Balanced Fertilization for Tea Production in Yunnan

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The main reasons for low tea production in Yunnan are poor soil fertility and unbalanced fertilization. Site-specific research conducted at three plantations highlights benefits that can be expected from science-based nutrient management.

Tea is a major crop in Yunnan…its total production ranks highest amongst all provinces of China. Despite this prominence, Yunnan's numerous tea-growing counties produce at relatively low yield levels—the majority with yields below 4.5 t/ha and some producing under 2.2 t/ha. A series of field studies at Menghai, Eshan, and Simao addressed this production gap and evaluated the effects of soil test-based fertilizer applications on tea yield and quality.

According to soil testing results, nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) were deficient at all three locations. Menghai and Eshan showed sulfur (S) deficiencies, and Simao was deficient in manganese (Mn). Specific ranges of fertilizer application rates were selected for each site (**Table 1**) and combined into a set of eight distinct treatments (**Table 2**). Each site used a plant density (Yunkang 10 tea variety) of 84,000 shoots/ha.

Research in Yunnan Province shows that soil test-based fertilizer applications can improve tea yield and quality.

Leaf Composition

Amino acid and protein content of tea leaves affect the quality of green tea and both of these are influenced by soil fertility. Long-term observations show that continued reliance on N alone reduces soil quality, in part through hastening of basic cation depletion. This decreases the potential for sustained high quality tea production. This experiment found enhanced accumulation of amino acids and proteins in leaves with increased supply of P, K, secondary nutrients, and micronutrients (**Table 2**). Leaf amino acid and protein content increased with K application up to 200 kg K_2O/ha. Beyond that level, K appeared to have a negative effect, possibly due to the competing effect between K^+ and cations like ammonium (NH_4^+). High rates of K did depress N uptake by tea at all locations (data not shown). The concentration of water extractable compounds was also enhanced with use of N, P, K, and Mg, but neither S nor Mn had

Table 1. Range of fertilizer application rates (kg/ha) selected for each plantation site, Yunnan.

Nutrient	Menghai	Simao	Eshan
N	414	375	420
P_2O_5 (P_1, P_2)	200, 300	200, 300	225, 300
K_2O (K_0, K_1, K_2, K_3)	0, 100, 200, 300	0, 100, 200, 300	0, 100, 200, 300
S (S_0, S_1)	0, 60	–	0, 50
Mg (Mg_0, Mg_1)	0, 60	0, 37.5	0, 50
Mn (Mn_0, Mn_1)	–	0, 7.5	–

Table 2. Treatment effect on amino acid, protein, and water extractable compounds in tea leaf tissue, Yunnan.

	Amino acid, %			Protein, %			Water extractable compounds, %		
Treatment	Menghai	Simao	Eshan	Menghai	Simao	Eshan	Menghai	Simao	Eshan
1. $NP_1K_0S_1Mg_1Mn_1$	16.03	18.35	18.20	25.74	28.45	27.16	52.99	55.75	54.51
2. $NP_1K_1S_1Mg_1Mn_1$	17.93	19.19	18.41	24.91	28.33	27.48	53.05	56.45	54.72
3. $NP_1K_2S_1Mg_1Mn_1$	18.24	19.24	18.85	26.63	28.57	28.13	53.25	56.32	55.20
4. $NP_1K_3S_1Mg_1Mn_1$	17.11	18.31	17.01	23.97	27.82	26.92	53.90	56.91	55.24
5. $NP_2K_2S_1Mg_1Mn_1$	18.78	19.56	18.77	24.90	28.39	27.16	55.04	56.74	57.13
6. $NP_1K_2S_0Mg_1Mn_0$	16.64	19.01	19.20	25.57	28.67	27.92	53.11	56.29	56.82
7. $NP_1K_2S_1Mg_0Mn_1$	17.81	18.20	17.86	26.24	28.48	26.95	53.06	55.88	55.03
8. $NP_1K_2S_1Mg_1Mn_1$	17.71	19.89	21.98	25.57	28.26	27.32	54.26	56.33	56.60

Selected fertilizers were urea, monoammonium phosphate, single superphosphate, KCl, K_2SO_4 (treatment 8), gypsum, magnesium chloride, magnesium sulfate, and manganese sulfate.
Note: Only the Simao site received Mn, and no S.

much influence on any of these leaf quality related compounds.

Agronomic Features of Tea

The agronomic quality of tea plants is evaluated by three indices: bud length, hundred-bud weight, and density of buds. Data indicate that all traits tended to increase with improved K nutrition status (**Table 3**). However, the use of potassium sulfate (K_2SO_4) did not offer any advantage over potassium chloride (KCl). Phosphorus had a major effect on bud length at all sites, while density of buds improved at all sites receiving S and Mn.

Tea Yield

Balanced fertilization noticeably increased yield since levels obtained with the best treatments were over three times those obtained by the vast majority of tea-growing counties in the province (**Table 4**). The three sites responded well to the range of K treatments with yield increases of up to 15% at Menghai, 30% at Simao, and 42% at Eshan. Simao showed an additional, albeit small, yield response (2.1%) as K rate increased from 200 to 300 kg K_2O/ha. The K source comparison (treatment 3 vs. treatment 8) showed an apparent yield advantage for K_2SO_4 over KCl at Simao and Menghai, but not Eshan.

Simao was the only site which responded to P application beyond 200 kg P_2O_5/ha. The effect of Mg was significant at all sites as yield increased by 1.22 t/ha (10.8%) at Menghai, 1.17 t/ha (9%) at Simao, and 770 kg/ha (7.7%) at Eshan. The S response was marginal at the two

Table 3. Treatment effect on selected agronomic features of tea, Yunnan.

		Treatment							
Location	Feature	1	2	3	4	5	6	7	8
Menghai	Bud length, cm	3.1	3.1	3.1	3.1	3.2	3.1	3.1	3.1
	Hundred-bud weight, g	91.8	92.4	94.6	109.0	95.5	95.0	95.8	99.2
	Germinate density, buds/m^2	1,536	1,555	1,654	1,619	1,620	1,538	1,551	1,623
Simao	Bud length, cm	3.0	3.1	3.2	3.3	3.3	3.2	3.1	3.2
	Hundred-bud weight, g	105.3	105.4	107.9	107.2	107.4	107.5	106.1	107.9
	Germinate density, buds/m^2	1,154	1,160	1,280	1,272	1,215	1,274	1,208	1,298
Eshan	Bud length, cm	2.5	2.9	2.9	3.0	3.0	2.9	2.9	3.0
	Hundred-bud weight, g	66.5	66.8	68.5	68.4	69.7	68.4	67.8	68.9
	Germinate density, buds/m^2	474	482	488	492	418	483	481	488

sites tested and Mn application at Simao produced a 285 kg/ha (2.2%) yield increase.

Table 4. Treatment effect on tea yield, Yunnan.

Treatment	Menghai		Simao		Eshan	
	Yield, t/ha					
1	9.76	(86.8)[1]	10.20	(78.8)	7.04	(70.2)
2	10.39	(92.4)	11.81	(90.9)	8.89	(88.7)
3	11.25	(100.0)	12.99	(100.0)	10.02	(100.0)
4	10.98	(97.6)	13.26	(102.1)	10.02	(100.0)
5	11.10	(98.7)	14.07	(108.3)	10.04	(100.2)
6	11.21	(99.6)	12.70	(97.8)	9.92	(99.0)
7	10.03	(89.2)	11.82	(91.0)	9.25	(92.3)
8	11.90	(105.8)	14.31	(110.2)	10.06	(100.4)
F-Test treatment	1.98*		2.83**		2.37**	

[1]Numbers in parenthesis represent relative yield.
*Significantly different at p = 0.25 level; **Significantly different at p = 0.1 level.

Economic Efficiency

Despite the varying degree of response to applied nutrients across sites, economic analysis found substantial advantage to a balanced approach to fertilization (**Table 5**). Amongst treatments 1 to 4 which varied K rate alone, net income at Menghai and Eshan was maximized with 200 kg K_2O/ha. At Simao, the marginal yield increase gained from applying 300 kg K_2O/ha was slightly more profitable. The use of 300 instead of 200 kg P_2O_5/ha was more profitable at Simao. However, these incomes were all lower than amounts generated with the complete treatment 8 which also relied on K_2SO_4 as the source. The Menghao site showed a similar advantage to the K_2SO_4-supplying treatment. At Eshan, which was the most responsive to K and the least responsive to S and Mg, no economic advantage was apparent for either K application beyond the 200 kg K_2O/ha level or any secondary and micronutrient application.

Table 5. The economic analysis for balanced fertilization on tea (US$/ha), Yunnan.

Locations	Treatment	1	2	3	4	5	6	7	8
Menghai	Output	4,167	4,433	4,801	4,686	4,738	4,785	4,280	5,078
	Input	457	486	516	545	568	481	403	558
	Balance	3,710	3,947	4,285	4,141	4,170	4,304	3,877	4,520
Simao	Output	2,487	2,880	3,168	3,234	3,433	3,098	2,882	3,490
	Input	303	332	362	391	413	355	352	449
	Balance	2,184	2,548	2,806	2,843	3,020	2,743	2,530	3,041
Eshan	Output	2,574	3,252	3,668	3,668	3,672	3,631	3,384	3,682
	Input	407	439	472	504	494	449	321	523
	Balance	2,167	2,813	3,196	3,164	3,178	3,182	3,063	3,159

Conclusion

Among the fertilizer nutrients tested, the influence of K on yield and profitability made its application essential at all locations. Combinations of secondary and micronutrient application had prominent importance at two of three sites. BC

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