Potassium fertilizer significantly improved potato yields in Yunnan province, China

Mei Yin, Lifang Hong and Shihua Tu

Applications of potassium (K) fertilizer significantly increased potato yields and economic returns, but the responses of potato grown in two different types of productivity soils varied considerably. The optimal K fertilizer rates were found to be 270 kg K_2O/ha in the high productivity soil and 135 kg K_2O/ha in the low productivity soil. The application of potassium fertilizer should be timed to coincide with the maximum accumulation of dry matter and potassium by the crop during its fast growing stages.

Potato is one of the most widely cultivated crops in China and it ranks third after only maize and rice in Yunnan province, southwest China; 703,000 hectares of potatoes were planted in 2012. However, potato yields are usually low even under the favorable climatic conditions in Yunnan. Low fertilizer use and imbalanced nutrient application, especially insufficient or lack of potassium fertilizer, are considered to be partially responsible for low yields and quality throughout (Duan et al., 2013). Therefore, a project was launched in 2012 to study the effects of different K rates on potato yields in two acid red soils with low and high fertility/productivity at two separate locations - Yuezhou and Dongshan in Qujing District, Yunnan - and to ultimately determine the optimal K rate for potato production in the region. The low fertility soil in Yuezhou was tested and found to be low in soil organic matter and deficient in nitrogen (N) and K, while the high fertility soil in Dongshan was sufficient in organic matter and had adequate N and K (**Table 1**).

The field experiments were set up in a randomized complete block design with four K rates (0, 135, 270 and 405 kg K_2O/ha) and three replications. A combination of 150 kg N/ha and 90 kg P_2O_5/ha was added to each treatment in addition to the designated K rate. The plot size was 20 m2 (4×5 m). The sources of fertilizers were urea (N 46%) for N, single superphosphate (P_2O_5 12%) for P and potassium chloride (K_2O 60%) for K. Fertilizer N was split as basal (50%) and topdressing (50% at the tuber bulking stage) applications. Fertilizer K was split as a basal dose (50%) and a topdressing (50%) at the tuber bulking stage. All of fertilizer P was used as basal application. The potato variety Hezuo 88 was selected as the testing crop and seeded in March and harvested in mid-August 2012.

Potato field

The potato was rainfed without irrigation throughout the growing season. Plant samples were collected at each growth stage to determine dry biomass accumulation and to analyze K uptake by shoot and tuber. At harvest, the potato shoot and tuber of each treatment were harvested, weighed and recorded separately. Plant samples were taken to analyze nutrient uptake by shoot and tuber. K use efficiency and economic analysis were conducted.

Table 1. Some of the selected properties of the soils in study.

Experiment site	pH	Organic matter (g/kg)	Alkali-hydr. N (mg/kg)	Availible P (mg/kg)	Availible K (mg/kg)
Yuezhou	5,1	26,2	69,9	12,9	77,8
Dongshan	5,0	44,4	108,4	12,4	105,8

Table 2. Potato tuber yields as affected by different K rates at two trial sites

Trial site	K rate, kg K_2O/ha	Tuber yield, kg/ha	Yield increase due to K	
			kg/ha	%
Yuezhou	0	10830 c	–	–
	135	12205 b	1375	12,70
	270	12585 b	1755	16,20
	405	13140 a	2310	21,33
Dongshan	0	21135 c	–	–
	135	27225 b	6090	28,81
	270	32715 a	11580	54,79
		28050 b	6915	32,72

Effects of potassium fertilizer on potato tuber yield

Different soil fertility/productivity had a significant effect on potato yields (**Table 2**). Potato yields from the high fertility/productivity soil at the Dongshan site were double or more than double those in the low fertility/productivity soil at the Yuezhou site, regardless of the K rate. In the low fertility soil, potato yields increased significantly with an increase in K rates without levelling off. Yield increases ranged from 12.70% to 21.33%. In the high fertility soil at the Dongshan site, however, though potato yields significantly increased with an increase in

Table 3. Biomass accumulation of potato as affected by different K rates during growth periods

Trial site	K rate, kg K_2O/ha	Seedling	Tuber initiation		Tuber bulking		Starch filling		Harvest	
		Shoot	Shoot	Tuber*	Shoot	Tuber	Shoot	Tuber	Shoot	Tuber
		kg\ha								
Yuezhou	0	139,95	627,15	18,00	758,70	722,70	940,80	1344,00	1083,00	2166,00
	135	139,95	750,15	13,05	882,15	868,05	1115,10	1607,40	1220,55	2440,95
	270	145,05	758,40	18,00	916,20	970,20	1137,60	1698,00	1358,55	2517,00
	405	145,05	762,30	15,00	966,75	982,35	1234,95	1762,05	1314,00	2628,00
Dongshan	0	241,95	919,95	63,90	1030,20	1204,95	1398,15	3856,65	1568,10	4327,05
	135	235,95	940,05	63,90	1320,30	1249,95	1783,50	4441,65	1833,45	5545,05
	270	241,95	960,00	58,65	1458,15	1414,95	2130,45	4788,30	2233,50	6544,05
		240,00	1000,05	63,90	1407,15	1530,00	2209,05	4983,30	2283,00	5910,00

* Here potato tuber biomass includes both tuber and root

Table 4. K uptake by potato at different growing stages as affected by K rates at sites

Trial site	K rate kgK_2O/ha	Seedling		Tuber initiation		Tuber bulking		Starch filling		Harvest	
		kg/ha	g/ha.d	kg/ha	g/ha.d	kg/ha	g/ha.d	kg/ha	g/ha.d	kg/ha	g/ha.d
Юежоу	0	7,04	0,12	25,35	1,41	21,98	1,05	26,15	1,87	6,08	0,23
	135	7,20	0,12	33,72	1,87	26,74	1,27	35,72	2,55	1,41	0,05
	270	7,71	0,13	34,4	1,91	28,51	1,36	39,11	2,79	10,19	0,38
	405	8,1	0,14	35,31	1,96	31,57	1,50	45,50	3,25	3,35	0,12
Донгшан	0	12,17	0,22	36,61	1,74	31,89	2,13	100,67	6,71	0,12	0,01
	135	12,14	0,22	40,83	1,94	46,74	3,12	132,44	8,83	1,71	0,12
	270	12,86	0,23	41,75	1,99	53,69	3,58	155,02	10,33	1,52	0,11
	405	12,74	0,24	45,93	2,16	53,65	3,58	168,62	11,24	0,04	0

Table 5. The economic benefits of potato as affected by K rate at two sites

Trial site	K rate, kg K_2O/ha	Tuber yield, kg/ha	Output	Cost	Net income	Income increase, %
			$US/ha			
Yuezhou	0	10830	2130,49	256,60	1873,89	–
	135	12205	2400,98	420,49	1980,25	5,68
	270	12585	2475,74	584,88	1890,86	0,91
	405	13140	2585,90	749,02	1835,90	-2,03
Dongshan	0	21135	4157,70	256,60	4144,55	-
	135	27225	5355,74	420,49	4935,00	19,07
	270	32715	6438,20	584,88	5852,88	41,22
		28050	5518,03	749,02	4769,02	15,07

K rates, the yield levelled off at 270 kg K_2O/ha and then decreased with a further increase in the K rate. Yield increases ranged from 28.81% to 54.79%, much higher than those in the low fertility soil. The potato yield at 270 kg K_2O/ha in the high fertility soil reached 32715 kg/ha, 160% higher than in the low fertility soil. The yield response curve of potato to different K rates in the high fertility soil was typical (Karam et al., 2009) and the curve in the low fertility soil was less common but also reported by Kelling et al. (2002) and Singh and Lal (2012). This implies that potato yields in the low fertility soil cannot be enhanced to the levels of the high fertility soil by adding K fertilizer alone. There must be other yield-limiting factors besides K which require further research. Thus, the optimal K rate was 135 kg K_2O/ha in the low productivity soil, since higher K rates, despite yield increases, produced little or no economic benefit (**Table 5**).

Biomass accumulation at different growing stages

The results in Table 3 showed clear trends of biomass accumulation for both shoot and tuber during the growing season at two sites. The fast biomass accumulation periods were from the tuber initiation stage to the starch filling stage for shoot and from the tuber bulking stage to the harvest stage for tuber. During the fast biomass accumulation periods, shoot and tuber weights increased with an increase in K rates. The dry matter weight of potato tissues at the Dongshan site was much higher or even double those at the Yuezhou site. According to the potato biomass accumulation patterns, K fertilizers should be applied at the seedling-tuber initiation stages to better meet its nutrient requirement for fast growth and tuber development (Guo et al., 2011).

Table 6. K use efficiency and agronomic efficiency as affected by different K application levels at two sites

Trial site	K rate, kg K_2O/ha	K uptake by potato, kg/ha	K use efficiency, %	K agronomic efficiency, kg/kg
Yuezhou	0	87	-	-
	135	103	12,43	10,19
	270	120	12,34	6,50
	405	124	9,19	5,70
Dongshan	0	182	-	-
	135	234	38,81	45,11
	270	265	30,88	42,93
		281	24,57	17,07

Tissue K accumulation at different growing stages

K accumulation occurred quickly from the tuber initiation stage to the starch filling stages and reached its peak values of 26.15-45.50 kg/ha at the Yuezhou site and 100.67-168.62 kg/ha at the Dongshan site at the starch filling stage (**Table 4**). These values were much higher than N or P accumulated in potato at the starch filling stage (data not shown), because K is the most required of the essential nutrients (Westermann, 2005). At the harvest stage, very little K was absorbed by potato plants. These results are in line with the studies of Gao et al. (2003) and Lu et al. (2013). The results imply that the stages when K is absorbed quickly are when adequate supply of K is essential for both potato yield and quality (Guo et al., 2011). The addition of K fertilizer to potato plants after the starch filling stage is of little significance; a similar report pointed out no yield or efficiency advantage for applying K later (Kelling et al., 2002).

Economic benefits of K fertilization

At the Yuezhou site, only the 135 kg/ha K rate was economically beneficial; higher rates were of little or no economic value compared to the omission treatment (**Table 5**). At the Dongshan site, however, economic benefits increased with an increase in K rates and leveled off at 270 kg K_2O/ha. Further increases in the K rate decreased the economic benefit. Net income due to K fertilization at the Dongshan site was more than double compared with the Yuezhou site. The results further indicate that higher K rates should be applied to potato plants in high fertility soil for higher yield increases and higher economic returns.

K use efficiency

K use efficiency and agronomic efficiency decreased with an increase in K rates at the two sites (**Table 6**). Both values were much higher at the Dongshan site than at the Yuezhou site. As usual, fertilizer use efficiency of a crop is higher in low fertility soil than in high fertility soil. The experiment at the Yuezhou site produced the opposite results. This implies that there must be some other yield-limiting factors other than K which impeded potato growth as well as its response to added K. Besides, as reported by Kelling et al. (2002), yearly weather variations may be, at least partly, responsible for the poor response of potato to added K in the low fertility soil.

Dr. Mei Yin is Associate Professor and Dr. Lifang Hong is Professor at the Agricultural Resources and Environment Institute, Yunnan Academy of Agricultural Sciences.

Dr. Tu is IPNI Deputy Director, Southwest China, and Professor, Soil and Fertilizer Institute, Sichuan Academy of Agricultural Sciences, Chengdu, China; e-mail: stu@ipni.net.

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Omission K plots