Ginger Yield and Quality Influenced by Potassium Fertilization

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Farmers are underemphasizing the application of K fertilizer in the face of increased nutrient demand by the crop. **Maximum benefits from K** were observed with the application of 450 kg K_2O/ha, when balanced with adequate N and P.

Ginger (*Zingiber officinale*) is an important industrial crop of China. Its rhizomes contain balmy essential oil and pungent Gingierone, making it popular as a flavoring agent, in Chinese medicines, and as a special vegetable in people's daily diets worldwide. China is currently one of the largest ginger producing countries in the world. Recent statistics indicate that the ginger production area in China has reached 240,000 ha, which accounts for 48% of the world's ginger-growing area (Ministry of Agriculture, 2006). Anhui is one of the leading ginger-producing provinces in China, where ginger planting has become a primary income source for local farmers.

Ginger requires large quantity of nutrients, especially K, for successful cultivation. However, in both Anhui and other areas in China, farmers usually over apply N and P fertilizers, while K fertilization is ignored. This imbalance in N, P and K applications results in low rhizome yield and inferior quality of ginger. Field experiments were conducted on a loam soil from 2007 to 2009 in Shanqiao and Yangqiao towns, Linquan county of Anhui to evaluate the effects of K application on ginger rhizome production. Some physical and chemical properties of the top 20 cm of all experimental soils are listed in **Table 1**. Available K was deficient in all the soils.

Potassium fertilizer at five different rates (0, 225, 450, 675, and 900 kg K_2O/ha applied as KCl) was broadcast in different plots before ginger transplanting each year of the experiment. All plots received 450 kg N (urea) and 90 kg P_2O_5 (DAP) per ha in each year as well. For all the experiments, basal fertilization included all of the P and K fertilizers plus 60% of the total N fertilizer, while the remaining 40% N was equally applied in two topdressings at about 105 and 135 days after ginger transplanting. The cultivar was local 'Lion-head' ginger planted at 106,000 plants/ha.

Ginger plants without K fertilization gradually showed K deficiency symptoms—from pale green to yellow coloration along the tip and edge of the older leaves in the lower part of the plant, while the veins of leaves remained green. Eventually the whole leaf withered, died, and fell with the development of K deficiency, and the whole plant became stunted with small leaves (**Figure 1**). Ginger plant grew normally in the treatment supplied with 450 kg K_2O/ha, and did not show any K deficiency symptoms.

Ginger rhizome yield responded significantly to K applications (**Table 2**). In 2007, K application with 225 to 900 kg K_2O/ha increased ginger rhizome yields by 13 to 41% (average 26%) as compared to no K treatment. The medium K application rate (450 kg K_2O/ha) produced the highest rhizome yield, while the highest K application rate (900 kg K_2O/ha) actually resulted in significantly lower rhizome yields than those obtained with K application rates of 225 or 675 kg K_2O/ha. The probable reasons for this yield decrease can be either excessive K application leading to imbalanced ginger plant nutrition compared to N and P, or Cl^- toxicity as ginger is a Cl^- sensitive crop. The K response trends were similar across all the three years as the yield of ginger rhizome increased by 18 to 45% (average 39%) in year 2, and by 14 to 37% (average 34%) in year 3 when compared with no K treatment.

Table 2. Fresh rhizome yields of ginger as affected by potassium application rates, Anhui, China.

kg K_2O/ha	2007	2008	2009	Average
	Yield, t/ha			
0	32.3 d	34.9 d	42.8 c	36.7 d
225	40.9 b	45.4 b	55.1 a	47.1 b
450	45.6 a	50.7 a	58.5 a	51.6 a
675	39.5 b	43.6 bc	52.2 ab	45.1 bc
900	36.5 c	41.4 c	48.9 b	42.2 c

Values in each column followed by different letters are statistically different at $p = 0.05$.

Various indicators of ginger rhizome quality as affected by K fertilization are shown in **Table 3**. Among all quality parameters, vitamin C, soluble sugar, crude protein, nitrate, and nitrite contents of ginger rhizome are the most important to consider. The first three parameters are known to influence edible quality, while the last two parameters govern food security because high concentrations of nitrate and nitrite in ginger rhizome are harmful to human health.

The vitamin C content in ginger rhizomes responded significantly to K

Table 1. Some physical and chemical properties of the top 20 cm of experimental soils in Anhui.

Year/Location	pH	O.M %	Ca	Mg	N	P	K	S	B	Cu	Fe	Mn	Zn
			mg/L										
2007/Shanqiao	6.2	0.8	3,306	555	13	15	62	8	0.1	1.6	42	15	2.4
2008/Yangqiao	6.6	1.4	3,683	473	18	17	59	12	2.2	2.6	16	69	1.2
2009/Yangqiao	6.6	0.6	3,040	507	14	37	70	13	0.6	3.1	61	50	1.7
Critical values*	–	–	401	122	50	12	78	12	0.2	1.0	10	5.0	2.0

*Critical values were determined using the procedure of Portch and Hunter (2002) and are used by the National Laboratory of Soil Testing and Fertilizer Recommendations in Beijing.
O.M. = organic matter; Ca = calcium; Mg = magnesium; S = sulfur; B = boron; Cu = copper; Fe = iron; Mn = manganese; Zn = zinc.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Cl^- = chloride; DAP = diammonium phosphate; KCl = potassium chloride. IPNI Project CHN-AN10

Table 3. Effect of potassium application rates on quality of ginger rhizome (average of 3 years), Anhui, China.

kg K_2O/ha	Vitamin C, mg/kg	Soluble sugar, %	Crude protein, %	Nitrate, mg/kg	Nitrite, mg/kg
0	33.8 c	3.35 b	11.9 b	160.7 a	3.85 a
225	38.2 b	3.62 ab	13.3 a	115.5 b	3.44 b
450	44.2 a	3.93 a	13.6 a	102.3 c	2.87 c
675	39.2 b	3.63 ab	13.3 a	107.4 bc	2.96 c
900	32.3 c	3.39 b	11.7 b	118.8 b	3.65 ab

Values in each column followed by different letters are statistically different at $p = 0.05$.

applications (**Table 3**). With K application rates of 225 to 675 kg K_2O/ha, there was a significant increase (13 to 31%, average 20%) in vitamin C content of ginger rhizome as compared to the no K treatment. The highest content of vitamin C was obtained with the application of 450 kg K_2O/ha, while as with the yield response, the application of 900 kg K_2O/ha lowered the content of vitamin C in rhizomes by 4% when compared with the no K treatment.

The soluble sugar content of ginger rhizomes responded to K applications quite differently than vitamin C content (**Table 3**). In general, the soluble sugar content increased by 1 to 17% (average 8%) across K treatments ranging from 225 to 900 kg K_2O/ha over no K treatment. However, most of these increases were not statistically significant. The highest soluble sugar content was found with the application of 450 kg K_2O/ha, but the value wasn't statistically different from the soluble sugar contents found with applications of 225 and 675 kg K_2O/ha. The effect of K applications on crude protein content in ginger rhizomes was similar to that on soluble sugar content. With K_2O applications of 225, 450 and 675 kg/ha, the crude protein content increased significantly by 12, 15 and 12% on average, respectively, as compared to no K treatment. The highest crude protein content was obtained with K_2O application of 450 kg/ha, while higher K applications were not beneficial in improving the crude protein content of rhizomes.

Nitrate and nitrite contents of ginger rhizomes responded significantly to different K application rates (**Table 3**). Applications of 225 to 900 kg K_2O/ha significantly reduced the contents of nitrate by an average of 31% (range of 26 to 36%) and nitrite by an average of 16% (range of 5 to 25%) in ginger rhizomes. Both nitrate and nitrite contents first dropped and then increased as K application rates increased, with the lowest values obtained with the application of 450 kg K_2O/ha.

Results from a series of demonstration trials conducted for three years in ginger-growing areas of China showed significant rhizome yield increases and economic benefits when fertilizer K application was balanced with other nutrients. Rhizome yield increased from 44 to 56 t/ha (26%) and farmer profits increased by US$3,213 (range of US$2,248 to 4,002 across the three years) by increasing farmer's K application rates by an average of 26%.

Summary

Potassium application at 450 kg K_2O/ha significantly increased yield and improved quality parameters of ginger rhizomes grown on K deficient soils in Anhui. More attention needs to be paid to potential K requirements of the ginger crop in Anhui and other ginger-growing provinces, where K deficiency may become more serious in future due to extensive K mining of soils and the adoption of high-yielding ginger cultivars and/or more intensive cropping systems. BC

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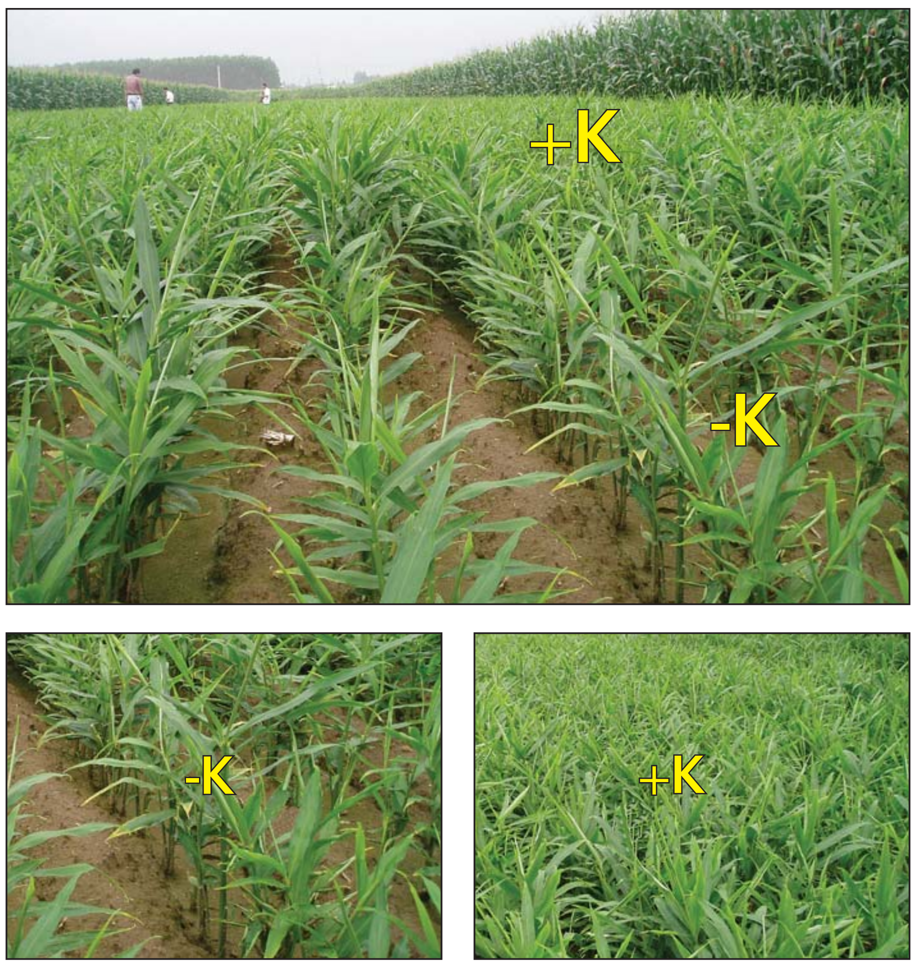

Figure 1. Ginger crop response to fertilizer 450 kg K_2O per ha. Plants grown without K shown in the foreground in top photo and in the bottom left photo. Plants grown with K shown in the background in top photo and in the bottom right photo.