

Effects of Phosphorus, Potassium, Sulfur, and Magnesium on Sugar Cane Yield and Quality in Yunnan

By Hong Lifang, Su Fan, Fu Libo, and Zhao Zongsheng

Nutrient depletion of sugar cane soils in Yunnan has limited the area's yield potential and profitability. This balanced fertilization study examines the impact of applied nutrients and provides recommendations that more closely match crop requirement.



Balanced fertilization studies in Yunnan are showing the importance of K application as part of a complete system for sugar cane yield and quality.

As a potassium (K)-loving plant, sugar cane removes large quantities of the nutrient from the soil every year. In the past, Yunnan's farmers applied only nitrogen (N) and phosphorus (P) fertilizer to the crop. Thus, the K required for production came from the soil, with K depletion resulting. The large demand for soil K exceeded amounts supplied by organic or inorganic fertilizers for quite some time. Thus, production decreased in Yunnan.

Increasing sugar cane yield and sugar content through the efficient use of fertilizer requires an understanding of the magnitude of the imbalance between plant nutrient supply and crop demand. To this end, the Soil and Fertilizer Institute of the Yunnan Academy of Agricultural Sciences studied balanced fertilizer application in a PPI/PPIC-sponsored project.

Material and Methods

Field experiments were conducted on ratooned sugar cane at three locations (Baoshan, Wenshan and Mile) representing soil conditions of the three main sugar cane growing areas in Yunnan. Plant nutrient application was based on soil test results. Plant nutrient sources were urea, diammonium phosphate (DAP), muriate of potash (MOP), potassium-magnesium sulfate (SKMg), gypsum (CaSO_4), and magnesium chloride (MgCl_2). Fertilizer application rates for the eight treatments are presented in **Table 1**. All sulfur (S) and Mg fertilizers were applied as basal applications. Phosphorus was applied in two splits (70 percent at basal dressing and 30 percent at seedling stage). Nitrogen and K were applied in five splits at basal dressing, seedling, tillering, elongating, and peak elongating stages.

Table 1. Effect of balanced fertilization on sugar cane yield and profit, Yunnan province.

Treatment	Treatment, kg/ha					Baoshan			Wenshan			Mile		
	N	P ₂ O ₅	K ₂ O	S	Mg	Yield, t/ha	Rel ² yield, %	Net profit ³ , Yuan/ha	Yield, t/ha	Rel ² yield, %	Net profit ³ , Yuan/ha	Yield, t/ha	Rel ² yield, %	Net profit ³ , Yuan/ha
1	350	203	0	60	60	108	68.2	36,000	82.2	65.8	27,200	80.4	82.8	19,700
2	350	203	225	60	60	149	94.5	56,300	115.0	91.8	40,200	85.3	87.8	23,400
3	350	203	375	60	60	158	100.0	61,800	125.0	100.0	47,800	97.1	100.0	28,200
4	350	203	525	60	60	167	106.0	68,100	120.0	96.8	47,100	101.0	104.0	28,900
5	350	135	375	60	60	133	84.5	50,900	95.0	76.0	34,700	85.8	88.4	24,200
6	350	203	375	0	60	156	98.7	60,400	116.0	92.7	42,800	93.6	96.4	26,300
7	350	203	375	60	0	138	87.2	53,900	110.0	88.2	42,200	88.8	91.5	24,700
8	350	203	375	90	60	162	103.0	63,600	131.0	104.0	51,000	96.8	99.7	27,400
F value ¹	Treatment Replication					2.8* NS			8.9** NS			6.4** NS		

¹ NS = Not significantly different; * = Significantly different at the 0.05 level; ** = Significantly different at the 0.01 level.

² Relative yield compares each treatment against treatment 3, which was set at 100%.

³ Value: Sugar = 3.2 Yuan/kg; SKMg = 1.6 Yuan/kg; MgCl₂ = 1.6 Yuan/kg; DAP = 2.0 Yuan/kg; Urea = 2.5 Yuan/kg; Gypsum = 1.2 Yuan/kg; KCl = 2.0 Yuan/kg.

Treatment plot areas were 30 m², with four replications. A randomized complete block design was used. Sugar cane varieties and plant populations followed local practices.

Results

Effect of Balanced Fertilization on Yield of Sugar Cane

Data indicate significant treatment effect on yield with balanced fertilizer use at all three locations in Yunnan (Table 1). Yield increased as applied fertilizer amounts increased. Phosphorus, K, S, and Mg had positive effects on yield. The effect on increasing yield was impressive when P, K and Mg were added with N applied at the high fixed rate of 350 kg/ha.

Potassium application resulted in significant increases ($P = 0.05$) in yield at all three sites. Some improvements in yield with P and Mg application were significant ($P = 0.10$). The effect of S was neither large nor statistically different from plots with no applied S at all three sites.

The effect of K diminished with increased application above 375 kg K₂O/ha only at the Wenshan site, indicating need for further study with higher rates at the other locations. The experiment at Wenshan showed a yield increase with rates between 225 to 375 kg K₂O/ha. At Baoshan and Mile, 525 kg K₂O/ha still increased sugar cane yield. This additional K rate was not profitable at Wenshan or Mile. However, at Baoshan, it was considerably more profitable, indicating even higher rates of K₂O need testing in that region. It should be noted the effect of K on sugar cane is not significant without S and Mg.

The P application (203 kg P₂O₅/ha), higher than normally used by farmers (105 to 135 kg/ha), produced a much greater and more

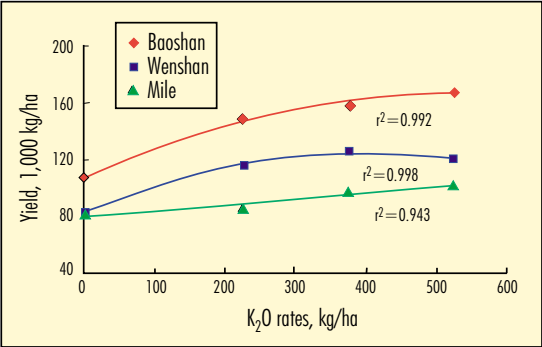


Figure 1. The effect of applied K on sugar cane yield at the three locations.

profitable yield increase at all three locations. Yield increases and profits with the higher rate of P_2O_5 for Baoshan, Wenshan and Mile were 25 t/ha and 10,900 Yuan/ha, 30 t/ha and 13,100 Yuan/ha, and 11.3 t/ha and 4,030 Yuan/ha, respectively.

The addition of 60 kg S/ha did not have a statistically significant effect at any site.

However, addition of 60 kg Mg/ha had a marked effect at all three locations. Yield increases and profits for Baoshan, Wenshan and Mile were 20.0 t/ha and 7,900 Yuan/ha, 15.0 t/ha and 5,600 Yuan/ha, and 8.3 t/ha and 3,500 Yuan/ha, respectively. Results clearly demonstrate the benefits of applying Mg to sugar cane in these three counties in Yunnan.

The main interest of this study was to evaluate K responses in sugar cane. Different regression curves were developed for the three trials (**Figure 1**). The relationship between K_2O and sugar cane yield for the three locations gave a positive correlation, with very high coefficients reaching significant levels. The response curves are rising at the three locations, but there is only a transition point on the curve for Wenshan, indicating need to test higher K application rates at Baoshan and Mile.

Effects of P, K, S and Mg on Sugar Content

Data in **Table 2** show the relationship among plant nutrient application, percent sugar content, and total sugar production per hectare at the three study sites.

Percent sugar content was most affected by applied K when other plant nutrients were adequate, increasing 2.0, 1.8 and 1.7 percent at Baoshan, Wenshan and Mile, respectively, when the highest sugar content with K_2O application was compared to no K application.

Total yield of sugar per hectare is calculated by multiplying sugar cane yield by percent sugar content (**Table 2**). The trend in sugar production was similar to sugar cane yield, where K stood out as the most influential plant nutrient. But

Table 2. Effect of K rates on sugar content and sugar yield with balanced fertilization, Yunnan province.									
Treatment, kg/ha				Baoshan		Wenshan		Mile	
P_2O_5	K_2O	S	Mg	Sugar content, %	Sugar yield, t/ha	Sugar content, %	Sugar yield, t/ha	Sugar content, %	Sugar yield, t/ha
203	0	60	60	11.9	12.8	13.0	10.7	15.6	12.6
203	225	60	60	12.9	18.0	13.2	15.1	16.8	14.3
203	375	60	60	13.4	21.1	14.3	17.8	17.3	16.8
203	525	60	60	13.9	23.2	14.8	17.8	17.2	17.3
135	375	60	60	13.2	17.7	14.1	14.0	17.2	14.8
203	375	0	60	13.3	20.7	14.0	16.2	17.0	15.9
203	375	60	0	13.3	18.3	14.2	15.7	17.0	15.1
203	375	90	60	13.4	21.8	14.5	18.9	17.1	16.6

P, S and Mg all had some positive influence, mainly due to their influence on sugar cane yield. Variety can also be a significant factor affecting sugar content.

Correlation studies were conducted between percent sugar content and the different rates of K fertilizer (**Figure 2**). Data indicated the effect of applied K on sugar content was significant. The correlations were $r^2=0.997$ at Mile, 0.941 at Wenshan, and 0.999 at Baoshan. Again, no downturn appeared from the effect of K at Wenshan and Baoshan, indicating higher doses of K need to be tested at these locations in the future.

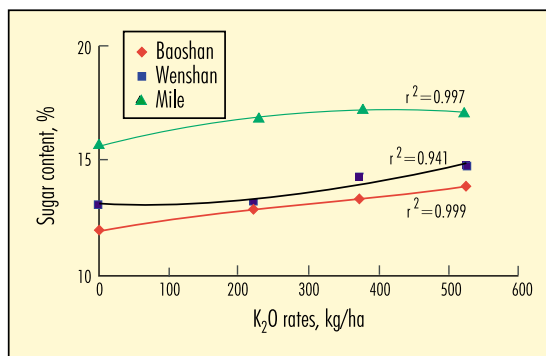


Figure 2. The effect of applied K on sugar content at the three locations.

Conclusions

Since the wide-scale adoption of balanced fertilization in Yunnan, variable rate fertilizer application and site-specific management provide one of the greatest new challenges and opportunities for improving fertilizer use efficiency for higher, more profitable crop yields. The assumption with balanced fertilization is that it will more closely match productivity, input efficiency, and profitability if compared with traditional farmer application methods. These experiments show that sugar cane yield, sugar content, and total sugar production per hectare can be increased by application of P, K, and Mg. Among these plant nutrients, K has the dominant effect. Both correlation coefficients for K and sugar cane yield and K and sugar content were very high at the three locations. However, at Baoshan and Mile, higher rates of all plant nutrients should be tested since response to the highest rate of K was still positive and may have been even greater had some of the other nutrients not been limiting to yield.

Considering that 60 percent of Yunnan's sugar production area harvests less than 45 t/ha, the trials presented herein demonstrate the potential to increase provincial sugar output by using balanced fertilization in an efficient and profitable manner. Until more precise data are obtained, the optimum rates for high yields and profits are recommended as N 375, P₂O₅ 203, K₂O 375, and Mg 60 kg/ha. Results indicate that these rates of plant nutrients will also produce higher sugar content and, therefore, higher total sugar production. However, additional research is needed to refine these recommendations. **BCI**

Hong Lifang is a Ph.D. student in Huazhong Agricultural University, Wuhan. Su Fan, Fu Libo, and Zhao Zongsheng are staff of the Soil and Fertilizer Institute of the Yunnan Academy of Agricultural Sciences, Kunming.