4R Potassium Management in Processing Tomato Production in Xinjiang

By Shutian Li and Yan Zhang

Production of processing tomato in the northwestern province of Xinjiang, China is often restricted by inadequate K nutrition. This article provides examples of K application practices that follow 4R Nutrient Stewardship guidelines, and the associated yield and quality benefits that can be gained through their implementation.

The province of Xinjiang is the largest center for processing tomato production in China. The area planted has increased from 22,000 to 93,000 ha between 2001 and 2010, and total fruit production has reached 5 million t. Xinjiang has high sunlight intensity (2,600 to 3,400 hours annually), large differences in temperature between day and night, and low humidity, all of which favor growth and dry matter accumulation in tomato plants.

Tomatoes for processing need large amounts of K for adequate growth. Often the K requirement exceeds its N requirement. Regardless, traditional beliefs that their desert grey soils can provide sufficient quantities of K have led farmers to omit K fertilizer application for years causing significant soil K depletion and decreased K availability (Zhang et al., 2006). As is evident from this review, the general principle of 4R Nutrient Stewardship as outlined by Roberts (2007)—apply the right source at the right rate, time, and place—can be adopted to guide the management of K applications in processing tomato.

Table 1. Effect of different sources of K on yield and quality of processing tomato in Xinjiang.

K source	Yield, kg/ha	Lycopene, mg/100g	Solids, %	Vitamin C, mg/100g	Income from fertilizer application, US$/ha
KCl	97,366 a*	2.26 a	1.50 a	6.14 a	407**
$K_2SO_4 \cdot 2MgSO_4$	90,862 b	3.05 a	2.33 a	7.96 a	130
K_2SO_4	90,725 b	3.04 a	2.17 a	7.96 a	143

*Within a column, numbers followed by a different letter are significantly different at $p<0.05$.
** Prices used: tomato fruit = US$0.03/kg; K_2O = US$0.64/kg KCl, US$0.67/kg K_2SO_4, US$0.84/kg $K_2SO_4 \cdot 2MgSO_4$. Income was calculated based on the difference between K treatment and K omission plots.
N-P_2O_5-K_2O rates were 179-108-90 kg/ha.

Table 2. Effect of K source and rate on fruit yield of processing tomato in Xinjiang.

Location	K source	Rate, kg K_2O/ha	Yield, kg/ha
Toutunhe 5*	KCl	50	63,225
	K_2SO_4	50	57,900
	Control	0	42,345
Toutunhe 1*	KCl	72	78,510
	K_2SO_4	72	73,350

*N and P_2O_5 rates at Toutunhe 5 were 173 and 110 kg/ha and at Toutunhe 1 were 173 and 104 kg/ha, respectively.

The Right Source

The most common sources of fertilizer K in China are potassium chloride (KCl), mono potassium phosphate (KH_2PO_4), potassium nitrate (KNO_3), and potassium sulfate (K_2SO_4). Out of these sources, KCl is the least expensive. Locascio et al. (1997) cites a majority of studies showing no significant influence of K source on fruit yield or leaf K concentration in field-grown tomatoes. Chapagain et al. (2003) observed that KCl could fully or partially replace KNO_3 in tomato production through fertigation without affecting growth and yield. In fact, KCl improved some fruit quality parameters such as fruit firmness and freshness of calyx and reduced the number of rotten and blotchy fruits compared with KNO_3. Fan et al. (2009) showed that in processing tomato grown under drip irrigation and mulch, the organic-inorganic fertilizer complex containing 5% humic acid and 49% NPK produced 6,230 kg/ha more fruits and US$196/ha more income than conventional drip-irrigated fertilizers with 50 to 55% NPK. Also, there was a significant ($p<0.05$) increase in soluble solids, vitamin C, and lycopene contents, thereby improving fruit quality with the combined application of organic-inorganic fertilizer. Hu et al. (2007) showed that at the same fertilizer application rate of 179-108-90 kg N-P_2O_5-K_2O/ha, KCl produced 7.2% and 7.3% more processing tomato yield and $277 and $264 more income than potassium magnesium sulfate ($K_2SO_4 \cdot 2MgSO_4$) and K_2SO_4, respectively (**Table 1**). Zhang et al. (2008) also showed that at the same K rate, KCl produced 7.0 to 9.2% more tomato fruit than K_2SO_4 (**Table 2**).

The Right Rate

Tang et al. (2009) observed that an average of 3.27 (2.88 ± 0.84) kg N, 0.86 (0.76 ± 0.13) kg P_2O_5 and 4.02 (3.85 ± 0.17) kg K_2O was required for producing each tonne of processing tomato within the desired yield range of 75 to 112 t/ha. Tang et al. (2010) showed that when processing tomato yields were between 90 to 95 t/ha crop NPK uptake averaged 285 kg N/ha, 31 kg P_2O_5/ha and 290 kg K_2O/ha. These data suggest that at least 300 to 400 kg K_2O/ha is required for producing 75 to 100 t/ha of processing tomato. The rate of K applied depends on the soil supply of K and the expected target yield. Wang et al. (2011) provided an equation to calculate K rate based

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; US$1 = ¥6.24 (Chinese yuan).

Irrigation must be managed carefully and nutrients must not be limiting to obtain high yields and high quality fruit of processing tomatoes under drip irrigation and plastic mulch in Xinjiang.

on target yield:

$R_K = 830.3427/(1+e^{-0.00002\times(TY-99019.6011)})$

where, R_K is the rate of K (kg K_2O/ha); TY is target yield (kg/ha)

Experiments conducted by IPNI China Program also found increased processing tomato yield, fruit quality and profits with application of K fertilizer. For example, in 2003-04 applications of 180 kg K_2O/ha together with 180 kg N/ha and 108 kg P_2O_5/ha increased fruit yield by 14.6 to 17.8% over the zero-K treatment and improved fruit quality characters such as lycopene, soluble solids and vitamin C (**Table 3**). In 2008, application of 105 kg K_2O/ha produced 11% more yield and $326/ha more income than the zero-K treatment in Ma'nasi County. The following year balanced fertilizer application (360-150-105 kg N-P_2O_5-K_2O/ha) produced 17% more yield and $530 more income over farmer's fertilizer practice (272-195-45 kg N-P_2O_5-K_2O/ha).

Cheng et al. (2007) determined the optimum rate of fertilizer for a drip-irrigated yield goal of 112 t/ha was 300-105-75 kg N-P_2O_5-K_2O/ha when soil available K was 260 mg/kg. Drip irrigation can result in a small volume of soil being explored by the root system. With higher expected yields, the amount of nutrients extracted from this reduced volume of soil should be taken into consideration in any fertilizer management program, especially when soil available K is in the low-to-medium category.

The Right Time

Studies have indicated that 7.7, 27.4, 25.2, and 32.3% of plant K is taken up by tomato plants at seedling, flowering/fruit setting, fruit ripening, and harvesting stages, respectively (Xue et al., 2004; Liang et al., 2006). This suggests that most of the K uptake by tomato plants happens in the later crop growth stages (i.e., after flowering and especially at fruit ripening and harvesting stages). Therefore, the timings of fertilizer K applications are important to achieve high yield and quality of fruits. More than 90% of the recommended fertilizer K should be applied after flowering and fruiting stage. Conventional practice applies 50 to 60% of recommended K fertilizer basally

Table 3. Effect of K rates on yield, quality and income from fertilizer application in processing tomato in Xinjiang

	K_2O rate, kg/ha	Yield, t/ha	Lycopene, mg/100g	Solids, %	Vitamin C, mg/100g	Income from fertilizer application, US$***
2003*	0	86.1 b**	-	-	10.48	-
	90	92.6 b	-	-	19.21	159
	180	101.3 a	-	-	11.08	388
	270	91.7 b	-	-	9.17	11
2004*	0	95.1 b	6.11 b	8.9	8.03	-
	90	98.8 b	7.97 ab	8.9	8.33	64
	180	109.0 a	10.48 a	10.5	9.73	341
	270	95.4 b	8.60 ab	8.5	8.92	-164

*N and P_2O_5 rates were 180 and 108 kg/ha, respectively.
**Within a column, numbers followed by a different letter are significantly different at $p<0.05$.
***Prices: US$0.03/kg tomato fruit; US$0.64/kg K_2O.

and 40 to 50% as topdressing at the fruit ripening stage, which is not consistent with the plant K uptake.

The timing of K application also usually depends on water management. Due to water shortage, most of the processing tomato in Xinjiang is drip-irrigated, which can affect nutrient distribution and movement in soil, and then influence K availability and plant uptake. Fu et al. (2005) observed that the movement of K with water was similar to N, which was distributed within 30 cm of the soil surface. So, in drip-irrigated systems most of the N (63 to 84%) and K (61 to 74%) were applied in the later stages from flowering to maturity (Wang et al., 2011).

The Right Place

Drip irrigated tomato is usually planted after plastic mulching. Since the irrigation pipelines are under the mulch between two rows of tomato plants, except for the pre-plant fertilizers applied before plastic mulching, the majority of N and K fertilizers are injected into the drip system via fertigation for delivery to the root system with water.

For the direct-seeded, furrow-irrigated processing tomato, fertilizers are usually side-dressed. In subsurface drip irrigation, the water is moving "from the inside out," whereas in furrow irrigation water moves in the opposite direction, carrying side-dressed N or K into the bed. This has implications on the placement of any banded fertilizer. Fertilizer bands located near the edge of the beds, which is an appropriate placement in furrow irrigation, is not effective in the drip-irrigation system.

Other Practices

The nutrient content in tomato fruit depends largely on genetic and environmental factors during the fruit ripening stage (Javanmardi and Kubota, 2008). Consistency and color parameters of tomato fruits was positively influenced by high water availability for plants, while the ascorbic acid content was positively affected by less frequent irrigations (Mitchell et al., 1991). Favati et al. (2009) indicated that extending irrigation intervals and limiting irrigation volume to the later part of the tomato crop cycle appeared to be the best management practice to optimize yield and nutritional quality of processing tomato.

With drip irrigation, we can precisely match the crop's nutrient needs using the right source and right rate so that high production goals can be achieved. Future extension efforts must focus on popularizing 4R Nutrient Stewardship in processing tomato production as a means of optimizing production and nutrient use efficiency.

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References

Chapagain, B.P., Z. Wiesman, M. Zaccai, P. Imas, and H. Magen. 2003. J. Plant Nutr. 26(3): 643–658.

Cheng, X.J., J. Wang, X.P. Huang, C. Li, L.P. Tian, L. Xue, and J.R. Zhao. 2007. J. Anhui Agri. Sci. 35(35): 11509-11511. (In Chinese).

Fan, Q.L., F.H. Yin, X.Y. Guan, and Y. Chen. 2009. Xinjiang Agri. Sci. 46 (4): 746-750. (In Chinese).

Favati, F., S. Lovelli, F. Galgano, V. Miccolis, T.D. Tommaso, and V. Candido. 2009. Sci. Hortic. 122: 562-571.

Fu, M.X., G.Y. Wang, and M.Y. Bao. 2005. Xinjiang Agri. Sci. 42(6): 426-429.

Hu, W., Y. Zhang, H.Y. Wang, G.H. Qi, and L.C. Yang. 2007. Xinjiang Agri. Sci. 44 (4): 494-497. (In Chinese).

Javanmardi, J. and C. Kubota. 2008. Postharvest Biol. Technol. 41, 151–155.

Liang, C.F., Z.F. Chen, and W.X. Li. 2006. Chinese J Eco-Agri. 14(2): 79-81. (In Chinese).

Locascio, S.J., G.J. Hochmuth, S.M. Olsan, R.C. Hochmuth, A.A. Csizinszky, and K.D. Shuler. 1997. HortSci. 32, 1204–1207.

Mitchell, J.P., C. Shennan, S.R. Grattan, and D.M. May. 1991. J. Am. Soc. Hortic. Sci. 116, 215–221.

Roberts, T.L. 2007. *In* Fertilizer Best Management Practices. IFA International Workshop on Fertilizer Best Management Practices (FBMPs). 7-9 March, 2007. Brussels, Belgium. pp. 29-32.

Tang, M.R., Y. Zhang, W. Hu, G.Z. Hu, Q.J. Li, Y.K. Yao, and Y. Gao. 2010. Plant Nutr. Fert. Sci. 16(5): 1238-1245. (In Chinese).

Tang, M.Y., Y. Zhang, and W. Hu. 2009. Soil Fert. Sci. China, 3: 26-30. (In Chinese).

Wang, J.C., S. Gao, L.P. Chen, and F.Y. Ma. 2011. Chinese J. Eco-Agri. 19(2): 285-292. (In Chinese).

Xue, L., L.P. Tian, and J. Wang. 2004. J Shihezi Univ. (Natural Sci.). 22(5): 289-292. (In Chinese).

Zhang, Y, J.H. Shi, and G.H. Luo. 2006. Xinjiang Agri. Sci. 43 (5): 375-379. (In Chinese).

Zhang, Y., H.G. Ma, W.L. Xu, H.Y. Wang, G.H. Qi, and L.C. Yang. 2008. Soil Fert. Sci. China. 3: 40-51. (In Chinese).

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