# Balanced Fertilization on Mango in Southern China

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**The objective of this project was to provide a scientific basis for high yield, high quality and profitable mango production by studying the nutritional characteristics, yield increases, and economic benefits of applying nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and sulfur (S) fertilizers.**

Mango is an important tropical fruit, ranking fifth amongst fruit production and consumption worldwide. Normal yields range from 7.5 to 15.0 t/ha. However, in the southern province of Guangdong, yields are low and unstable due to the combined effects of intense climate, poor soil fertility with a spectrum of plant nutrient deficiencies, and a lack of understanding by farmers of the benefits from balanced fertilization. Average mango yield in a Guangdong orchard is only 3.75 t/ha. Fruit quality is poor and less competitive in the global marketplace, resulting in low profits for local mango producers. Sustained profitability in southern China depends on balanced fertilization research in the region.

## Experimental Conditions

Trials were conducted in four mango orchards, two each in Shenzhen and Sanshui cities. Test soils were acidic sandy loam, with low available N and deficient levels of available P, K, Mg, S, and zinc (Zn). The eight fertilizer treatments (**Table 1**) were produced using sources available in China (**Table 2**). Since the only available source of Zn was zinc sulfate ($ZnSO_4$) and S was a variable, no application of Zn was made to the treatments.

**Table 1.** Plant nutrients applied in the different treatments (g/tree/year).

| Treatment | N | $P_2O_5$ | $K_2O$ | Mg | S |
|---|---|---|---|---|---|
| 1. $N_2PSK_1Mg_1$ | 400 | 125 | 320 | 40 | 80 |
| 2. $N_2PSK_1$ | 400 | 125 | 320 | 0 | 80 |
| 3. $N_2PSMg_1$ | 400 | 125 | 0 | 40 | 80 |
| 4. $N_2PK_1Mg_1$ | 400 | 125 | 320 | 40 | 0 |
| 5. $N_2SK_1Mg_1$ | 400 | 0 | 320 | 40 | 80 |
| 6. $N_1PSK_1Mg_1$ | 300 | 125 | 320 | 40 | 80 |
| 7. $N_2PSK_2Mg_1$ | 400 | 125 | 440 | 40 | 80 |
| 8. $N_2PSK_2Mg_2$ | 400 | 125 | 440 | 80 | 80 |

Treatment plot size was 46.8 to 58 $m^2$, arranged in a randomized complete block design with four replications. Mango trees were seven to nine years old, planted at a density of 855 plants/ha (2.92 m x 4 m). The variety was Zihuaman.

Total fertilizer application rate was split into three applications depending on orchard growth

period (**Table 3**). Fertilizers were applied in small furrows at two opposite sides of each tree; furrows were covered after each application. Fruit was harvested during July 2 to 21.

**Table 2.** Fertilizers sources and use rates for the different treatments (g/tree/year).

| Treatment | Urea | DAP | MOP | SOP[1] | SPM | $MgSO_4$ | $MgCl_2$ | $S^o$ |
|---|---|---|---|---|---|---|---|---|
| 1. $N_2PSK_1Mg_1$ | 763 | 272 | 400 | 0 | 364 | 0 | 0 | 0 |
| 2. $N_2PSK_1$ | 763 | 272 | 200 | 444 | 0 | 0 | 0 | 0 |
| 3. $N_2PSMg_1$ | 763 | 272 | 0 | 0 | 0 | 400 | 0 | 29 |
| 4. $N_2PK_1Mg_1$ | 763 | 272 | 533 | 0 | 0 | 0 | 333 | 0 |
| 5. $N_2SK_1Mg_1$ | 870 | 0 | 400 | 0 | 364 | 0 | 0 | 0 |
| 6. $N_1PSK_1Mg$ | 546 | 272 | 400 | 0 | 364 | 0 | 0 | 0 |
| 7. $N_2PSK_2Mg_1$ | 763 | 272 | 600 | 0 | 364 | 0 | 0 | 0 |
| 8. $N_2PSK_2Mg_2$ | 763 | 272 | 600 | 0 | 364 | 0 | 333 | 0 |

DAP=diammonium phosphate; MOP=muriate of potash; SOP=potassium sulfate; SPM=potassium-magnesium sulfate; $MgSO_4$ =magnesium sulfate; $MgCl_2$ =magnesium chloride.
[1]SOP (made in China) contains 45 percent $K_2O$ and 18 percent S

## Plant Nutrient Content and Ratios in Mango Leaf Tissue

Nutrient contents of the most recently matured leaf (MRML) of the fall growth branch are shown in **Table 4**. Under adequate N, P, K, Mg, and S supply, the ranking of plant nutrient leaf contents was N>calcium (Ca)>K>P, Mg and S. The N:P:K:Ca:Mg:S ratio was nearly identical between sites and was 1:0.10:0.60:0.86:0.09:0.09 in Shenzhen and 1:0.09:0.62:0.96:0.09:0.10 in Sanshui.

No significant difference in leaf N content was observed between mango trees receiving 400 and 300 g N/plant. When soil-available P content reached 4.8 to 19.4 parts per million (ppm) there was also no significant difference in leaf P content between the no P application and 125 g $P_2O_5$/plant. Application of 320 g $K_2O$/plant increased leaf K content by 0.16 to 0.18 percent over no K application. Application of 40 g Mg/plant increased leaf Mg content by 0.04 to 0.09 percent over no Mg application. Application of 80 g S/plant increased leaf S content by 0.03 to 0.04 percent over no S application.

**Table 3.** Timing of fertilizer application to mango orchards in Guangdong province.

| Growth period | Split application, % | Date |
|---|---|---|
| Fall branch promoting fertilizer | 40 | August 12 to September 11 |
| Flower promoting fertilizer | 30 | February 24 to March 2 |
| Fruit strengthening fertilizer | 30 | April 20 to May 17 |

**Table 4.** Most recently matured leaf nutrient content for Mango grown in Shenzhen and Sanshui cities, Guangdong province.

| | Nutrient content, % | | | | | |
|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S |
| Shenzhen | 1.62 | 0.16 | 0.98 | 1.39 | 0.14 | 0.14 |
| Sanshui | 1.70 | 0.16 | 1.05 | 1.64 | 0.15 | 0.17 |

**Table 5.** Yield and plant nutrient removal for Mango fruit grown in Shenzhen and Sanshui cities, Guangdong province.

| | | Plant nutrient uptake in fruit, kg/ha | | | | | |
|---|---|---|---|---|---|---|---|
| | Yield, kg/ha | N | $P_2O_5$ | $K_2O$ | Ca | Mg | S |
| Shenzhen | 13,300 | 17.7 | 3.2 | 25.8 | 2.6 | 2.2 | 1.7 |
| Sanshui | 18,700 | 22.4 | 3.9 | 37.1 | 3.2 | 3.0 | 2.3 |

## Plant Nutrient Removal Rate and Ratio with Different Mango Yields

Mango fruit yield and plant nutrient removal by fruit for Shenzhen and Sanshui are shown in **Table 5**. As would be expected, uptake and removal were higher with the higher yield. The ranking of plant nutrient uptake by the fruit was $K_2O$>N>$P_2O_5$>Ca>Mg>S. It was also noted that while there was more removal with higher yield,

the ratio of nutrient removal for the different yield levels was quite similar. Using an average of treatments supplying all nutrients, the N:$P_2O_5$:$K_2O$:Ca:Mg:S ratio was 1:0.18:1.46:0.15:0.12:0.10 in Shenzhen and 1:0.17:1.66:0.14:0.13:0.10 in Sanshui.

**Table 6.** Yield of mango fruit for different treatments at different locations (1997-1999), Guangdong province.

| | Average yield, kg/ha | | | | Four trial average yields[1] | |
|---|---|---|---|---|---|---|
| | 1998 | 1999 | 1997 | 1998 | | |
| Treatment | Shenzhen | Shenzhen | Sanshui | Sanshui | kg/ha | kg/plant |
| 1. $N_2PSK_1Mg_1$ | 12,800 | 18,800 | 9,100 | 18,200 | 14,700 | 17.2 |
| 2. $N_2PSK_1$ | 11,100 | 16,200 | 8,400 | 13,000 | 12,200 | 14.2 |
| 3. $N_2PSMg_1$ | 9,500 | 16,500 | 8,000 | 13,300 | 11,800 | 13.8 |
| 4. $N_2PK_1Mg_1$ | 12,000 | 16,700 | 8,300 | 16,500 | 13,400 | 15.7 |
| 5. $N_2SK_1Mg_1$ | 10,800 | 15,800 | 9,100 | 14,700 | 12,600 | 14.7 |
| 6. $N_1PSK_1Mg_1$ | 10,300 | 17,300 | 8,200 | 16,700 | 13,100 | 15.3 |
| 7. $N_2PSK_2Mg_1$ | 13,200 | 18,000 | 9,300 | 18,800 | 14,800 | 17.4 |
| 8. $N_2PSK_2Mg_2$ | 14,000 | 18,300 | 9,500 | 19,000 | 15,200 | 17.8 |

[1]L.S.D. (0.10) = 1,190 kg/ha, L.S.D. (0.05) = 1,440 kg/ha, L.S.D. (0.10) = 1,960 kg/ha.

## Effect of Different Plant Nutrients on Mango Fruit Yield, Quality and Profits

Data from both sites show lower fruit yields in the first year, due to excessive rain during flowering. However, by the second year, yields above 18,000 kg/ha were obtained (**Table 6**). Treatment 8 produced the highest four-year average yield of 15,200 kg/ha, with an average of 17.8 kg fruit/tree. However, profit analysis indicated it was not significantly different from treatments 1 or 7, which had similar yields of 14,700 and 14,800 kg/h and 17.2 and 17.4 kg fruit/tree, respectively. Moreover, the quality of mango fruit was equally good for treatments 1, 7 and 8 (data not shown).

**Table 7** shows that, subtracting the costs of fertilizers, manpower, pesticides, and rent, growers would realize economic returns of 32,100 Yuan/ha for treatment 8 (ratio of output/input equal to 3.4), while treatments 1 and 7 resulted in returns of 31,300 Yuan/ha.

Since no significant difference in profit could be found among the three best treatments, treatment 1 was deemed the best recommendation because the cost of the fertilizers was lowest at 2,440 Yuan/ha compared with 3,050 Yuan/ha for treatment 8.

**Table 7.** Profits of different fertilization in mango (1997-1999), Guangdong province.

| | Yield, | Cost, Yuan/ha | | Output, | Net profit, | Value to |
|---|---|---|---|---|---|---|
| Treatment | kg/ha | Fertilizer | Other | Yuan/ha | Yuan/ha | cost ratio |
| 1. $N_2PSK_1Mg_1$ | 14,700 | 2,440 | 10,500 | 44,200 | 31,300 | 3.4 |
| 2. $N_2PSK_1$ | 12,200 | 2,520 | 10,500 | 36,500 | 23,500 | 2.8 |
| 3. $N_2PSMg_1$ | 11,800 | 2,160 | 10,500 | 35,500 | 22,800 | 2.8 |
| 4. $N_2PK_1Mg_1$ | 13,400 | 2,560 | 10,500 | 40,200 | 27,100 | 3.1 |
| 5. $N_2SK_1Mg_1$ | 12,600 | 2,070 | 10,500 | 37,700 | 25,200 | 3.0 |
| 6. $N_1PSK_1Mg_1$ | 13,100 | 2,140 | 10,500 | 39,300 | 26,700 | 3.1 |
| 7. $N_2PSK_2Mg_1$ | 14,800 | 2,680 | 10,500 | 44,500 | 31,300 | 3.4 |
| 8. $N_2PSK_1Mg_2$ | 15,200 | 3,050 | 10,500 | 45,600 | 32,100 | 3.4 |

Note: Fertilizer prices: urea = 1,600 Yuan/t; DAP = 2,200 Yuan/t; MOP = 1,400 Yuan/t; SOP = 1,900 Yuan/t; $MgSO_4$ = 1,600 Yuan/t; $MgCl_2$ = 1,300 Yuan/t; SPM = 1,300 Yuan/t; S = 2,500 Yuan/t. Price of Mango = 3 Yuan/kg.

## Effects of Individual Plant Nutrients on Mango

**Nitrogen.** Application of 300 g N/tree resulted in significantly


**Research** in southern China shows the importance of balanced fertilization for sustained yields, quality, and profitability of mango.

lower yield and profit than 400 g N/tree. With 400 g N/tree, mango produced 5.7 more fruits per tree, each with a weight increase of 9 g, for a total yield increase of 1,630 kg/ha (12.4 percent). Net profit for 400 g N/tree was 4,600 Yuan/ha, providing growers with good returns. Thus, the appropriate recommendation when other plant nutrients are applied in adequate amounts would be 400 g N/tree/year.

**Phosphorus.** Comparing application of 125 g $P_2O_5$/tree with no P, trees fertilized with P had 8.1 more fruits per tree, each weighing an average 8 g more per fruit, for a significant yield increase of 2,170 kg/ha (17.3 percent). Net profit increased 6,150 Yuan/ha. Each kg of $P_2O_5$ produced 20.3 kg fruit. Thus, the proper application rate of P should be 125 g $P_2O_5$/tree/year.

**Potassium.** Comparing application of 320 g $K_2O$/tree with no K application, trees fertilized with K had 10.9 more fruits per tree, weighing 9 g more per fruit, for a significant yield increase of 2,920 kg/ha (24.7 percent). Each kg of $K_2O$ produced 10.7 kg fruit. Net profit increased 8,490 Yuan/ha. Thus, the proper application rate of K should be 320 g $K_2O$/plant/year.

**Magnesium.** Comparing application of 40 g Mg/tree to the treatment without Mg showed that mango with Mg applied had 11.1 more fruits per plant, weighing 6 g more per fruit, for a significant yield increase of 2,570 kg/ha (21.1 percent). Each kg of Mg produced 64.3 kg fruit. Net profit increased 7,790 Yuan/ha when Mg was applied. Higher Mg rates gave a slightly higher yield, but no economic benefit. Thus, the proper application rate of Mg should be 40 g Mg/plant/year.

**Sulfur.** Comparing application of 80 g S/tree to the treatment without S showed that mango with S applied produced 5.5 more fruits per plant, weighing 2 g more per fruit, for a yield increase of 1,340 kg/ha (10.0 percent). Each kg of S produced 19.7 kg fruit. This yield increment was significant at the 0.10 level, indicating a reasonably high probability of increasing yield. Net income increased 4,160 Yuan/ha when S was applied at 80 g/tree. Thus, the proper application rate of S should be 80 g S/plant/year.

## Conclusions

Based on the results of this study, it is recommended that growers use a balanced approach to fertilizer use that includes N, P, K, Mg, and S in the Shenzhen and Sanshui mango growing areas. This balance was achieved by applying urea, DAP, MOP, and SPM. Seventy-five percent of the K was provided by MOP, while the remaining 25 percent of the

## *New Handbook on Rice Nutrient Management Now Available*


The International Rice Research Institute (IRRI) in the Philippines has forecast that rice yields must increase by 30 percent by 2020 to keep pace with growing demand due to population increases.

A new handbook published by IRRI and PPI/PPIC describes site-specific nutrient management methods and provides a reference to assist with the identification and management of nutrient disorders. Titled *Rice: Nutrient Disorders & Nutrient Management*, the 191 page book is authored by Dr. Achim Dobermann, formerly with IRRI and now with the University of Nebraska, and Dr. Thomas H. Fairhurst, Deputy Director, PPI/PPIC East and Southeast Asia Program, Singapore.

Oriented to production in tropical and subtropical regions, topics include rice ecosystems, nutrient management, nutrient deficiencies, and mineral toxicities. Estimates of nutrient removal in grain and straw are included to help researchers and extension workers calculate the amount of nutrients lost from the field under various management systems. The publication will improve understanding of new approaches to nutrient management at the farm level.

The book with CD-ROM is available for purchase. The price (including shipping/ handling) is US$32.00 in less developed countries and US$77.00 in highly developed countries. For more details, check the website at **www.eseap.org**, or contact Doris Tan, PPI/PPIC (ESEAP), 126 Watten Estate Road, Singapore 287599. E-mail: dtan@ppi-ppic.org, phone: 65 468 1143, or fax: 65 467 0416. BC

required K and all Mg and S were supplied by SPM.

Under the conditions of this study, where soil N and P were low to medium and K, Mg and S were deficient, four-year average profitable yields of up to 15,200 kg mango/ha were produced using the following recommendation: 400 g N, 125 g $P_2O_5$, 320 g $K_2O$, 40 g Mg, and 80 g S/plant/year.

Nutrient removal of N, $P_2O_5$, $K_2O$, Ca, Mg, and S by the fruit from a crop producing 15,000 kg mango/ha was measured at 22.4, 3.9, 37.1, 3.2, 3.0, and 2.3 kg/ha, respectively.

Mango quality was also improved by the recommended application as measured by color, fragrance and taste. Also, fruit weights were higher, with 14 percent solids, 9 percent soluble carbohydrate, 21 mg vitamin C/100 g, and less than 0.3 percent organic acids.The ratio of carbohydrate to acid was 30.

**If mango planters follow the above recommendations, they will obtain high yields of good quality fruit, and they will receive higher profits. BCI**

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