Nutrient Uptake and Distribution in Lychee

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Knowing how nutrients are distributed within fruit tree cultivars can lead to better nutrient source, rate, time and place decisions that, in turn, will support tree health and the nutritive value of their fruit. This study detected differences in nutrient need between two cultivars of widespread use, and identified some specific management strategies to address these differences.

Lychee (*Litchi chinensis* Sonn.) is a very popular Asian fruit that originated in southern China (Menzel, 1983) and has now spread throughout many subtropical areas where summers are long and hot. Fruits like lychee, commonly high in K, N, Fe, Zn, and Cu can play an important role in human nutrition. However, despite a long history of cultivation, there has been a lack of systematic research on soil nutrient characteristics in relation to total crop nutrient requirement, uptake ratios, and nutrient use efficiency. Reports from Guangdong suggest a good link between low soil fertility, imbalanced nutrient application and low and variable yields (Chapman, 1984; Li et al., 2009). This study addresses a knowledge gap by examining the nutrient uptake and distribution characteristics of two popular cultivars in order to provide scientific information on best nutrient management practice.

Guiwei is one of the most popular lychee varieties in the world, while Feizixiao is the most widely cultivated variety in China. A healthy 15-year-old Guiwei tree was sampled at fruit maturity from a representative farm orchard in Huazhou, Guangdong with medium to high yield. Similarly, a 15-year-old Feizixiao tree was sampled from another representative farm in Huidong.

Table 1. Selected properties of soils sampled from Guiwei and Feizixiao orchards, Guangdong, China.

Location (variety)	Guiwei	Feizixiao
Texture	Sandy clay loam	Clay loam
pH	4.2	4.6
OM, %	0.9	0.7
Alkali hydrol. N, mg/kg	53	42
Avail. P, mg/kg	46	2
Avail. K, mg/kg	42	44
Exch. Ca, mg/kg	121	115
Exch. Mg, mg/kg	10	9
Avail. S, mg/kg	44	27
Avail. Si, mg/kg	12	11
Avail. Fe, mg/kg	110	44
Avail. Mn, mg/kg	2	2
Avail. Cu, mg/kg	1	0.2
Avail. Zn, mg/kg	0.6	0.6
Avail. B, mg/kg	0.4	0.1
Avail. Mo, mg/kg	0.1	0.1

Soils extractants for N = 1 M NaOH; P = 0.03 M HCl + 0.025 M NH_4F; K = 1 M NH_4OAc; Ca and Mg = 1 M NH_4OAc + 0.05 M EDTA; S = 0.008 M $Ca(H_2PO_4)_2$-HOAc; Si = 0.25 M Citric acid; Fe, Mn, Cu, and Zn = 0.1 M HCl extraction; B = Boiling water extraction; Mo = 0.1 M $H_2C_2O_4$ + 0.175 M $(NH_4)_2C_2O_4$ extraction (Lu, R.K. 2000).

Prior to tree sampling, soil samples were collected from 0 to 50 cm depth, 20 cm away from the water drip line formed by the tree crown. Both soils had low fertility (i.e., very acidic, low in organic matter, deficient in N, K, Mg, Zn, B, and Mo; moderate Ca, Mn, and Si; and adequate Fe and S. Soil P and Cu are adequate under Guiwei trees, but was deficient under the Feizixiao trees; **Table 1**). Four subsamples of the root, trunk, fruit, and leaves were collected from each tree and washed. Fresh weights of each plant organ/tissue were recorded. All samples were rinsed with deionized water and then oven-dried at 70°C. Dry weights were then recorded. The samples were pulverized and analyzed for nutrient content using standard methods.

Biomass Composition

The two cultivars, Guiwei and Feizixiao, produced a total fresh biomass of 189.4 kg and 290.9 kg and fruit yields of 52.5 kg and 62.5 kg, respectively (**Table 2**). Tree trunks accounted for 30.4% of the total biomass for Guiwei and 55.5% for Feizixiao, while the roots only weighed 8.3% of the total for Guiwei and 16.8% for Feizixiao. Since the two cultivars were grown as grafted seedlings, their taproots only grew 50 to 70 cm deep.

Table 2. Biomass of main tissues of Guiwei and Feizixiao lychee cultivars grown in Guangdong, China.

	Guiwei		Feizixiao	
	Biomass, kg/tree	Percentage, %	Biomass, kg/tree	Percentage, %
Fruit	52.5	27.8	61.5	21.1
Leaf	24.6	12.9	19.7	6.8
Trunk	88.2	46.6	161.0	55.3
Root	24.1	12.7	48.7	16.8
Total	189.4	100	290.9	100

Lychee fruit consists of a pericarp (shell), pulp (fruit flesh) and seed. The shell can be separated by hand into an epicarp (outer layer) and a membranous endocarp (inner layer). Fruit flesh comprised 76% of the total Guiwei fruit weight, which was higher than Feizixiao fruit (70%). Both cultivars had similar weight percentages for the epicarp and seed. However, the endocarp showed a larger difference at 7.3% of the fruit weight for Feizixiao and 3% for Guiwei.

Nutrient Uptake

Large differences in nutrient uptake were recorded in the leaves, trunks and roots of the two lychee tree types, thereby reflecting a large difference between the size of these two trees (**Table 2**). The available information on nutrient accumulation

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; B = boron; Cu = copper; Fe = iron; Mo = molybdenum; Mn = manganese; Zn = zinc; Si = silicon.

in lychee fruits is in fact very limited. This work did find considerable difference in the nutrient uptake for each 50 kg fruit produced by the two cultivars (**Table 3**). While part of these differences might be linked to the differences in yield, the nutrient concentrations within the two fruit varieties were surprisingly similar.

Nutrient Concentration

Irrespective of cultivar, K concentrations in all organs/tissues of the lychee tree were highest amongst nutrients, especially in the fruit, followed by N in leaves, fruit shell (epicarp and endocarp), fruit flesh, and seed (or Ca in the case of the trunk and roots). The Feizixiao variety had similar or higher nutrient concentrations in the trunk and the fruit flesh compared to Guiwei. Low soil Mo content plus variable Mo mobility in plants (depending on plant part and Mo supply) as reported by Jongruaysup et al. (1994) may be responsible for undetectable Mo levels in the trunk and pulp in this study. Because Mo is indispensable for higher plants and plays an important role in metabolism of C, S and N and normal functions of plant hormones (Mendel and Bittner, 2006), it could be a major yield-limiting factor for lychee production in China, especially since Mo is not commonly applied.

The lychee tree has been cultivated in China since 2000 BC. It bears fleshy fruit with a rough outer shell.

Nutrient Distribution

The examination of nutrient partitioning amongst Guiwei tree parts revealed that N, P, K, and Cu were mainly distributed in trunk, leaves and fruit, with Ca being primarily in the trunk; and Mg, S, Fe, Zn, and B were distributed in trunk and leaves, and Mo in the fruit and leaves only. For Feizixiao, the trunk acted as the major sink of nutrients, except for Mo, which was split 41%, 41% and 18% between the leaves, roots and fruit, respectively. It should be noted that almost all Mo stored in the Guiwei tree and nearly two-thirds of the Mo within the Feizixiao tree is removed mechanically by pruning—indicating that Mo application would be most beneficial right after this pruning practice.

Nutrient distribution in fruit showed that most of N, P, K, Mg, S, Cu, and Zn accumulated in the fruit flesh, followed by the outer shell layer, while the inner shell layer had their lowest contents (**Table 4**). Calcium and B, two important components of cell walls, were primarily located in outer shell. It has been reported that B application promotes Ca uptake by the fruit (Wojcik and Wojcik, 2003; Gong et al., 2009), and that foliar Ca spray alone could not significantly prevent fruit cracking (Huang et al., 2008). This does suggest that it might be effective to apply B and Ca together. In Guiwei fruit, 64.5% of the Mo concentration was in outer shell and the remainder was in seed and inner shell layer. In Feizixiao fruit, however, all Mo was accumulated in the seed.

Not only the concentrations of different nutrients, but also the distribution of the same nutrient in different plant organs/parts varied considerably. For example, N content was higher in leaves and was lower in the fruit flesh regardless of cultivar. Phosphorus was concentrated in the inner shell layer, while the lowest amount of P was found in the trunk of both varieties. Similarly, K content was highest in the fruit flesh, but

Table 3. Nutrient uptake by different organs of Guiwei and Feizixiao lychee cultivars to produce 50 kg of fruit in Guangdong China.

Nutrient	Fruit	Leaf	Trunk	Root	Total
			Guiwei		
N, g	96	180	127	47	450
P, g	15	11	15	6	46
K, g	169	141	183	52	545
Ca, g	20	97	279	57	453
Mg, g	11	18	24	10	64
S, g	11	22	36	11	81
Fe, mg	334	1,967	3,688	2,514	8,503
Mn, mg	324	3,371	845	209	4,749
Cu, mg	75	57	99	49	280
Zn, mg	173	215	189	95	672
B, mg	112	174	292	115	693
Mo, mg	0.126	0.069	-	-	0.196
			Feizixiao		
N, g	95	134	329	66	624
P, g	16	11	151	10	187
K, g	140	101	653	62	957
Ca, g	17	54	521	86	679
Mg, g	12	12	44	13	80
S, g	11	19	64	19	112
Fe, mg	404	836	8,016	5,369	14,625
Mn, mg	117	650	715	137	1,619
Cu, mg	97	65	194	52	408
Zn, mg	179	272	872	184	1,507
B, mg	114	208	382	139	843
Mo, mg	0.293	0.661	-	0.661	1.615

Table 4. Nutrient distribution in different fruit tissues of Guiwei and Feizixiao varieties of lychee grown in Guangdong, China.

Nutrient	------ Fruit shell ------ Epicarp (outer), %	Endocarp (inner), %	Fruit flesh, %	Seed, %
		Guiwei		
N	21.4	40.1	28.1	10.4
P	31.5	24.8	31.6	12.1
K	31.0	25.9	33.6	9.5
Ca	4.5	21.3	61.7	12.5
Mg	17.5	28.6	38.0	15.8
S	14.0	27.4	44.6	14.1
Fe	3.9	23.1	43.4	29.6
Mn	6.8	71.0	17.8	4.4
Cu	26.9	20.2	35.3	17.6
Zn	25.8	31.9	28.2	14.1
B	16.2	25.1	42.1	16.6
Mo	64.5	35.5	-	-
		Feizixiao		
N	15.3	21.4	52.8	10.5
P	8.4	5.9	80.3	5.4
K	14.6	10.6	68.3	6.5
Ca	2.6	8.0	76.8	12.7
Mg	14.6	14.6	54.8	16.0
S	9.5	16.5	57.4	16.6
Fe	2.8	5.7	54.8	36.7
Mn	7.2	40.1	44.2	8.5
Cu	23.7	16.0	47.5	12.7
Zn	11.9	18.1	57.9	12.2
B	13.6	24.6	45.3	16.5
Mo	18.2	40.9	0.0	40.9

was lowest in the roots of both cultivars. Calcium was highest in leaves of Guiwei and the trunk of Feizixiao, but only trace amounts of Ca were detected in the fruit flesh of both cultivars. It should be noted that although Ca is commonly regarded as a secondary nutrient for plants, its concentrations in trunk and roots of tree were higher than N concentrations.

Summary

These results build upon known relationships between improved fertilization techniques and stable tree fruit production. Valuable insight was gained into nutrient uptake and storage patterns in lychee, which is vital information to growers as they decide how best to adapt 4R Nutrient Stewardship principles to achieve high quality fruit production.

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