4R Nutrient Management for Banana in China

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A review organized within the 4R Nutrient Stewardship framework demonstrates yield and quality boosting practices for banana grown within southern China.

Banana is widely grown in southern China. The crop covers 400,000 ha, which produces 12 million t. Banana's unusually high biomass yield requires a much larger quantity of nutrients than other common field crops. However, in practice, both over- and under-applications of fertilizers coexist. In fact, surveys reveal that differences between the high and low fertilizer rates used for banana in a given location can be up to ten times (Yao et al., 2006). Inappropriate fertilizer applications to banana can significantly reduce yield, quality, economic returns, and potentially pose a threat to the environment. The 4R Nutrient Stewardship approach to nutrient management considers the right fertilizer source in combination with the right application rate, timing, and placement. Considered together, the 4R management approach can improve profitability, nutrient use efficiency and promote sustainable fertilizer use.

Right Source

Banana responds to a wide range of fertilizers and those commonly applied include: urea, ammonium sulfate [$(NH_4)_2SO_4$], single superphosphate (SSP), monoammonium phosphate (MAP), diammonium phosphate (DAP), potassium chloride (KCl), potassium sulfate (K_2SO_4), calcium nitrate [$Ca(NO_3)_2$], magnesium sulfate ($MgSO_4$), zinc sulfate ($ZnSO_4$), borax, and boric acid. Recent research has revealed that controlled release urea (CRU), as compared to regular urea, can reduce both rates and frequency of applications, and increase yield of banana as well as N use efficiency.

Each of the fertilizers mentioned above can be used separately, and most can be mixed in different proportions or formulated into specialty compound fertilizers for banana. Nevertheless, evidence suggests a preference for nitrate (NO_3^--N) over ammonium (NH_4^+-N) at the seedling stage, with the optimal NO_3^-: NH_4^+ ratio being 9:1 (Wang, 2012).

It has been common perception that K_2SO_4 is superior to KCl as a K source for banana, but research has demonstrated that partial replacement of KCl with K_2SO_4 often has little impact on growth, fruit yield and quality of banana (**Table 1**). Of course, this can be attributed to the soil containing sufficient S, and to abundant rainfall able to leach any excess Cl^- out of soil profile. In regions where soil S is inadequate or deficient, it is necessary to include an appropriate S source.

Right Rate

The nutrient requirement of banana varies with crop variety, location (climate), and yield goal. To achieve a yield goal of 60 t/ha in the southern province of Guangdong, banana generally needs 4.6, 0.41, 15, 2.5, and 1.2 kg of N, P, K, Ca, and Mg, respectively, to produce 1 t fruit (Yao et al., 2005).

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Banana plantation in southern China.

Nitrogen and K are required in the largest amounts by banana. Accordingly, N and K usually become the most limiting nutrients for yield and quality. Soil test-based recommendations for fertilizer N and K rates for the fertile Pearl River Delta region and less fertile, western Guangdong are provided in

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; Cl^- = chloride.

Table 1. Banana fruit characteristics, yield, quality and profit as affected by K sources (Yao et al., 2014-2015, unpublished data)

Treatment	Finger length, cm	Finger girth, cm	Hand weight, kg/hand	Solid, %	Vit. C, mg/100g	Soluble sugar, %	Fruit yield, t/ha	Profit, US$/ha
KCl	26.4	13.2	3.36	23	6.54	17.6	47.04 a	11,026
K_2SO_4+KCl (25:75)	27.3	13.3	3.00	23	6.73	17.7	47.10 a	11,007

N, P_2O_5 and K_2O rates were 975, 245 and 1,072 kg/ha with retail prices (US$) of 0.64/kg N, 0.66/kg P_2O_5 and 0.45 (KCl) or 0.59 (K_2SO_4)/kg K_2O, respectively. Banana price was US$0.26/kg.

Table 2. Rating of available soil N and K in relation to amounts of fertilizers recommended in Pearl River Delta and western Guangdong.

Region	Soil available N, mg/kg	N recommended, kg/ha	Soil available K, mg/kg	K recommended, kg K_2O/ha
Pearl River Delta	>180	330-390	>300	450-525
	150-180	390-450	200-299	525-600
	120-149	450-510	150-199	600-675
	90-119	510-570	100-149	675-750
	60-89	570-630	50-99	750-825
	<60	630-690	<50	825-900
Western Guangdong	>180	390-450	>300	600-675
	150-180	450-510	200-299	675-750
	120-149	510-570	150-199	750-825
	90-119	570-630	100-149	825-900
	60-89	630-690	50-99	900-975
	<60	690-750	<50	975-1,050

Table 3. Percentage of N, P and K fertilizer allocations at different growth stages of banana in Guangdong (Yao et al., 2004).

Growth stage	N	P_2O_5	K_2O	Mg
	---------------- % ----------------			
Vegetative	25	100	20	0
Flower development	45	0	50	50
After bud shooting	30	0	30	50

Table 2. The amount of P required by banana can usually be calculated based on the N rate, multiplying N rate by a factor of 0.28 to 0.3 for the Pearl River Delta and 0.24 to 0.28 for western Guangdong based on soil P status (Yao et al., 2005).

Fertilizer application rates generally increase along with the higher rainfall and temperatures experienced in the more southern production zones. The best K_2O:N application ratio for the Pearl River Delta region ranged between 1.12 to 1.2:1, but in western Guangdong it tends to be wider at 1.25:1. In neighboring Fujian Province, K_2O:N ratios of 1.67 and 1.39 have been reported for high and low yield banana orchards, respectively (Zhang et al., 2015).

Fertilizer K, when used at high rates, can inhibit uptake of Mg due to the competitive relationship observed between the two nutrients. Care should be taken in areas where soil Mg is inadequate or deficient. Since soil Mg deficiency is a widespread problem in most banana orchards in China, the amounts of Mg fertilizer used to correct Mg deficiency, in addition to meeting the K x Mg interaction, must appropriately balance with the amounts of K being added. For example, in western Guangdong application of 36 kg Mg/ha is adequate to correct Mg deficiency when the K rate is 990 kg K_2O/ha, while 72 kg Mg/ha is needed when K rate rises to 1,170 kg K_2O/ha. It is crucial to maintain an adequate Mg supply to promote yield and prolong the critically important shelf-life characteristic of banana.

Right Time

The quantity of nutrients required by banana varies with growth stages and this is well reflected in the nutrient concentration in leaves (**Figure 1**). Nitrogen concentrations in leaves remain stable during the vegetative stage, but decline from floral bud differentiation to bunch harvest. Potassium concentrations keep increasing from vegetative stage until the bud shooting stage and then gradually decline with further plant growth. Flower bud development stage (the period between bud differentiation to bud shooting) is very crucial for plant N and K nutrition. During this period the dominant nutrient metabolism evolves from N to both N and K. Thus, sufficient K should be supplied before bud shooting as well as at the fruit finger swelling stage. Farmers commonly apply the majority of K after the bud shooting stage, which misses one optimal timing opportunity, and leads to low K use efficiency.

Leaf Ca and Mg concentrations show an opposite pattern to K concentration (**Figure 1**), once again demonstrating their competitive relationship and emphasizing an importance for seasonal supply of the two nutrients. Application of SSP and lime on the acidic soils of southern China can supply sufficient Ca to banana, but the addition of Mg fertilizer also becomes a necessity. If available, dolomitic lime is a better alternative to calcium carbonate under conditions of both Ca and Mg deficiency.

Leaf P and S concentrations remain low and constant through the growing season, indicating a relatively low requirement and an appropriate maintenance nutrient supply.

Nutrient accumulation in the banana plant also varies considerably with growth stage. Accumulation of N, P and K in the plant accounted for 19.3%, 17.8% and 16.5% at vegetative stage, 40.5%, 45% and 52.6% at floral bud development stage, and 40.2%, 37.2% and 30.9% after bud shooting stage (**Figure 2**).

Based on characteristics of nutrient uptake and accumulation, and years of experience, Yao et al (2004) suggested the percentages of N, P and K fertilizer allocations at different banana-growing stages in Guangdong (**Table 3**).

Frequent and small doses, rather than fewer, large appli-

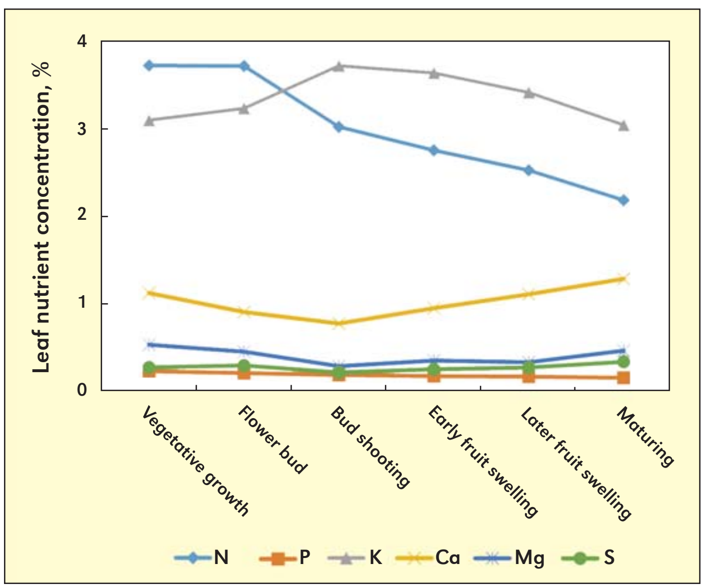

Figure 1. Nutrient concentrations in banana leaves at different growth stages (Yao et al., 2005).

cations of N fertilizer are preferred, unless controlled-release fertilizers can be used. Usually, N fertilizers are split six to eight times within one growing season. This includes one basal application, one or two side-dressings at the vegetative stage, two splits at the flower development stage, and one or two at the fruit-swelling stage. Using CRU instead of regular urea can reduce N applications to one basal application and one side-dressing (at flower development stage) to achieve the same or even higher yield goals. Phosphate fertilizer is usually only applied in one basal application, unless drip fertigation is used. Most of the N and K fertilizers are applied at the flower development stage and fruit-swelling stage because such allocations can significantly enhance fertilizer use efficiency (Murthy and Iyengar, 1995).

Right Place

Banana has a typical fibrous root system that is mainly distributed within the top 10 to 50 cm of soil. The most rapid root development occurs at the flower differentiation stage in banana. During this stage roots can grow up to 235 cm in length, but 45 cm is the average (**Table 4**). As buds emerge, the mean root length starts to decline, but roots keep proliferating to sustain its overall nutrient demand. Based on these rooting patterns, fertilizers should be banded or hole applied into the rooting zone or around the drip line about 35 to 50 cm from the pseudostem base.

Table 4. Characteristics of banana roots at different growth stages (Pearl River Delta; Yao, 2008, unpublished data)

Growth stage	Maximum root length, cm	Average root length, cm	Root number per plant
Vegetative	-	-	76
Flower bud differentiation	236	46	230
Bud shooting	108	35	239
Fruit swelling	193	36	321

Though drip fertigation has become a more popular practice in China, most farmers use traditional methods of broadcasting, banding. Li et al. (2011) compared different methods of fertilizer application and found no differences in yield and quality (**Table 5**). Despite the highest yield produced from a fertigation + banding treatment (i.e., fertigation before shooting and banding thereafter), broadcasting throughout the season achieved the highest profit due to a lower labor cost. During the fast-growing, mid-to-late growing stage period that usually coincides with the hot and rainy season, surface broadcasting followed by covering with soil can be a better alternative to avoid root damage-induced infection from Fusarium wilt due to soil disturbance within the root zone, and at the same time to enhance fertilizer use efficiency.

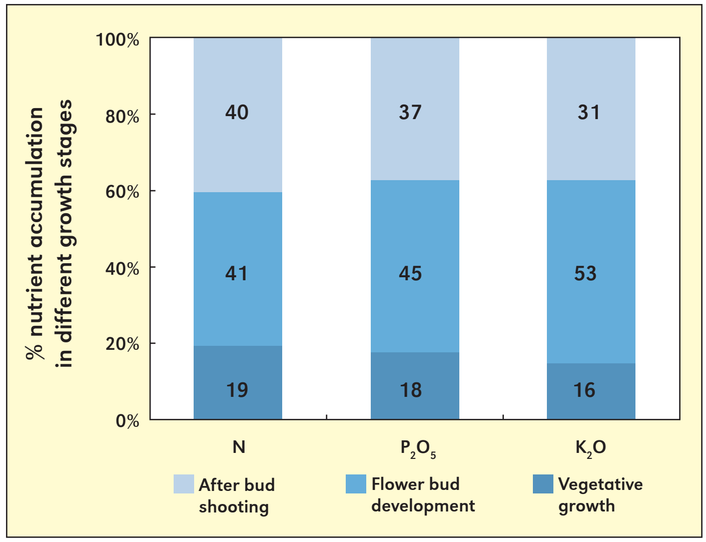

Figure 2. Percentage of N, P and K accumulation in banana plant at different growth stages.

Summary

Implementation of improved nutrient management can not only improve banana yield, but also narrow the current yield gaps and enhance nutrient use efficiency and environment protection. The actual nutrient needs of banana largely depend on local variety, soil fertility, yield goal, and weather conditions. Appropriate fertilizer timing and placement must coincide with banana growth stages for maximum nutrient uptake and better yield and quality. The 4R Nutrient Stewardship approach provides a framework to identify the best options to meet banana's nutrient demands. BC

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Table 5. Banana yield, quality and economic returns as affected by methods of fertilizer applications (Li et al., 2011)

Treatment	Yield, t/ha	Soluble solids	Soluble sugar	Vit. C	Output	Cost	Profit
		-------- % --------		mg/100g	-------------- US$/ha --------------		
Broadcasting	49.85 a	21.7 a	16.74 a	9.08 a	16,343	7,928	8,415
Broadcasting + banding	48.75 a	22.7 a	17.28 a	9.52 a	15,984	8,616	7,367
Fertigation + broadcasting	48.87 a	22.5 a	17.20 a	8.75 a	16,025	8,223	7,802
Fertigation + banding	50.72 a	22.0 a	18.12 a	9.30 a	16,628	8,961	7,667

Different letters following means within columns indicate a significant difference at $p < 0.05$.