	601	106 - 320	185
JX	19	250 - 690	485	58 - 224	128
JXX	10	230 - 950	622	46 - 352	136
JD	21	450 - 1340	810	46 - 158	105
All	124	230 - 1340	595	46 - 352	134

Table 6. Statistics of slowly available potassium contents at various grades in topsoil samples in 2015, Xuancheng City.

Region	Severe deficient		Deficient		Medium		Sufficient		Total	
	Sample No.	%	Sample No.	%	Sample No.	%	Sample No.	%	Sample No.	%
XZ	0	0	7	16.7	13	31.0	22	52.3	42	100
LX	0	0	2	18.2	3	27.3	6	54.6	11	100
GD	0	0	1	7.7	4	30.8	8	61.6	13	100
NG	0	0	1	12.5	0	0	7	87.5	8	100
JX	1	5.3	2	10.5	7	36.8	9	47.4	19	100
JXX	3	30.0	0	0	0	0	7	70.0	10	100
JD	0	0	0	0	2	9.5	19	90.5	21	100
Total	4	3.2	13	10.5	29	23.4	78	62.9	124	100

the total samples were in the deficient grade while 62.9% (78 samples) of the total samples were in sufficient grade. To various administrative regions, SA-K content in Jingde was in the sufficient grade, while 8% - 30% of the corresponding total samples in other regions were in the deficient grade.

Table 7 shows the sample number distribution in various grades of RA-K contents of topsoil samples in 2015. To the whole region, 25.8% (32 samples) of the total samples were in the deficient grade, while 29.8% (37 samples) of the total samples were in the sufficient grade. To various administrative regions, RA-K content in Langxi and Ningguo were in the sufficient grade, while 15-36% of the corresponding total samples in other regions were insufficient in RA-K.

4. Discussion

According to the data of RA-K contents in 1987 obtained during the 2nd National Soil Survey in Xuancheng City, 89.4% of topsoils were lack of RA-K (<100 $mg \cdot kg^{-1}$), however, in 2005-2007 the percentage of RA-K deficient was decreased down to 82.7%, indicating RA-K status of farmlands were slightly improved, which is attributed to potassium fertilization: before 2005-2007, most of the farmlands in Xuancheng were given priority to double rice rotation or rice-wheat rotation. Historical field survey data showed that during this period the annual average crop yield (double rice or rice + wheat) was 1000 kg/667 m^2 in total, the grains usually contain 0.4% of K_2O, almost all the crop straws were returned to the fields or burnt directly in the fields [15] [16], thus about 4 kg /667 m^2 of K_2O was removed out from the topsoil by the harvested grains. Meanwhile, average 80 kg/667 m^2 of the compound fertilizer (containing 8% of K_2O) was applied annually to the fields, about 6.4 kg/667m^2 of K_2O brought into the topsoils, so annually the "net" input of K_2O to the topsoils is about 2.4 kg/667m^2.

For the surveyed model farmers' farmlands with tobacco-rice rotation, only 25.8% of the total 124 topsoil samples are insufficient in RA-K content, while the proportion of RA-K content in medium or above grades was 74.2% in total, indicating that obvious improved in RA-K content in topsoil under the tobacco-rice rotation compared with the data under double rice cropping or rice-wheat rotation in 2005-2007, which is resulted from surplus potassium fertilizers applied into the topsoils during the tobacco-planting period. The field survey data surveyed in 2015 showed that during the tobacco-planting period, 55

Table 7. Statistics of rapidly available potassium contents at various grades in topsoil samples in 2015, Xuancheng City.

Region	Severe deficient		Deficient		Medium		Sufficient		Total	
	Sample No.	%	Sample No.	%	Sample No.	%	Sample No.	%	Sample No.	%
XZ	0	0	15	35.7	15	35.7	12	28.6	42	100
LX	0	0	0	0	7	63.6	4	36.4	11	100
GD	0	0	2	15.4	4	30.8	7	53.9	13	100
NG	0	0	0	0	3	37.5	5	62.5	8	100
JX	0	0	5	26.3	9	47.4	5	26.3	19	100
JXX	1	10.0	3	30.0	3	30.0	3	30.0	10	100
JD	2	9.5	4	19.0	14	66.7	1	4.8	21	100
Total	3	2.4	29	23.4	55	44.4	37	29.8	124	100

kg/667 m^2 of tobacco specific fertilizer (containing 24% of K_2O), 5 kg/667 m^2 of potassium sulphate (containing 50% of K_2O) and 6.6 kg/667 m^2 of potassium nitrate (containing 44% of K_2O) were applied into the topsoil, while during the rice-planting period 15 kg/667 m^2 of rice specific fertilizer (containing 15% of K_2O) was applied to the soil, thus 20.85 kg/667 m^2 of K_2O in total was input into the topsoil from fertilization. Both the yields of tobacco leaves and stems are about 150 kg/667 m^2, which contain 2.2% and 2.0% of K_2O, respectively, but the tobacco stems usually were removed out from the tobacco fields to avoid disease spread. The yield of late rice is about 500 kg/667 m^2, which containing 0.4% of K_2O, also almost all the rice straws were returned to the fields or burnt directly in the fields, thus, about 5.0 kg of K_2O was removed out from the soil by the leaves and stems of tobacco and the grains of rice, so the "net" input of K_2O into the topsoil is about 15.85 kg/667m^2 annually. It is the reason for mean RA-K content (134 mg·kg^{-1}) in the model tobacco-farmers' farmlands in 2015 is 49.3% higher than that under double rice rotation or rice-wheat rotation in 2005-2007 (68 mg·kg^{-1}), also higher than that of the 20 long-term monitoring farmlands (under double rice rotation or rice-wheat rotation) in Xuancheng City in the same year (ranged from 58 mg·kg^{-1} to 188 mg·kg^{-1} with an average of 104 mg·kg^{-1}).

Some tobacco-farmers thought that no potassium fertilizers should be applied into fields during the rice planting period, but the field survey data surveyed in 2015 showed further that for the 87.5% of 'new tobacco-planting farmlands' (under tobacco-rice rotation less than 3 years, 23 topsoil samples in total in 2015), the potassium accumulative effect in topsoils is not obvious, RA-K content in topsoil is still in the deficient grade, so the fields need continuous potassium fertilization during the rice planting period.

5. Conclusion

Generally, the content of rapidly available potassium content has increased gradually in topsoil farmlands in Xuancheng City, which is mainly due to potassium fertilization since 1980s, particularly due to farmlands under tobacco-rice rotation which initially started since 2007. However, more potassium fertilizers should be applied into the farmlands under double rice rotation or wheat-rice rotation, while more potassium fertilizers should be used during the rice planting period to the farmlands under tobacco-rice rotation less than 3 years.

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