Investigation on Soil Fertility and Citrus Yield in South China

Chen Fang[A], LU Jianwei[B], LIU Dongbi[C], WAN Kaiyuan[A]

[A] Wuhan Botanical Garden, Chinese Academy of Sciences, IPNI China Program, Wuhan 430074, China
[B] Agricultural Resources and Environment College, Huazhong Agriculture University, Wuhan 430070, China
[C] Plant Protection & Soil and Fertilizer Institute, Hubei Academy of Agricultural Sciences, Wuhan 430064, China

Abstract
The soil fertility and physical property were evaluated for some orchards of three main citrus species in southern China to understand the suitable soil types and fertility status required for high yield citrus production. Three groups of soil samples from high, medium and low yield orchards, and from 17 counties of 6 provinces were taken and tested respectively. Soil analysis result indicated that over 50% of the soils were low in organic matter (OM), pH, total N, P, K, available Mg, Si, B, and Zn. Higher citrus yields were found from the orchards with higher soil OM, pH, total N and P, available K, Ca, Mg, Si, Zn, Mo and slowly available K contents. But soil total K, available N, Mn and B didn't show significant relationship with citrus yields. More than 30% of the soils' available Al, Na, Fe and S levels were higher than the critical levels and brought negative effects on citrus yields. Soil available B and Zn were positively related to citrus yields, while soil Al negatively related to it. When soil pH was lower than 6.5, citrus yield showed a positive relationship with the increase of soil pH. Higher citrus yields were also found in soils with higher percentage of base saturation and proportion of small clay particles. Results also showed that base saturation and soil pH were less variable than other parameters.

Key Words
Citrus; Fertility; Nutrient; Critical index, Yield

Introduction
Citrus is grown world-wide with about 100 million tons yield per year. It is the largest fruit in southern China and its production plays an important role for local economic and poverty alleviation in mountainous regions. There were over 1.81 million ha of citrus planted in 18 provinces and 70% of them located in Hunan, Hubei, Sichuan, Jiangxi, Zhejiang and Guangdong provinces. Three major types of citrus-- Satsuma Mandarin (C. unshiu), Navel Orange (C. sinensis L.), and "Ponkan" Mandarin (*Citrus reticulata* Blanco) are planted on red soils in south China. Most of them planted on poor, marginal and newly reclaimed lands. Therefore, citrus yield was low (7,695 kg/ha) in the region, comparing with the world average of 14,190 kg/ha (He 1999). Lower yield is mainly caused by poor soil fertility and poor nutrient management. Inadequate nutrient management mainly due to producer lacks of information and knowledge of soil fertility. Therefore, fertilizers were not properly applied to match with citrus growth.

Soil testing is crucial for evaluating soil fertility and making fertilizing recommendations. Previous study mainly focused on a relatively small area and generally assessed one or two nutrient elements in China. Therefore, no report on the soil fertility status of citrus with large scale areas was found in the region. Research reports have confirmed that soil nutrient deficiencies of P, K, Mg, Zn, B, and Fe were widespread and they reduced citrus yield and quality (Li *et al.* 1997; Lu *et al.* 2001; 2002). Thus, discovering the critical limiting nutrients is essential for improving citrus nutrient management.

Materials and methods
A total of 63 soil samples were taken from the citrus orchards in 17 counties of 6 provinces during 2000 to 2001. In each county, soil samples were taken from 3-7 orchards with low (<22,500 kg/ha), medium (22,500 to 45,000 kg/ha) and high (>45,000 kg/ha) yields. Each soil sample was consisted of 20 sub-samples taken under the crown of citrus tree with depth of 30 cm. Soil pH, OM, nitrogen (N), phosphorus (P) and potassium (K), slowly available K, base-saturation percentage (S%), silicon (Si), calcium (Ca), magnesium (Mg), sulfur (S), sodium (Na), aluminum (Al), iron (Fe), manganese (Mn), zinc (Zn), boron (B), molybdenum (Mo) and soil particle size were tested. All of the soil sample were analyzed by routine methods (Bao 2000). Criteria for the classification of citrus soil nutrient status were based on the reported common standards showed in Table 2 (Lu *et al.* 2002). Range, mean, standard deviation and coefficient of variance were calculated using Microsoft Excel (Microsoft, WA, USA) spread sheet.

Result and discussion

Soil pH and organic matter

Although citrus can be planted in soils with either a high or low pH, the optimal soil pH for citrus ranges from 5.5 to 6.5 (He 1999). We found that the soil pH in the region ranged from 3.9 to 8.9 and most were below 6.5. When the citrus orchards were grouped into high, medium and low yielding orchards, it was observed that the average soil pH in high and medium yielding orchards was above 5.9 while in low yielding orchards was 5.4. The percentages of acidic soils in the medium and low yielding orchards occupied 50% and 68%, while in high yielding orchards was 45%. Our results also indicated that citrus yields tend to increase with the increase of soil pH when they were below 6.5.

Soil OM is one of the most important soil fertility indicators and usually its content positively related to citrus yield. Our result showed that the average soil OM content was 15.6 g/kg (2-54.9 g/kg). The average soil OM content of high yielding orchards was 18.2 g/kg, while medium and low yielding orchards were below 16.2 g/kg (Table 1). Table 2 shows the modified classification standard for citrus based on traditional standards (Lu *et al.* 2002). According to the standard, over 50% of citrus soils were low (<15 g/kg) in OM.

Table 1. Average soil OM and macronutrient analysis results (g/kg, mg/kg)

Items	TN* g/kg	TP g/kg	TK g/kg	OM g/kg	AN mg/kg	AP mg/kg	AK mg/kg	SAK mg/kg
High yielding orchards (n=22)	1.5550	0.6400	14.979	18.181	89.996	22.436	156.19	344.00
Medium yielding orchards (n=22)	1.0668	0.5845	15.020	16.050	84.446	21.990	146.55	333.68
Low yielding orchards (n=19)	1.0747	0.5053	14.242	16.105	88.288	15.788	95.556	231.32

*TN= total N, TP= total P, TK= total K, AN= available N, AP= available P, AK= available K, SAK= slowly available K, OM=organic matter.

Soil nutrients

Soil analysis results showed that all the soil nutrients tend to decrease from the high yielding orchards to the low yielding orchards (Table 1). According to routine soil critical levels, the proportions of tested soils that lower than the suggested critical levels were: total N 92.1%, available N 67.8%, total P 66.7%, available P 60.2%, slowly available K 55.6% and available K 43.7% respectively. The unbalance of soil nutrients may be one of the major reasons for low yields.

Soil Ca, Mg, and Si levels tend to decrease from the high yielding orchards to the low yielding orchards. Sulphur, however, tend to be high in the low yielding orchard than in the high yielding orchards (Table 2). About half of the soils from high yielding orchards were low in Ca and Mg, while 36.4% and 68.4% of the soils were low in soil Ca in medium and low yielding orchards. Similarly, 68.2% of medium and 74.1% of low yielding orchards were rated as low in soil Mg. Up to now, we didn't find citrus soil standards for evaluating soil available S and Si. Our research suggested that S 35 mg/kg and Si 80 mg/kg could be considered as temporary critical levels. Based on these critical levels, the proportions of tested soils that below the critical levels were: soil Ca 48.6%, soil Mg 64.1%, and soil Si 79.4% respectively. For soil S, 36.5% of them were higher than 35 mg/kg.

Table 2. Soil base saturation percentage, second and micronutrient analysis result (mg/kg)

Nutrient	Si	Ca	Mg	S	Na	Al	Fe	Mn	Zn	B	Mo	BS%
High (n=22)	115.1	1973	186.2	33.09	42.03	133.5	22.85	30.75	1.46	0.373	0.147	92.8
Middle (n=22)	78.39	1777	129.7	37.46	45.23	128.3	33.82	26.11	1.32	0.334	0.130	87.9
Low (n=19)	43.44	1073	136.5	71.22	57.98	221.9	36.30	30.34	1.03	0.343	0.120	80.9

Soil analysis results also showed that available Zn, B and Mo were high and the available Na, Al and Fe were relatively low in high yielding orchards (Table 2). There was no significant difference on soil available Mn between high and low yielding orchards and it may not a yield limiting nutrient factor in the region. Our data recommend that 45 mg/kg and 130 mg/kg can be considered as temporary critical levels for soil available Na and Al. Result also showed that 25.7% of the soil Mn, 57.2% of the Zn, 85.9% of B, 16.1% of Mo, 20.9% of Fe, 34.9% of Na and 55.9% of Al were not in optimum ranges. This result indicated that B and Zn were the most important micronutrients and Al was the most important toxic soil element in the regions as well.

Soil base-saturation (BS%) and particle size distribution

Soil analysis result indicated that soil base saturation percentage was positively related to citrus yield. The

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

highest average soil base saturation (92.8%) was found in the high yielding orchards and lowest one (80.9%) was found in the low yielding orchards (Table 2). Result showed that 41.9% of the tested soils' base saturation was below 90%. This level could be temporary set as the critical level of soil base saturation for citrus.

Our result also showed that the small particle (<0.001mm) content was positively related to citrus yield. Clay contents of high yielding orchards were higher than those in the low yielding orchards (Table 3). In some low yielding orchards, the surface soil layer was quite thin (<30cm) with high proportion of gravel. Soil analysis showed that the percentages of large (0.05~ 0.01mm) to medium (0.005~ 0.001mm) particles were relatively stable (50.81~50.99%) in all the orchards. The proportion of small particles was much more variable compared with medium and large particles.

Table 3. Soil particle size distribution and proportion

Particle size (mm)	〉0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	〈0.001
High yielding orchards (n=22)	7.15	16.36	24.43	12.18	14.20	25.68
Medium yielding orchards (n=22)	8.80	19.00	24.16	11.08	15.90	21.06
Low yielding orchards (n=18)	10.39	19.46	23.67	10.58	16.74	19.16

Conclusions

In the citrus orchards of China, low soil fertility was one of the major, if not the primary, factors limiting citrus yield. Our soil fertility investigation and soil analyses results indicated that over 60% of the soils were low in N, P, Mg, Si, and B, and over 50% of the soils were low in OM, pH, K, and Zn. We also found that the available Mn have no significant relationship with citrus yield. Those soils with high Al, Na and S showed lower fertility for citrus. Higher citrus yields were strongly associated with higher soil base saturation percentage and higher proportion of small soil particles.

Variability in soil base-saturation percentage and soil pH was smaller than other soil fertility parameters. Variability in total N, P and K was smaller than the soil available N, P, K and other available nutrients. A strong positive relationship was found between soil OM and total N, available soil N, and soil Mg contents.

Acknowledgment

This project supported by the International Plant Nutrition Institute (IPNI-Hubei-10) and the Key Laboratory of Aquatic Plant and Watershed Ecology, Wuhan Botanical Garden, CAS.

References

Bao Shidan (2000) Agro-chemical Analysis of Soil. Agricultural Publish House of China, Beijing.

He T.F (1999) Mineral Nutrient of Citrus. Citrus. Agriculture Publish House of China, Beijing. 281-328.

Li JS, Chen F, Lu ZG (1997) Effect of application Fe-chelate on citrus in Three Gorges Region. *Hubei Agriculture Science* **2**, 25-26.

Lu JW, Chen F, Wan YF (2001) Effect of potassium on the yield and quality of navel orange. *Journal of Fruit Science* **18**(5), 272-275.

Lu JW, Chen F, Wang FH (2002) Study of classification of the soil nutrient status of citrus orchard in Hubei province. *Plant Nutrition and Fertilizer Science* **8**(4), 390-394.