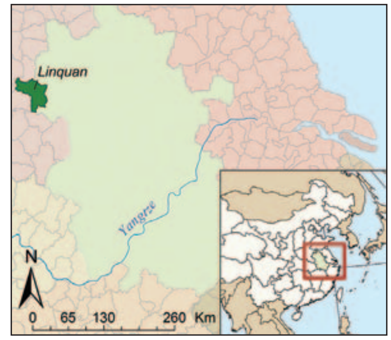
Balanced Fertilization for Ginger Production – Why Potassium Is Important



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Potassium is one of the most important limiting factors for ginger production. The main practices to obtain high rhizome yield with optimal nutrient use efficiency include fertilizer application based on soil testing, topdressing K fertilizer at growth stages with peak demand, and applying enough K to balance the appropriate N and P application rates.

Ginger is a leading high value crop in southeastern China and a primary source of income for the region's farmers. Ginger rhizomes and their products are consumed as a spice, in Chinese medicine, and as a special vegetable in daily diets worldwide. Most recent statistics indicate that area planted to ginger in China is about 240,000 ha, which accounts for 48% of the total ginger crop area globally.

This paper focuses on Anhui Province, which is one of the most important ginger production regions. Nutrient management is always an important consideration for ginger because it requires large quantities of nutrients, especially K. However, farmers in Anhui typically overuse N and P, and ignore K fertilization. They are unaccustomed to applying potash in upland crops, and this region has a general lack of K fertilization products and knowledge regarding balanced fertilization.

Table 1. Physical and chemical properties of tested soils by National Laboratory of Soil Testing and Fertilizer Recommendations in Beijing.

Year/Location	pH	OM %	Ca	Mg	N	P	K	S	B	Cu	Fe	Mn	Zn
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2002/Gaotang	6.9	0.5	3,040	396	13	33	73	12	0.7	3.3	38	17	1.8
2003/Tanpeng	6.2	0.6	3,039	618	15	40	67	13	0.5	2.9	84	83	1.5
2007/Shanqiao-1	6.4	0.6	3,206	418	12	25	70	9	0.1	1.3	21	12	0.9
2007/Shanqiao-2	6.2	0.8	3,306	555	13	15	62	8	0.1	1.6	42	15	2.4
2008/Yangqiao-1	6.5	1.3	4,336	556	24	15	74	4	2.5	2.9	15	46	1.6
2008/Yangqiao-2	6.6	1.4	3,683	473	18	17	59	12	2.2	2.6	16	69	1.2
Critical values	–	1.5	401	122	50	12	78	12	0.2	1.0	10	5	2.0

Experimental sites that test below the soil test critical level are likely to respond positively to the nutrient application.

This research program in Linquan County began with a series of field experiments carried out in 2002 and 2003 in the towns of Gaotang and Tanpeng to test fixed 'optimum' (OPT) NPK treatments, as well as corresponding nutrient omission treatments. Recommended N, P, and K rates in the OPT considered both the average rates traditionally used by local farmers as well as soil analysis and fertilizer recommendation according to the Agro-Services International (ASI) method (Portch and Hunter, 2002), which is used by the National Laboratory of Soil Testing and Fertilizer Recommendations in Beijing. According to traditional practice, basal fertilization included all of the P and K plus 60% of the total N rate. The remaining N was split between topdressings applied at the vigorous growth stage and rhizome expansion growth stage.

Ginger rhizomes are consumed as a spice, in medicine, and as a vegetable in diets around the world.

List of Abbreviations: N = nitrogen; P = phosphorus; K = potassium; DAP = diammonium phosphate; SSP = single superphosphate; KCl = potassium chloride; Zn = zinc; Ca = calcium; Mg = magnesium; S = sulfur; B = boron; Cu = copper; Fe = iron; Mn = Mangenese; OM = organic matter.

Fixed OPT field trials were also conducted in 2007 (Shanqiao-1) and 2008 (Yangqiao-1). Field testing at these sites evolved to include more detailed investigation of the effects of N, P, and K application rates on rhizome yield, K uptake, and profitability. The trials were designed as three independent experiments, each focusing on the evaluation of five rates of either N, P, or K co-applied with fixed rates of the other two nutrients. As an alternative to traditional practice, basal fertilization in these trials included 40% of the total N and K plus the entire P rate. The remaining N and K were equally topdressed by in-row band application in early August (three branch growth stage) and early September (vigorous growth stage). Usually, common practice does not include any topdressing of K fertilizer. A plant biomass and K accumulation experiment was also initiated in 2007 at Shanqiao in order to describe crop K demand throughout the season. Ginger plant samples were taken on July 11 (seedling stage), August 1 (three branch stage), August 27 (vigorous growth stage), September 23 (rhizome expansion stage), and October 22 (harvest stage). Stalk, foliage, and rhizome of ginger were collected and analyzed.

All experiments were located on a common Shajiang black vertisol **(Table 1)**. The list of soil properties indicates the soils of these fixed trials were low in organic matter, available N, K, S, and Zn. The soil in Shanqiao also showed low B content. Because of many years of P fertilization, available soil P was relatively high in all of the sites, especially in Gaotang and

Table 2. Effect of K rates on accumulation of ginger plant biomass and K uptake.

	-- Biomass accumulation, kg/ha --					K nutrient uptake, kg/ha				
$N-P_2O_5-K_2O$	S[1]	T	V	E	H	S	T	V	E	H
400-90-0	396	525	1,567	4,418	744	21	21	45	80	25
400-90-200	612	861	1,722	4,946	1,267	35	38	45	133	54
400-90-400	779	955	2,046	5,305	1,439	49	47	68	214	84
400-90-600	865	722	1,931	5,227	1,356	58	38	76	271	89
400-90-800	714	734	1,930	4,783	1,119	53	46	79	228	126

[1]S = seedling stage (1 to 90 days after seeding [DAS]); T = three branches stage (90 to 110 DAS); V = vigorous growth stage (110 to 130 DAS); E = rhizome expansion stage (130 to 160 DAS), and H = harvest stage (160 DAS).

Ginger plants require large amounts of nutrients, especially K.

Table 3. Effect of K rates on ginger rhizome yield and net returns.

Year/Location	$N-P_2O_5-K_2O$	Yield, kg/ha	Yield increase, %	Total K uptake, kg/ha	Net return over fertilizer, US$/ha
2007/Shanqiao-1	400-90-0	37,847 c	-	108	14,975
	400-90-200	42,188 b	11.5	154	16,791
	400-90-400	45,651 a	20.6	236	18,256
	400-90-600	41,319 b	9.2	285	16,603
	400-90-800	40,858 bc	8.0	264	16,499
2008/Yangqiao-1	450-90-0	36,382 d	-	104	19,104
	450-90-225	45,384 b	24.7	166	23,995
	450-90-450	51,260 a	40.9	250	27,228
	450-90-675	44,789 b	23.1	309	23,918
	450-90-900	41,288 c	13.5	267	22,181

For Tables 3 to 6, numbers followed by the same letter are not significantly different at $p = 0.05$.
In 2007, the price of ginger rhizome was $US0.40/kg, N was $US0.53/kg, P_2O_5 was $US0.53/kg, and K_2O was $US0.40/kg.
In 2008, the price of ginger rhizome was $US0.53/kg, N was $US0.53/kg, P_2O_5 was $US0.67/kg, and K_2O was $US0.53/kg.
(1US$=7.5 RMB).

Table 4. Effect of N rates on ginger rhizome yield and net returns.

Year/Location	$N-P_2O_5-K_2O$	Yield, kg/ha	Yield increase, %	Total K uptake, kg/ha	Net return over fertilizer, US$/ha
2007/Shanqiao-1	0-90-400	32,350 c	-	173	13,052
	200-90-400	39,931 b	23.4	247	16,074
	400-90-400	45,602 a	41.0	323	18,237
	600-90-400	37,529 b	16.0	272	14,901
	800-90-400	35,010 bc	8.2	262	13,788
2008/Yangqiao-1	0-90-450	34,976 c	-	187	18,715
	225-90-450	42,647 b	21.9	263	22,782
	450-90-450	51,117 a	46.1	362	27,152
	675-90-450	43,657 b	24.8	316	23,079
	900-90-450	41,440 b	18.5	310	21,785

Tanpeng. All plots were arranged in a randomized complete block design with four replicates. The sources of fertilizer were urea, DAP or SSP, and KCl. The cultivar was local "lion-head" ginger, and the plant populations were 106,000 plants/ha.

Results from the biomass and nutrient accumulation study found relatively slower rates for both plant growth and K uptake prior to the vigorous growth stage, which marked the beginning of much more rapid accumulation of both until plant harvest **(Table 2)**. The mean proportion of total biomass accumulated at the seedling, three branch, vigorous growth, rhizome expansion, and harvest stages was 7%, 8%, 20%, 53%, and 12%, respectively. Plant biomass responded to increases in K application rate, and the highest biomass accumulation was commonly observed under 400 kg K_2O/ha. The mean proportion of total K accumulated at each of the stages listed was 11%, 10%, 16%, 45%, and 18%, respectively. The effect of N and P application rates was consistent with results observed for that of K (data not shown).

Results from the three NPK rate trials at Shanqiao in 2007 agreed that the most profitable, high yielding combination was 400 kg K_2O/ha applied along with 400 kg N/ha and 90 kg P_2O_5/ha. The best results at Yangqiao in 2008 were achieved with 450-120-450 kg $N-P_2O_5-K_2O$/ha **(Tables 3, 4, and 5)**. For farmers who traditionally ignore K application, the economic benefit from co-applying adequate K represented an additional net return approaching US$3,000/ha.

The OPTs were tested once again against nutrient omission plots at two other locations (Shanqiao-2 and Yangqiao-2) and results agreed with earlier attempts at identifying an optimal NPK strategy **(Table 6)**. That is, collectively the six fixed OPT trials conducted over 4 years agree that N is the most important limiting factor for ginger rhizome yield in Anhui, followed by K and P. Across sites, balanced fertilization significantly increased ginger rhizome yield by 42%, 13%, and 27%, compared to the OPT-N, OPT-P, and OPT-K, respectively. Any increase in N application rate towards the OPT should be accompanied with a proportional increase in K application rate.

Table 5. Effect of P rates on ginger rhizome yield and net returns.

Year/Location	$N-P_2O_5-K_2O$	Yield, kg/ha	Yield increase, %	Total K uptake, kg/ha	Net return over fertilizer, US$/ha
2007/Shanqiao	400-0-400	40,567 b	-	168	16,175
	400-60-400	44,213 a	9.0	199	17,665
	400-120-400	45,685 a	12.6	251	18,286
	400-160-400	43,345 ab	6.8	242	17,371
	400-240-400	42,604 ab	5.0	233	17,117
2008/Yangqiao	450-0-450	42,940 c	-	178	22,758
	450-60-450	46,678 b	8.7	210	24,780
	450-120-450	51,386 a	19.7	282	27,315
	450-180-450	46,998 b	9.5	262	25,030
	450-240-450	45,634 bc	6.3	250	24,347

Table 6. Effect of N, P, or K omission on ginger rhizome yields.

Treatments	2002 Gaotang	2003 Tanpeng	2007 Shanqiao-1	2007 Shanqiao-2	2008 Yangqiao-1	2008 Yangqiao-2
	- - - - - - - - - -	- - - - - - - - - -	- - - - - kg/ha	- - - - -	- - - - - - - - - -	- - - - - - - - - -
OPT1	43,120 a	37,790 a	46,290 a	47,220 a	52,190 a	50,160 a
OPT-N	32,010 d	27,530 c	33,560 c	32,180 c	34,910 d	34,850 d
OPT-P	39,250 b	34,120 b	42,130 b	41,120 b	45,380 b	43,380 b
OPT-K	35,370 c	29,210 c	36,570 c	38,660 b	39,110 c	39,290 c

[1]OPT: $N-P_2O_5-K_2O$ rates were 375-90-450 (2002 and 2003); 400-90-400 (2007); and 450-120-450 (2008).

Studies in Anhui Province show benefits of soil testing to evaluate nutrient supply for ginger.

The authors recommended P fertilization rate for ginger in this region at 120 kg P_2O_5/ha and as such recommend an N: P_2O_5: K_2O fertilization ratio of 100: 25 to 30: 100.

These results show that K is an important limiting factor for ginger production in Anhui. Ginger is sensitive to and needs a large amount of available soil K. Balanced use of fertilizers will improve rhizome yields and it contributes greatly to the economic viability of the crop. Profits were highest under this study's recommended K rates, and balanced fertilization of N and P were effective at supporting improved farmer profit. Soil testing used to evaluate soil nutrient supply also provided good guidance for avoiding over fertilization. BC

Acknowledgments

This research project was supported by the IPNI China Program. IPNI Project # Anhui-10.

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