Optimal Fertilization of Banana for High Yield, Quality, and Nutrient Use Efficiency

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Prescribed fertilizer application in first season banana crops (mother plants) uncovered a situation of oversupply due to seasonal differences in yield potential. This finding is of great importance in helping farmers adjust fertilizer inputs and improve fertilizer use efficiency, while maintaining high banana yield and quality.

Banana yield and quality improvement due to balanced fertilization has been well documented in China and elsewhere (Moreira et al., 1986; Hegde and Srinivas, 1991; McIntyre et al., 2000; Yao et al., 2005). However, adequate information on agronomic efficiency (AE - expressed as kg fruit per kg of nutrient) in China's banana crops is generally lacking, which identifies an important knowledge gap for these economically important and nutrient-demanding systems. Information on improving fruit storage quality and the storage properties of banana fruit through proper nutrient use is also very crucial since large quantities of fruit are sold to far-away markets.

Banana is widely grown in southern China and among the southern provinces, Guangdong is the number one producer. It has a planting area of 126,000 ha and a production (2006) of 3.35 million metric tons (M t), or about half of the banana production in China. It is reported that more than 20% of yield losses occur during transportation (Hu et al., 2003). This field study was designed to identify fruit yield and storage trait responses under improved NPK fertilization and to document AE data within two successive banana crops grown in southern China.

The experiment was located in Dongfu Village, Fusha Town, Zhongshan City of Guangdong Province, during 2006-2007 on an alluvial soil that is typical of the Pearl River Delta. The soil, analyzed using the ASI method used by the Sino-Canada Lab in Beijing and described by Portch and Hunter (2002), was determined to be deficient in N (10.5 mg/L), P (4.6 mg/L), and K (39.1 mg/L), and medium to high in Ca, Mg, S, Mn, Zn, Fe, and B. The soil test for N is often considered an unreliable indicator of soil N status under banana, as close relationships between soil N test and banana response to applied N are difficult to obtain (López and Espinosa, 2000). As a result, soil test information was combined with regional knowledge to construct an optimal (OPT) treatment of 900-270-1,080 kg N-P_2O_5-K_2O/ha for mother plant fertilization and 825-248-990 kg N-P_2O_5-K_2O/ha for the crop of daughter plants. A randomized plot design was used with four treatments and three replications. Three deletion plots individually omitted N, P, and K based on rates used in the OPT treatment. Urea, single superphosphate, and potassium chloride were used as sources for N, P, and K, respectively. The total N, P, and K fertilizers were split into eight dressings amounting to 35% of N, P, and K application during vegetative growth after planting and before flower differentiation, 40% before flower emergence, and the remaining 25% after flower emergence. The banana variety Baxi was planted at 1,620 seedlings/ha with 10 plants per plot. Mother plants were planted in early March 2006 and were harvested in late December 2006 to early March 2007. Daughter plants were selected in mid-August 2006 and harvested in early October to early November 2007.

Abbreviations and notes for this article: N = nitrogen, P = phosphorus, K = potassium, Ca = calcium, Mg = magnesium, S = sulfur, Mn = manganese, Zn = zinc, Fe = iron, B = boron; FW = fresh weight.

In both mother and daughter crops, K was the most limiting macronutrient for banana production.

Yield, Profits, and Nutrient Use Efficiency

Banana fruit yields for each treatment are shown in **Table 1**. As is typical to the Pearl River Delta, mother plant yields were generally lower than those obtained by daughter plants. This is a climatic effect caused by a shorter growth period and lower temperatures during the growth of mother plants. Though these mother plant yields were lower than usual, the yields under the OPT were still about 20% higher than those commonly obtained under traditional farm practice. The OPT-K and OPT-P treatments produced significantly lower mother plant fruit yields than the OPT treatment. However, yield under OPT-N was only 4% less than that produced by

Table 1. Banana fruit yields in different treatments at Dongfu.

Treatment	Mother plant Yield, t/ha	Mother plant Yield reduction, %	Daughter plant Yield, t/ha	Daughter plant Yield reduction, %
OPT	40.5 a	-	58.2 a	-
OPT-N	38.9 ab	4.0	52.7 b	9.5
OPT-P	37.7 b	6.8	53.5 b	8.1
OPT-K	34.8 c	14.0	51.0 b	12.3

Means within a column followed by the same letter are not significantly different at p = 0.05.

the OPT. In the subsequent crop of daughter plants, the set of omission treatments all led to significant yield declines, which were greatest in the OPT-K treatment followed by the OPT-N and OPT-P treatments. Thus, K was the most limiting macronutrient in both crops – a result which is in good agreement with the crop's large demand for K and the characteristically inadequate K supply capacity of the region's banana soils (Yao et al., 2005).

After subtracting all the production costs for mother plants, the OPT treatment obtained the highest plantation profit of 73,507 Yuan/ha (**Table 2**). The OPT-N treatment was slightly less profitable (-407 Yuan/ha), and the OPT-P and OPT-K treatments generated considerably less income. In daughter plants, the three omission treatments resulted in significant profit reductions which were greatest in the OPT-K, followed by the OPT-P and OPT-N.

The prescribed OPT treatments led to AE values for applied P of 10.3 kg fruit/kg P_2O_5 for mother plants and 19.1 kg fruit/kg P_2O_5 for daughter plants. The AE values for N and K were considerably lower (**Figure 1**). Higher AE values from daughter plants are a reflection of higher yields compared to the preceding mother plants. Yield generated by daughter plants was considerably higher than that from mother plants, even when N, P, or K was omitted over both crops. It is apparent that the NPK recommendation prescribed for mother plants, although being more balanced than the region's common practice, failed to prevent nutrient oversupply under the specific conditions experienced in this study.

Fruit Quality and Storage

Nutrient supply to banana plants affected not only yield, but also fruit storage properties. Storage quality can be evaluated by pigment content in the fruit peel (Leshem et al., 1986). Fruits from the OPT treatment had higher contents of chlorophyll and the lowest cyanin and flavonoid contents, all of which contributed to delayed post-harvest ripening and longer shelf life (**Table 3**). In contrast, the OPT-N, OPT-P, and OPT-K treatments prompted the degradation of chlorophyll and formation of cyanin and flavonoid in the peels of fruits.

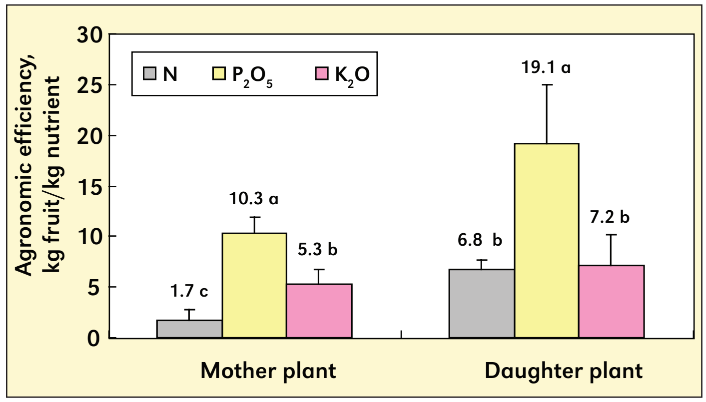

Figure 1. Agronomic efficiency of N, P, and K fertilizer in the respective OPT treatments applied to banana at Dongfu. Means within a bar group followed by the same letter are not significantly different at p = 0.05.

Table 3. Pigment content in banana fruit peel for different treatments at Dongfu, Guangdong.

Treatment	Chlorophyll, mg/g FW	Cyanin, △A530- A600 = 0.1[1]	Flavonoid, A325/g[2]
OPT	0.038 a	0.097 b	0.384 b
OPT-N	0.037 a	0.137 b	0.490 a
OPT-P	0.029 a	0.255 a	0.492 a
OPT-K	0.038 a	0.287 a	0.469 ab

Means within a column followed by the same letter are not significantly different at p = 0.05.
[1]Absorbance difference between 530 and 600 nm
[2]Absorbance at 325 nm

The post-maturation of banana fruit is due to climatic respiration caused by ethylene. The rate of ethylene released from fruit is also a reflection of storage conditions. The key during banana storage is to limit ethylene formation and prevent the occurrence of a respiratory peak during banana storage (Hu et al, 2003). It was found that the ethylene release rates from fruits 0 to 16 days after harvest were greatest in the OPT-K treatment, followed in order by the OPT-N > OPT-P > OPT (**Figure 2**). Furthermore, ethylene release from banana in the three omission treatments, especially in the OPT-K treatment, increased with time, while there was only a slight increase in the rate of ethylene release in fruits harvested from the OPT treatment. This evidence suggests that balanced fertilization can slow down the process of post harvest ripening and help reduce weight loss during banana storage and transportation. Additional advantages also exist from keeping fruits free from possible contamination caused by the utilization of chemical anti-staling agents.

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Table 2. Banana plantation profit in different treatments at Dongfu, Guangdong.

Treatment	Mother plant, Yuan/ha Output	Fertilizer cost	Profit	Profit reduction	Daughter plant, Yuan/ha Output	Fertilizer cost	Profit	Profit reduction
OPT	111,650	8,781	73,507	–	116,276	8,050	84,226	–
OPT-N	107,331	4,869	73,100	407	105,132	4,463	76,669	7,557
OPT-P	103,955	7,656	66,937	6,570	106,842	7,019	75,823	8,403
OPT-K	95,946	5,038	61,546	11,961	102,060	4,618	73,442	10,784

Notes: 1) Fertilizer price (Yuan/t): urea 2,000, SSP 500, KCl 2,080.
2) All the other costs totaled 29,362 Yuan/ha for mother plants, including land rent (16,500), seedlings (2,362), bamboo (3,000), labor (6,000), and pesticides (1,500). Those for daughter plants totaled 24,000 Yuan/ha, including land rent (16,500), labor (6,000), and pesticides (1,500).
3) Mean purchasing prices are 2.76 and 2.0 Yuan/kg for mother and daughter plant fruit, respectively. US$1 = 6.88 Yuan.