International Journal of Animal Breeding and Genetics Vol. 4 (10), pp. 001-006, October, 2015. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Relationship between the calcium content in soil and the calcium content of flue-cured tobacco in Enshi tobacco-growing area

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Accepted 21 February, 2015

Distribution of the calcium content in soil and the calcium content of flue-cured tobacco in Enshi tobacco-growing area of Hubei Province and their relationships were analyzed. The results indicated that: (1) the average content in soil of total and exchangeable calcium was 2124.60 and 1091.44 mg/kg in Enshi tobacco-growing area. The calcium content showed the trends of high altitude > middle altitude >lower altitude among different altitudes, and the trends of 0 to 20 > 20 to 40 > 40 to 60 cm in different soil depths. (2) Significant differences of the calcium content of flue-cured tobacco were found among the different cultivars and grades, indicating the trends of Yunyan87 >Yunyan85 > K326, the trends of X2F > C3F > B2F, and the trends of high altitude > middle altitude > lower altitude. (3) The calcium content in soil and the calcium content of flue-cured tobacco were both increased with the altitude height going up. When the exchangeable calcium content in soil was grouped and increasing, the calcium content of flue-cured tobacco also increased. Linear regression equation was established between the calcium content of flue-cured tobacco and the exchangeable calcium content in soil with high significant correlation coefficient.

Key words: Calcium content in soil, calcium content of flue-cured tobacco, altitude height, relationship analysis, Enshi tobacco-growing area.

INTRODUCTION

Calcium (Ca) was an essential element to flue-cured tobacco growth and development, which was a mineral nutrient ingredient second to potassium. Though calcium was not easily transportable, it played an important role in coordinating and balancing the nutrients absorption in tobacco, which has been shown to ameliorate adverse effects of salinity on plants (Ehret et al., 1990) and is also well known to have regulatory roles in metabolism (Cramer et al., 1986).The change of calcium could affect the soil physicochemical property and the absorption of other nutrients (Xu et al., 2007; Liu et al., 2005).

Diminished soil Ca reduces growth and disease resistance in Acer saccharum on acidic soils (St Clair et al., 2008). Furthermore, Ca availability is strongly related to individual tree growth across natural (Bailey et al., 2004) and experimentally manipulated Ca gradients (Kobe et al., 2002), and correlates with fine root production (Reich et al., 1997; Park et al., 2008). Fertilization with Ca in the field can elicit positive growth responses in seedlings (Kobe et al., 2002), saplings (St Clair and Lynch, 2005). Calcium deficiency would cause physical disorders and FAA (free acid amino) increasing; on the other hand, excess calcium would lead to rough and stiff tobacco leaves and lower the use value of tobacco. Generally, the calcium content of flue-cured tobacco was from 1.5 to 2.5% and 2.5% for quality flue-cured tobacco abroad with upper limit of 3.5%; and the average calcium content was obviously high with 3.45% in China (Ruan et al., 2006; Liao et al., 2007; Li et al., 2006). Altitude and soil conditions were important ecological factors that influenced the quality formation of flue-cured tobacco (Xu et al., 2005, 2008). Change of altitude height caused significant differences for solar radiation amount, effective accumulated temperature, temperature difference, air humidity, etc (Jian et al., 2005). It has been reported that high significant positive correlation existed between the calcium content of flue-cured tobacco and the exchangeable calcium in soil (Nie

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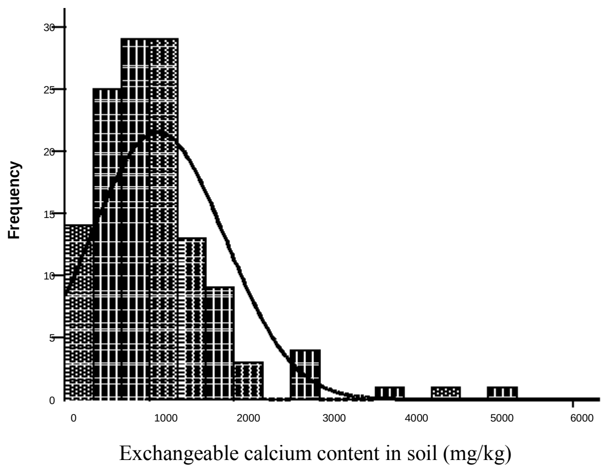

Figure 1. Frequency distribution of the exchangeable calcium content in soil.

et al., 2003); moreover, the relationship was found between the calcium content of flue-cured tobacco and total nitrogen, boron, zinc and manganese. Enshi is located in the southwest of Hubei province, which was one of high quality flue-cured tobacco producing area, with mountainous and hilly land and high degree of curing soil. This paper studied the calcium content in soil and the calcium content of flue-cured tobacco in the method of field survey and laboratory analysis, aiming to supply theoretical proofs for calcium nutrient.

MATERIALS AND METHODS

Soil samples collection

The collection of soil samples were carried out from Xuan'en and Xianfeng counties, on behalf of Enshi tobacco-growing area. The soil samples were chosen from three soil depths of 0 to 20cm (129 samples), 20 to 40cm (24 samples) and 40 to 60cm (24 samples) with GPS positioning technology adopted. In one collection unit, 8 to 10 spots' soil samples were mixed to one of 1.50 kg. Then, the soil samples were labeled followed by preprocessing, air drying, levigating, sieving, blending and bottling to analyze.

Tobacco samples collection

When the soil samples were collected, the tobacco samples were gathered accordingly. The main cultivars of K326, Yunyan87 and Yunyan85 were chosen, including B2F, C3F and X2F grades. The tobacco samples were given by the special professional rating staff based on the flue-cured tobacco standard of GB 2635-92. Each sample weighed 1.50 kg and were dried, levigated and sieved (d = 0.3 mm).

Index determination method

The calcium content of flue-cured tobacco was determined by atomic absorption spectrophotometry (Wang, 2003).

The calcium content in soil was determined according to the analysis Method for soil Agro-Chemistry (Bao, 2000). The samples were first prepared to obtain soil leach solutions then, diluted to a certain concentration. By using atomic absorption spectrophotometry, its OD value can be measured with a detection wavelength at 422.7 nm.

Statistical analysis

All the data were subject to statistical analysis using the SPSS 14.0 software.

RESULTS

Distribution of calcium content in soil in Enshi tobacco-growing area

Status of calcium content in soil

The calcium content, especially the exchangeable calcium content in soil, affected the calcium supply level directly. Frequency distribution of the exchangeable calcium content in soil in Enshi tobacco-growing area was shown in Figure 1. Total calcium content ranged from 1243.2 to 5353.4 mg/kg with the mean of 2124.60 mg/kg and variation coefficient of 39.48%. Exchangeable calcium content ranged from 69.30 to 2916.78 mg/kg with the mean of 1091.44 mg/kg and variation coefficient of 72.92%, and kurtosis and skewness were more than zero, indicating positive deviation and tip peak.

Considering the classification standard for soil (Li et al., 2004), the exchangeable calcium content in soil was grouped into five levels: < 400 mg/kg, 400 to 800 mg/kg, 800 to 1200 mg/kg, 1200 to 2000 mg/kg, ≥ 2000 mg/kg (Table 1). The exchangeable calcium content in soil from 14.73% of the samples was below 400 mg/kg, indicating severe deficiency of calcium, and 24.03% of samples were deficient of calcium (400 to 800 mg/kg). This showed severe deficiency of calcium in this area, so more attention should be paid to the application of calcium fertilizer.

Status of exchangeable calcium content in soil at different altitudes

Altitude was an important factor affecting the soil fertility, and the status of exchangeable calcium content at different altitudes was shown in Table 2. The height went up, accompanied with the total and exchangeable calcium content in soil increasing, while the variation coefficient showed the trend of lower altitude > high altitude > medium altitude.

Status of exchangeable calcium content in soil at different soil depths

Status of exchangeable calcium content in soil at three

Table 1. Status of the exchangeable calcium content in soil in Enshi tobacco-growing area (mg/kg).

Exchangeable calcium content	Samples	Range	Mean	Sd	CV (%)
<400	19	69.30 to 377.03	246.78	103.25	41.84
400 to 800	31	440.74 to 790.81	616.87	104.05	16.87
800 to 1200	32	800.20 to 1187.20	989.56	110.72	11.19
1200 to 2000	37	1203.39 to 1912.86	1464.09	222.55	15.20
≥2000	10	2048.41 to 2916.78	3114.65	1127.86	36.21

Table 2. Status of the calcium content in soil in different altitudes (mg/kg).

Index (mg/kg)	Altitude (m)	Samples	Range	Mean	Sd	CV (%)
Total calcium	<800	43	1243.20 to 2710.40	1900.33 a	665.64	35.03
	800 to 1000	43	1332.40 to 2541.10	2054.80 a	529.00	25.74
	>1000	43	1483.40 to 5353.40	2418.68 a	725.89	30.01
Exchangeable calcium	<800	43	69.30 to 1516.53	822.03 b	383.90	46.70
	800 to 1000	43	1500.25 to 2870.50	1992.27 a	436.62	21.92
	>1000	43	1889.17 to 2916.78	2104.78 a	513.82	24.41

Different small letters in the same line indicated the significant differences at the 0.05 level, the same follow.

Table 3. Status of calcium content in soil in different soil depths (mg/kg).

Index	Depths(cm)	Samples	Range	Mean	Sd	CV (%)
Total calcium (mg/kg)	0 to 20	129	1243.20 to 5353.40	2124.60 a	626.40	29.48
	20 to 40	43	791.30 to 2067.70	1875.13 b	795.72	42.44
	40 to 60	43	809.40 to 200.17	1714.87 b	794.26	46.32
Exchangeable calcium (mg/kg)	0 to 20	129	69.30 to 2916.78	1091.44 a	795.84	72.92
	20 to 40	43	87.38 to 2083.39	765.05 b	235.60	30.80
	40 to 60	43	123.52 to 1394.91	699.67 b	200.69	28.68

different depths was shown in Table 3. The total and exchangeable calcium content was highest at 0 to 20 cm depth, medium at 20 to 40 cm depth, and at 40 to 60 cm depth, it was similar to that of 20 to 40 cm depth. The soil depths increased, accompanied with the decreasing calcium content in soil; the variation coefficient indicated the trend of 0 to 20 > 40 to 60 > 20 to 40 cm for exchangeable calcium and the opposite trend for total calcium.

Status of calcium content of flue-cured tobacco in Enshi tobacco-growing area

General status of calcium content of flue-cured tobacco

Mineral elements played an important part in tobacco growth. Applying calcium could increase sugar and nicotine content and filling power. Generally, 1.7 to 3.4% for calcium content was an appropriate scale for Chinese flue-cured tobacco (Yuan et al., 2007). 48.28% of the 124 tobacco samples selected from Enshi were in this range. Frequency distribution of calcium content of flue-cured tobacco was shown in Figure 2. The kurtosis (-0.2182) was less than zero and skewness (0.8071) was more than zero, indicating positive deviation and flat peak.

Status of calcium content of flue-cured tobacco in different cultivars

K326, Yunyan85 and Yunyan87 were main cultivars in Enshi tobacco-growing area. Status of calcium content of flue-cured tobacco in different cultivars was shown in Table 4. Among the three cultivars, the calcium content of flue-cured tobacco showed the trend of Yunyan87 > Yunyan85 > K326, and the same for the variation

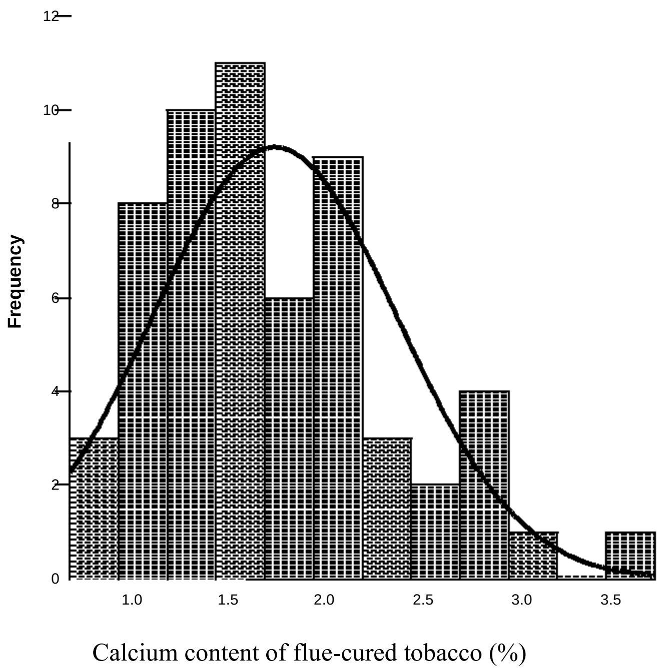

Figure 2. Frequency distribution of calcium content of flue-cured tobacco.

Table 4. Status of calcium content of flue-cured tobacco of different cultivars (%).

Cultivars	Samples	Range	Mean	Sd	CV (%)
K326	27	0.87 to 1.96	1.40[b]	0.39	28.10
Yunyan85	50	0.91 to 2.79	1.69[b]	0.51	30.19

Table 5. Status of calcium content of flue-cured tobacco of different gradings (%).

Gradings	Samples	Range	Mean	Sd	CV (%)
B2F	41	0.87 to 2.49	1.52[b]	0.42	27.56
C3F	41	0.91 to 2.88	1.70[b]	0.60	35.34
X2F	42	1.07 to 3.73	2.16[a]	0.67	31.11

coefficient. One-way ANOVA analysis showed significant variance to the calcium content of flue-cured tobacco. Multiple comparisons were carried out on the basis of variance analysis, indicating significant difference between K326 and Yunyan85, Yunyan87.

Status of calcium content of flue-cured tobacco in different grades

Status of calcium content of flue-cured tobacco of different grades in Enshi tobacco-growing areas was shown in Table 5. The calcium content of flue-cured tobacco showed the trend of X2F > C3F > B2F and the trend of C3F > X2F > B2F for the variation coefficient. One-way ANOVA analysis showed significant variance to the calcium content of flue-cured tobacco. Multiple comparisons were carried out on the basis of variance analysis, indicating significant difference between X2F and C3F, B2F.

Status of calcium content of flue-cured tobacco at different altitudes

Altitude was an important ecological factor affecting the quality of flue-cured tobacco, status of calcium content of flue-cured tobacco at different altitudes in Enshi tobacco-growing areas was shown in Table 6. The height went up, accompanied with the calcium content of flue-cured tobacco, which was increased. The variation coefficient showed the trend of medium altitude > lower altitude > high altitude. One-way ANOVA analysis showed the variance was significant to the calcium content of flue-cured tobacco.

Relationship analysis between the calcium content of flue-cured tobacco and the calcium content in soil

Relationship between the calcium content of flue-cured tobacco and the exchangeable calcium content in soil at different altitudes was shown in Figure 3. Accompanying the altitude height increase, the exchangeable calcium content in soil also increased, which was identical with the research results (Jiao et al., 2007), and also of the calcium content of flue-cured tobacco.

Regression analysis was conducted for the exchangeable calcium content in soil (x) and the calcium content of flue-cured tobacco ($\hat{Y}$), the regression equation ($\hat{Y}$ = 1.3986 + 0.0008x) was established with correlation coefficient of 0.9409. It had much significant difference by *F* test. After the exchangeable calcium content was grouped, their relationship was shown in Figure 4. Accompanying the exchangeable calcium content increase, the calcium content of flue-cured tobacco also increased.

DISCUSSION

Total and exchangeable calcium content in soil in Enshi tobacco-growing area were 2124.60 and 1091.44 mg/kg respectively, 38.76% of the samples were severely deficient of calcium and 36.43% were sufficient. This status means that both supplying calcium and controlling calcium should be taken according to different situations. Accompanying the altitude height increase, the total and exchangeable calcium content in soil increased and with

Table 6. Status of calcium content of flue-cured tobacco of different altitudes (%).

Altitude(m)	Samples	Range	Mean	Sd	CV (%)
<800	49	0.91 to 2.88	1.64[a]	0.58	35.45
800 to1000	36	0.87 to 3.73	1.82[a]	0.69	37.73
>1000	39	0.93 to 3.24	1.86[a]	0.61	32.97

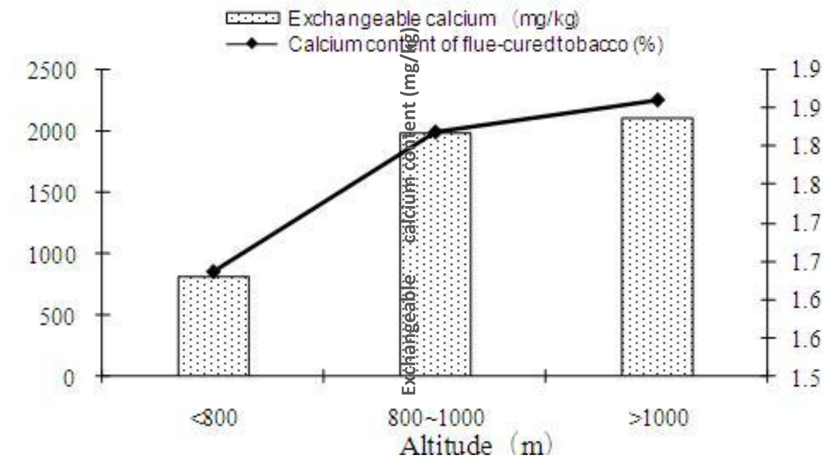

Figure 3. Relationship between the calcium content of flue-cured tobacco and the exchangeable calcium content in soil in different altitudes.

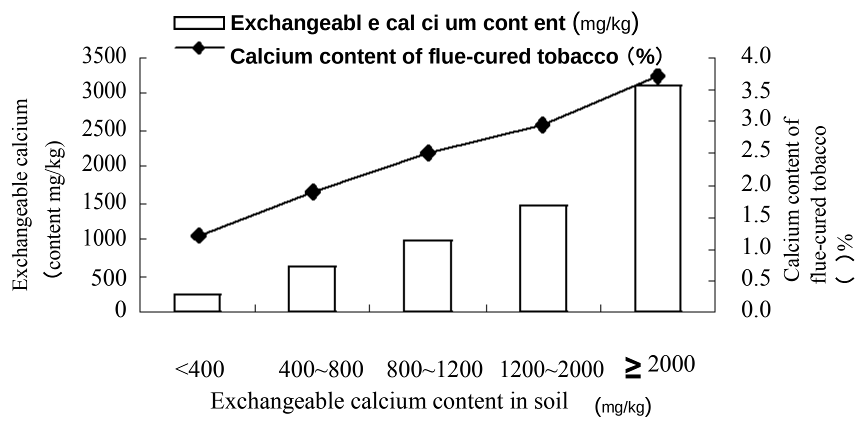

Figure 4. Relationship between the calcium content of flue-cured tobacco and the exchangeable calcium content after the exchangeable calcium content was grouped.

the soil depths deepening, the calcium content in soil decreased. Our results are in agreement with the findings of Dang et al. (2006) that, with the rise of altitude height, organic matter and rapidly available phosphorus and potassium contents in soil went up and the variation coefficient of soil fertility decreased, which might be related to less influenced surroundings by humanity in high altitudes. Altitude is an important factor that affects soil organic matter and soil nutrients contents. Soil parent materials and soil types changed with altitude heights, light, temperature and water. Also, heat varied, which made different physical and chemical soil properties that at last had different influences on soil nutrients (Jiao et al., 2007).

There existed significant differences among various cultivars and grades for the calcium contents of flue-cured tobacco, but not for the different altitudes. It showed the trends of Yunyan87 > Yunyan85 > K326 and the trends of X2F > C3F > B2F for the calcium content of flue-cured tobacco, and respectively, the trends of high altitude > medium altitude > lower altitude. According to the data available, there isn't any proof for appropriate altitude heights that make for calcium in flued-cured tobacco. However, some researches (Jian et al., 2005) had showed that raising the planting altitudes contributed to elevated aroma quantity in tobacco and coordinate chemical compositions greatly, which can improve tobacco utility in a large degree.

There was close relationship between the calcium content in soil and the calcium content of flue-cured tobacco. Positive regression correlation was established. With the altitude going up, the calcium content in soil and the calcium content of flue-cured tobacco increased. Moreover, the calcium content of flue-cured tobacco increased when the exchangeable calcium content in soil was grouped. It is well known that altitudes affect mineral elements in soil, including calcium. It is also illustrated that, calcium in tobacco is closely related to exchangeable calcium in soil, which put it forward that, altitude heights had much larger effects on tobacco quality than soil types did (Mu et al., 2008). As a result, enough notice should be paid to the difference between various ecological areas when choosing tobacco habitats and applying certain production technologies.

ACKNOWLEDGEMENTS

This project was supported by Science and Technology Research Project of Hubei Province (No. 2006AA201C73), Science and Technology Research Project of Tobacco Monopoly Bureau of Hubei Province (No. 027Y2011-050).

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