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Potassium management in potato production in Northwest region of China

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ABSTRACT

Field trials were conducted to study response of potato (*Solanum tuberosum* L) yield and quality to potassium (K) application, soil indigenous K supply (IKS) and productivity (IKP), K use efficiency and critical level of soil test K to establish scientific methods for K management in potato production. Results indicated that K application increased tuber yield by a range of −2.8 to 7.2 Mg ha^{-1} with an average of 3.2 Mg ha^{-1}, 90% positive responses. Potassium application produced an average of 4.9 percentage more commercial rate, 11.3 g more mean tuber weight and 0.4 percentage more tuber starch content and 0.2 percentage less tuber sugar content than those of treatment without K application. The average agronomic efficiency of potassium (AE_K) was 30.2 kg tuber kg^{-1} K_2O, 56% observations was in 10–40 kg tuber kg^{-1} K_2O. 79.2% of the observations showed negative K balance in potato fields with an average of 101.7 kg K ha^{-1} deficit. 87.5% of all the observations showed positive benefit from K application with an average return of US$715 ha^{-1}. The average IKS and IKP was 141.8 kg K ha^{-1} and 25.9 Mg ha^{-1} which can be explained 25% and 30% of variations, respectively, by soil exchangeable K. Significant negative quadratic relationship ($R^2 = 0.75$, $P < 0.01$) between yield response and relative yield, and significant linear relationship ($R^2 = 0.80$, $P < 0.01$) between yield response and AE_K were obtained. There was a significant relationship ($R^2 = 0.74$, $P < 0.01$) between total uptake K by potato plant and total tuber yield. The critical level of soil exchangeable K at 90% relative yield was 105 mg kg^{-1} which can be a reference for K recommendation.

1. Introduction

Potato is one of the main vegetable crops. China is now the world's largest potato (*Solanum tuberosum* L.) producer and the output has reached 93 million tons in 2012. The Northwest region of China is the main potato production region with a planting area of nearly 2 million ha and a total tuber production of 29 million tons, accounting for 36% and 31% of total area and production in China, respectively.

Potato is high K requirement crop. It takes up K in quantities much greater than those of N and P (Panagiotopoulos, 1995). On an average, potato removed about 91 kg K_2O ha^{-1} at the yield of 29 Mg ha^{-1} (Moinuddin et al., 2005). Duan et al. (2013) found that the average uptake of K by rainfed potato and irrigated potato in Inner Mongolia of China was 82.2 and 221.7 kg K_2O ha^{-1} at the yield of 14.9 and 35.7 Mg ha^{-1}, respectively. Potassium is a quality element. The positive effect of K fertilization is greater on tuber quality than on yield (Kavvadias et al., 2012). Potassium is partially responsible for light-colored chips characteristic through a positive influence on lowering the sugar, amino acid, and tyrosine content in potatoes, which tend to darken the chips (Wilcox et al., 1968; Cummings and Wilcox, 1968). It also plays an important role for maintaining tone and vigor of the plants.

Farmers traditionally applied nitrogen (N) and phosphorus (P) fertilizers but neglected K fertilizer in potato production of Northwestern China, due to a conception of sufficient soil K in this region. As a result, potato plants acquired K from native soil, leading to mining of soil K reserves and decrease of soil K supply, adversely affected tuber yields/quality (Khan et al., 2012). There is great potential to improve both yield and quality of potato to a great

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Table 1
Experimental sites and number of field trials.

Province	Location	Number of trials
Inner Mongolia	Wuchuan County	50
	Chayouzhong County	20
Gansu	Dingxi city	40
	Hezheng County	10
	Jishishan County	10
	Zhangjiachuan County	10
Ningxia	Haiyuan County	10
	Tongxin County	10
Qinghai	Huzhu County	12
	Ledu County	10
	Gonghe County	10

Table 2
Properties of tested soils and nutrients applied in trials.

Items	Range	Mean (SD)
Soil texture	Sandy loam, loam, clay loam	
pH in water (1:2.5)	7.6–8.3	8.2 (0.2)
Soil organic matter (g kg^{-1})	3.0–15.0	8.0 (4.5)
Mineral N (mg kg^{-1})	3.6–86.8	21.9 (21.2)
Available P (mg kg^{-1})	5.5–36.6	16.7 (7.0)
Exchangeable K (mg kg^{-1})	58.6–287.3	122.2 (53.5)
N applied (kg ha^{-1})	128–240	189 (35)
P_2O_5 applied (kg ha^{-1})	45–135	81 (19)
K_2O applied (kg ha^{-1})	30–165	90 (32)

extent with balanced use of N, P and K. However, farmers did not know how much K should be applied due to lack of scientific information and method for K recommendations.

The commonly used methods for K recommendations for crops are based on soil testing and sometimes can be used effectively for guiding fertilizer applications (Hannan et al., 2011), but the critical level of soil test K should be determined. The alternative way is to make fertilizer recommendation based on yield response and agronomic efficiency, which was successfully used in fertilizer recommendation for wheat and maize (Chuan et al., 2013; Xu et al., 2014). Another method for K recommendation is based on K balance in soil plant systems and the recommended rate of K should be at least the amount of K removed by crop products.

However, information on yield/quality response to K application, K use efficiency, soil K supply and productivity, the relationship between potato tuber yield and plant uptake K and the critical level of soil test K in potato systems are not available. The purpose of this study is to: (1) determine agronomic and economic response of potato to K application, (2) determine supply capacity of soil K and the critical level of soil test K, (3) establish scientific basis for K recommendation for potato production.

2. Materials and methods

2.1. Field trials

Total of 192 field trials were conducted in farm's fields during 2003–2013 in Inner Mongolia, Gansu, Qinghai and Ningxia provinces, the main potato production regions in Northwest China. The sites and number of trials were listed in Table 1. Each trial had two treatments: (1) Nitrogen, phosphorus and potassium (NPK); (2) Nitrogen and phosphorus (NP). The amount of N, P_2O_5 and K_2O applied was recommended based on Agro Services International (ASI) systematic approach (Hunter, 1980; Portch and Hunter, 2002). K used in the experiments was KCl and applied as basal before planting. The plot area was 50 m^2 for all trials. Potato cultivars used in the experiments were round white and oblong yellows including the Chinese selections in the numbered series Kexin (Su and Lai, 2007), Longshu (Wen et al., 2007) and Qingshu (Zhang et al., 2006).

Soil samples were collected before planting for analysis. During the growth period the amounts of irrigation and rainfall was recorded and samples were taken for analysis of K contents. At harvest, tuber yield, dry matter of vines, commercial tuber rate and mean tuber weight were recorded. Samples of tubers and vines were taken for analyzing K content, starch and reducing sugar contents in tubers. Soil properties and nutrients applied in trials were listed in Table 2.

2.2. Analytical procedures

Soil organic C and mineral N (NH_4^+—N + NO_3^-—N) were determined according to the corresponding methods in Sparks et al. (1996). Soil available P was analyzed by Olsen extraction (Olsen et al., 1954) and exchangeable K by ammonium acetate (NH_4OAc) extraction (Knudsen et al., 1982). Soil pH was determined in a 1:2 soil/manure water mixture (McKeague, 1978).

Starch content was determined by making dried tubers sugars free by repeatedly extracting with 80% iso-propanol then tubers were dried at 70 °C overnight in a drying oven. The dried pieces were ground to a fine powder and starch was hydrolyzed using 60% per-chloric acid (Haase, 2003). Sugar contents were determined by Krik and Sawyer (1991) and starch by Anthrone method (Westermann et al., 1994). Total K in tuber and vines were extracted by H_2SO_4–H_2O_2 digestion and K in the solution was determined by Flame Emission Spectrophotometer (Lu, 2000). K contents in irrigation water and rainfall were determined by atomic absorption spectrophotometry after filtration.

2.3. Calculations

$$\text{Yield reponse}\left(\text{Mg ha}^{-1}\right) = Y - Y_0$$

$$\text{The relative yield}\,(\%) = \frac{Y_0}{Y} \times 100\%$$

$$\text{Agronomic efficiency of K}\,(\text{AE}_\text{K})\left(\text{kg tuber kg K}_2\text{O}^{-1}\right) = \frac{(Y - Y_0)}{K_f}$$

$$\text{K balance} = \left(K_f + K_s + K_i + K_r\right) - K_t$$

$$\text{Economic benefits from K application}\left(\text{US\$ ha}^{-1}\right) = (Y - Y_0) \times P_t - \text{K} \times P_f$$

where: Y = tuber yields of treatments with K fertilization (Mg ha^{-1}), Y_0 = tuber yields (Mg ha^{-1}) of treatments without K fertilization, K_f = K fertilizer rate (kg K_2O ha^{-1}), K_s = K from tuber seeds (kg K_2O ha^{-1}), K_i = K from irrigation (kg K_2O ha^{-1}), K_r = K from rainfall, K_t = total uptake K by tubers and vines, P_t = price of tuber (US$ 250 Mg^{-1}), P_f = price of K fertilizer (US$ 480 Mg^{-1} KCl).

2.4. Statistical analysis

Paired comparisons of tuber yield and quality indices between treatments with K fertilization and treatments without K fertilization were performed by SAS statistical software. For frequency distributions and statistics of yield response, relative yield, agronomic efficiency, indigenous potassium supply and productivity, changes of potato commercial rate, tuber weight, content of starch and reducing sugar as well as plotting graphs, Microsoft EXCEL package 2010 was used. Linear model was used to describe relationships between soil exchangeable K (x) and soil indigenous K supply