Investigation of Soil Fertility in Citrus Orchards of Southern China

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A recent comprehensive analysis defines complete soil fertility profiles for mandarin and navel orange orchards based on orchard productivity.

Citrus fruit production comprises the largest fruit sector in southern China. However, most citrus orchards in China are located on poor soils and newly reclaimed lands (Zhuang, 1994; He, 1999). The potential for these orchards to alleviate poverty in marginal farming areas is well appreciated, but low yields and poor fruit quality are major hurdles to overcome for a large number of production areas. Poor soil fertility and substandard management are to blame. Poor fertilization strategies are largely a result of insufficient information on the soil fertility status in these areas.

Past research has been mainly focused on relatively small areas and/or based on a single nutrient or selected macronutrients such as N or P. Some examples of citrus soil nutrient evaluation standards do exist based on local conditions (Yue, 1990; Xie et al., 2001; Yu, 1985; Zhang, 1996; Zhang, 1990; Achituv and Akiva, 1973; Alva and Paramasivam, 1998).

The group of "brand-name" citrus in China mainly includes satsuma mandarin (*Citrus unshiu*), navel orange (*C. sinensis* L.), and "Ponkan" mandarin (*C. reticulata* Blanco). They are mainly planted on red soil in hilly regions. Some orchards are located on old river beds and sea beaches, and others are planted in flood plain soils and paddy fields. Soil pH, OM content, and soil physical properties are all important factors to be managed. Soil nutrient deficiencies, including P, K, Mg, Zn, B, and Fe are also widespread (Qin et al., 1986; Li et al., 1997; Lu et al., 2001; 2002). One of the major efforts towards improving citrus yield and quality is the identification and correction of critical soil fertility factors. This paper outlines a major citrus soil fertility investigation involving the six prominent brand-name citrus production provinces in southern China.

A total of 63 soil samples were taken from citrus orchards in 17 counties of six provinces (Hunan, Hubei, Sichuan, Jiangxi, Zhejiang, and Guangdong) during 2000 to 2001. In each county, samples were taken from several orchards considered to be low yielding (<22,500 kg/ha), mid-yielding (22,500 to 45,000 kg/ha), and high yielding (>45,000 kg/ha). Each soil sample was comprised of 20 subsoil samples taken from under the crown of citrus trees at a 0 to 30 cm depth. Soil pH, OM, total soil N, P, K, non-exchangeable K, available N, P, K, S, Ca, Mg, Si, Na, Al, Fe, Mn, Zn, B, Mo, base saturation percentage, and soil physical properties were determined. Standards for the classification of citrus soil nutrient status refer to the commonly reported standards shown in **Table 1** (Lu et al., 2002).

Soil pH for the group of orchards ranged between 3.9 and 8.9 with most being below 6.5. Usually, the optimum soil pH for citrus exists between 5.5 and 6.5, although citrus can be successfully planted in a wider pH range. Earlier results from the authors indicate that sites with initial pH values under 6.5 will show yield responses to soil amendments, causing an upward shift in soil pH. The average soil pH in high and mid-yielding orchards was 5.9, and was 5.4 in low yielding orchards (**Table 2**). In high yield orchards, 45% of soils had low to extremely low pH values under 5.5, while mid and low yielding orchards had 50% and 68% of soils under pH 5.5, respectively.

Soil OM is often used as an indicator of soil fertility for citrus orchards as yields tend to increase along with OM content. However, some believe that low OM soils, even as low as 10 g/kg, can also produce high yields with rational fertilizer application. Orchards in this study had an average OM content of 15.6 g/kg (range = 2 to 54.9 g/kg). Over 50% of orchard soils had OM contents less than 15 g/kg. Average OM for high yielding orchards was 18.2 g/kg, while mid and low yielding orchards had OM contents of 16.0 and 16.1 g/kg, respectively (**Table 2**).

Trends for total and available N, P, K, and non-exchangeable K all showed declining levels between high and low yielding orchards (**Table 2**). Using established standards, 68% of orchards were below the critical value for available N, 60% for available P, and 44% for available K. In the absence of published fertility classification standards, this research suggests 1.5 g total N/kg, 0.6 g total P/kg, 15 g total K/kg, and 300 mg non-exchangeable K/kg as tentative critical values. If considered, 92% of

Table 1. Established standards for soil fertility classification and nutrient status of citrus orchards, southern China.

Items	Extreme low	Low	Optimum	High	Extreme high
pH	<4.8	4.8-5.5	5.5-6.5	6.5-8.5	>8.5
OM, g/kg	<5	5-15	15-30	>30	-
Available N, mg/kg	<50	50-100	100-200	>200	-
Available P, mg/kg	<5	5-15	15-80	>80	-
Available K, mg/kg	<50	50-100	100-200	>200	-
Available Ca, mg/kg	<200	200-1,000	1,000-2,000	2,000-3,000	>3,000
Available Mg, mg/kg	<80	80-150	150-300	300-500	>500
Available Fe, mg/kg	<5	5-10	10-20	20-50	>50
Available Mn, mg/kg	<2	2-5	5-20	20-50	>50
Available Zn, mg/kg	<0.5	0.5-1.0	1.0-5.0	5.0-10.0	>10.0
Available Mo, mg/kg	-	<0.05	0.05-0.20	0.20-0.30	>0.3
Available B, mg/kg	-	<0.5	0.5-1.0	>1.0	-

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; Zn = zinc; B = boron; Fe = iron; Mn = manganese; Mo = molybdenum; Si = silicon; Na = sodium; Al = aluminum; OM = organic matter; v% = base saturation percentage; SD = standard deviation.

Table 2. Soil OM and macronutrients within selected citrus orchards, southern China.

Item	Low yielding Average	Low yielding SD[1]	Mid yielding Average	Mid yielding SD	High yielding Average	High yielding SD
pH	5.4	1.3	5.9	1.3	5.9	1.2
OM, g/kg	16.1	7.0	16.0	4.8	18.2	7.6
Total N, g/kg	1.1	0.3	1.1	0.2	1.6	0.3
Total P, g/kg	0.5	0.2	0.6	0.3	0.6	0.3
Total K, g/kg	14.2	4.6	15.0	5.6	15.0	4.5
Available N, mg/kg	88.3	33.3	84.4	4.8	90.0	26.9
Available P, mg/kg	15.8	19.1	22.0	27.7	22.4	22.4
Available K, mg/kg	95.6	61.2	146.6	98.1	156.2	100.4
Non-exchangeable K, mg/kg	231.3	152.4	333.7	133.3	344.0	236.2

[1]SD = standard deviation

orchards would be below the critical value for total N, 67% for total P, 59% for total K, and 56% for non-exchangeable K. Soil Ca, Mg, and Si also decreased from high to low yielding orchards (data not shown). No citrus soil fertility standards currently exist for available S and Si, but results from this study suggest 35 mg S/kg and 80 mg Si/kg as critical values. The survey found 49% of orchards had soil Ca contents lower than the critical value, 64% for Mg, 79% for Si, and 36% for S.

The established standards indicate all orchards had adequate available Zn and Mo, but were low in B. High yielding orchards had less available Na, Al, and Fe compared to low yielding orchards. Boron and Zn availability were considered as the most-limiting micronutrients, while Al represents the most important toxicity risk for the orchards investigated. Available Mn was high in all orchard groups and showed no significant difference between high and low yielding orchards. Results show 26% of orchards had soil Mn contents lower than the critical value, 57% for Zn, 86% for B, 16% for Mo, while 21% of orchards had soil Fe contents higher than the critical value, 35% for Na, and 56% for Al. Once again, standards for available Na and Al are not available for citrus, but results from this study suggest that 45 mg Na/kg and 130 mg Al/kg could be considered as suitable critical values.

Soil base saturation was also highest in high yielding orchards. This investigation suggests a standard critical value of 90% for citrus soils in China. Soil analysis indicates that 42% of soils had low soil base saturation.

The proportion of clay-sized particles was much more variable among orchards compared with other particle size fractions (data not provided). Soil clay content was highest in high yielding orchard sites. A positive relationship was also noted between clay-sized particles and improved citrus quality. Some low yielding orchards had soil layers less than 30 cm in depth and had a high proportion of gravel and sand, leading to very low nutrient supply rates.

Low soil fertility is one of the main factors limiting yield and quality for brand-name citrus orchards in south China. Over 60% of the orchard soils had low to extremely low available N, P, Mg, Si, and B. Over 50% of soils had low to extremely low OM, pH, available K, and Zn. Over one-third of soils (35 to 56%) had Al, Na, and S contents above suggested critical values. Higher citrus yield was always associated with higher soil base saturation percentage and a higher proportion of clay-sized particles. Soil OM showed a strong positive relationship with total N, available N, and available Mg. Existing farm practice varied significantly among sites and was one of the most important factors affecting soil available nutrient status. BC

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Production of navel oranges and other citrus from orchards in southern China could benefit greatly from improved soil fertility.