Title

Agronomic evaluation of nutrient management for potato in Northwest China

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Introduction

China is now the world's largest potato (*Solanum tuberosum L.*) producer and the output reached 74 million tons in 2007. The northwest region of China is the main potato production region with a planting area of 1.8 million ha and a total production of 24.4 million tons, accounting for 40.6% and 37.7% of the national total, respectively (MOA, 2007).

The climatic conditions in the northwest region, such as cool temperatures, adequate sunlight, and a large differential between day and night temperatures are favorable for potato production. However, imbalances of nutrient application are partially responsible for the low tuber yields and quality of potato in this region where K and/or P has usually been ignored by farmer's practice. Thus, nutrient management for N, P and K is important in potato production. However, the indigenous soil productivity and yield response to nutrient application were not clear, and appropriate nutrient management practices for potato are not available in northwest China.

Therefore, the objectives of this study were to: (1) determine the main limiting nutrient and nutrient use efficiency in potato production and (2) evaluate the nutrient management practice based on an Agro Services International (ASI) systematic approach.

Materials and methods

Field trials

Field trials were conducted from 2002 to 2007. Each trial has a treatment of nutrient management practice (NMP) and nutrient omission plots: NMP-N, NMP-P or NMP-K. The amount of N, P_2O_5 and K_2O applied in NMP was determined by the ASI systematic approach (Hunter, 1980; Portch and Hunter, 2002). Each trial had three or four replicates. In selected sites farmer practice (FP) was included to compare with NMP. 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).

ASI systematic approach

The ASI systematic approach was developed by Hunter (1980) and revised by Portch and Hunter (2002). Soil organic matter was extracted by 0.2 mol L^{-1} NaOH-0.01 mol L^{-1} EDTA-2% methanol and determined by spectrophotometry at 420 nm. Soil-available P and K was extracted by 0.25 mol L^{-1} $NaHCO_3$-0.01mol L^{-1} EDTA-0.01mol L^{-1} NH_4F solution, and P was determined colorimetrically, K by atomic absorption. Mineral N including NH_4^+-N and NO_3^--N were extracted by 1 mol L^{-1} KCl, and determined by colorimetry and ultraviolet spectrophotometer, respectively. The amount of N, P and K was recommended using a fertilizer recommendation program based on organic matter content/mineral N, available P and available K, respectively. Descriptions of soil testing data are summarized in Table 1.

Table 1 Soil texture, soil pH, soil organic matter, and nutrient concentrations of tested soils prior to trials

Soil parameters	N trials (n=28)		P trials (n=34)		K trials (n=66)	
	Mean (SD)	CV (%)	Mean (SD)	CV (%)	Mean (SD)	CV (%)
Soil texture	Sandy loam, loam		Sandy loam, loam		Sandy loam, loam	
pH in water (1:2.5)	8.3 (0.3)	3	8.2 (0.2)	3	8.2 (0.2)	3
Soil organic matter (g kg^{-1})	10.0 (4.5)	44	9.0 (5.0)	59	9.0 (5.0)	62
Mineral N (mg L^{-1})	28.3 (22.9)	81	24.2 (21.8)	90	21.0 (20.2)	96
Available P (mg L^{-1})	16.3 (7.6)	47	17.7 (7.6)	43	17.0 (6.8)	40
Available K (mg L^{-1})	94.2 (34.7)	37	97.2 (31.4)	32	94.5 (30.7)	35

Data analysis

Yield response and nutrient use efficiency including agronomic efficiency (AE) and partial factor productivity (PFP) was calculated. AE represents crop yield increase per unit nutrient applied, and it was usually used to evaluate the yield increase derived from applied nutrient. PFP represents crop yield per unit nutrient applied, and is usually used to estimate the integrated use efficiency of both indigenous and applied nutrient.

Yield response (%) = $(Y-Y_0)/Y_0 \times 100$

AE = $(Y - Y_0)/F$

PFP = Y/F

Where Y = tuber yield of NMP (kg ha^{-1}), Y_0 = tuber yield (kg ha^{-1}) of nutrient omission plots, F = nutrient applied (kg ha^{-1}). AE_N, AE_P and AE_K represent agronomic efficiency of N, P and K, and PFP_N, PFP_P and PFP_K represents partial factor productivity of N, P and K, respectively.

Analysis of variance was completed using SAS statistical software. Plots and relationships were made and analyzed using Microsoft Office Excel 2007.

Results and discussion

Indigenous nutrient fertility and nutrient response

Initial soil analysis using the ASI approach indicated large variation in soil fertility characteristics among sites in N trials, P trials and K trials, respectively (Table 1). Seven- to 9-fold ranges of potato yields in nutrient omission plots were found among sites, with an average coefficient of variation (CV) of 53%, 53% and 43%, respectively for N, P and K (Table 2). Average potato yields in nutrient omission plots were in the order 0-N (22.2 t ha^{-1}) ≈ 0-P (22.4 t ha^{-1}) < 0-K (31.5 t ha^{-1}). Twenty-four of 28 N trials, twenty of 34 P trials and forty-two of 66 K trials showed significant ($P<0.05$) yield increase due to N, P and K application, respectively, indicating that N deficiency is a general feature of irrigated potato in northwest region, but P and K supply are frequently additional limiting factors on many soils.

The average tuber yield response to N, P and K application was 20.8%, 14.9%, 16.4%, with a CV of 47%, 81%, 68%, respectively (Table 2). N recommended in this research was 45 to 307 kg N ha^{-1} with an average of 135 kg N ha^{-1}. Studies completed in the Columbia Basin of Washington showed optimal N rates for Russet Burbank ranging from 336 to 448 kg ha^{-1} (Roberts et al., 1982; Lauer 1986). As for P, the application rate was 30 to 322 kg P_2O_5 ha^{-1} with an average of 124 kg

P_2O_5 ha^{-1} (Table 2). Grewal and Sud (1990) reported that optimum dose of phosphorus for potato was 90 kg P_2O_5 ha^{-1} in northern India. Kumar et al. (2007b) indicated that response to P fertilization was significant with total tuber yield and biomass at the rate of 80 kg P_2O_5 ha^{-1}, beyond that tuber yield did not further increase in the west-central plains of India. Most studies on K nutrition in potato focused on source, time and application method (Chadha et al., 2006; Sasani et al., 2006; Haase et al., 2007; Kumer et al., 2007c).

Table 2 Yield response and nutrient use efficiency indicators of potato grown in nutrient omission plots at various sites

Measurement	Mean	SD	Min.	Max.	CV (%)
Yield in 0-N plot (t ha^{-1})	22.2	11.8	7.5	54.6	53
Yield in 0-P plot (t ha^{-1})	22.4	11.9	5.9	55.7	53
Yield in 0-K plot (t ha^{-1})	31.5	13.7	8.2	56.0	43
Recommended N	135	58	45	307	43
Recommended P_2O_5	124	83	30	322	67
Recommended K_2O	139	68	30	300	49
Yield response to N (%)	20.8	10.0	3.1	44.0	47
Yield response to P (%)	14.9	12.1	-1.0	62.7	81
Yield response to K (%)	16.4	11.1	2.3	57.1	68
AE_N (kg kg^{-1} N)	34.6	19.0	3.4	80.0	56
AE_P (kg kg^{-1} P_2O_5)	32.4	27.5	-2.4	117.0	85
AE_K (kg kg^{-1} K_2O)	42.6	42.0	6.2	233	98
PFP_N (kg kg^{-1} N)	220	122	67	622	55
PFP_P (kg kg^{-1} P_2O_5)	291	218	50	934	75
PFP_K (kg kg^{-1} K_2O)	312	157	39	643	50

Nutrient use efficiency

The average AE_N, AE_P and AE_K were 34.4 kg tuber kg^{-1} N, 32.4 kg tuber kg^{-1} P_2O_5 and 41.3 kg tuber kg^{-1} K_2O. The average PFP_N, PFP_P and PFP_K were 220 kg tuber kg^{-1} N, 291 kg tuber kg^{-1} P_2O_5 and 306 kg tuber kg^{-1} K_2O, respectively (Table 2). Many factors such as potato cultivars (Zebarth et al., 2004) and nutrient application rate can affect the variability of AE and PFP. In the current study there were negative correlations between AE or PFP and the amount of nutrient applied (Fig. 1). Other researchers also observed that AE_N or PFP_N decreased with increase dose of applied N (Zvomuya et al. 2002; Love et al. 2005; Kumar et al, 2007a). Curless et al (2004) showed that when 134 kg ha^{-1} N was applied, AE_N was 46 kg tuber kg^{-1} N and PFP_N was 348 kg tuber kg^{-1} N, which was higher than in our experiment in which the mean AE_N was 35 kg tuber kg^{-1} N, and PFP_N was 220 kg tuber kg^{-1} N when almost the same amount of N (135 kg N ha^{-1}) was applied. In Canada the AE_N and PFP_N could be 117 kg tuber kg^{-1} N and 353 kg tuber kg^{-1} N at 100 kg ha^{-1} of N (Zebarth et al., 2006). For Ps, Kumar et al. (2007b) reported that there was a sharp increase in AE_P or PFP_P when the P dose was increased from 0 to 80 kg P_2O_5

ha^{-1}, and a sharp decline in AE_P was observed when the P dose was further increased from 80 to 120 kg P_2O_5 ha^{-1}. The indigenous soil productivity can be expressed by the tuber yield in nutrient omission plots. So, the positive relationship between tuber yield of nutrient omission plots and PFP and AE (Fig. 2) suggest that indigenous soil productivity is another factor influencing nutrient use efficiency in addition to nutrient application rate.

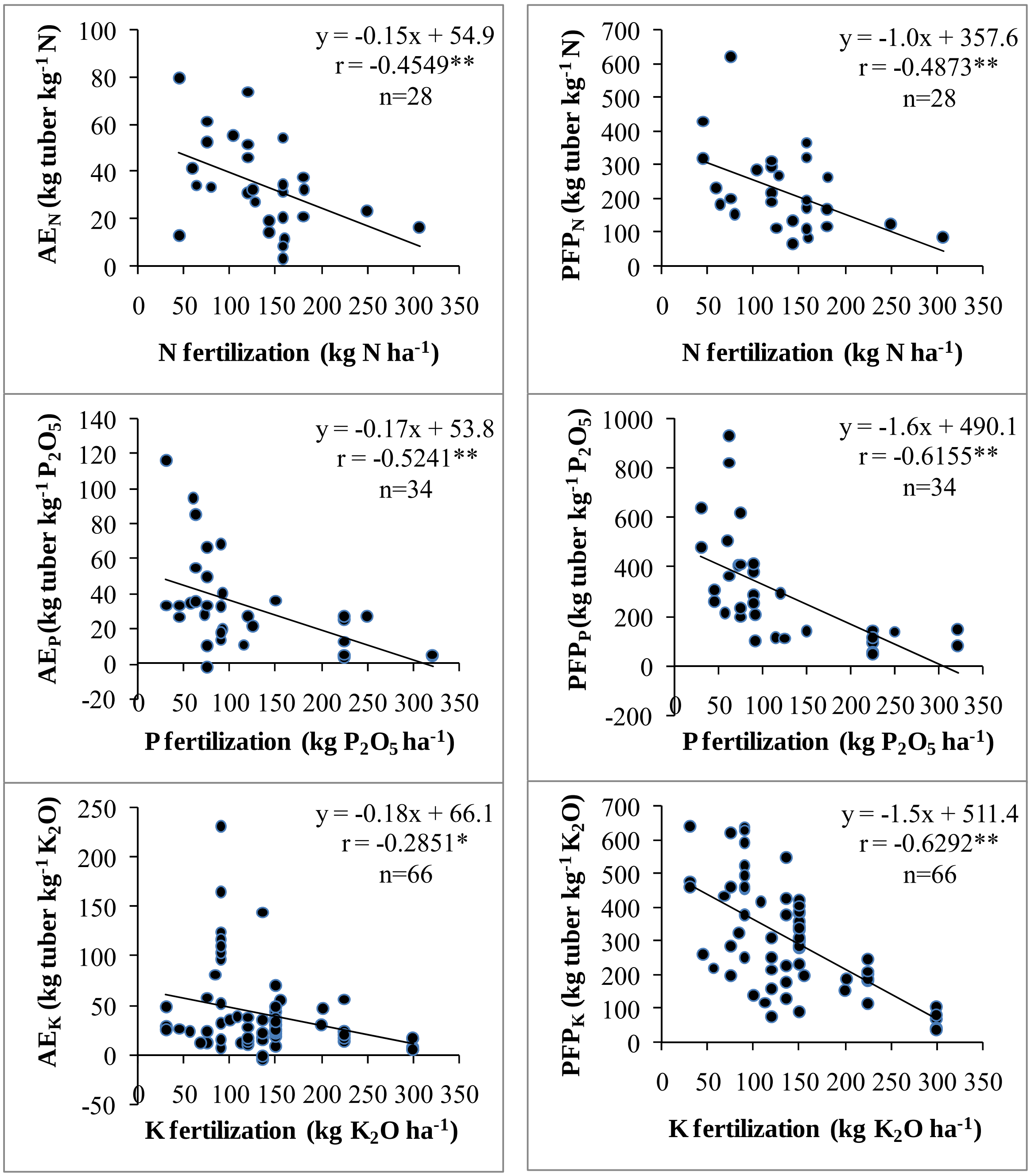

Figure 1. Relationships between N, P, K application rates and AE (left) and PFP (right)

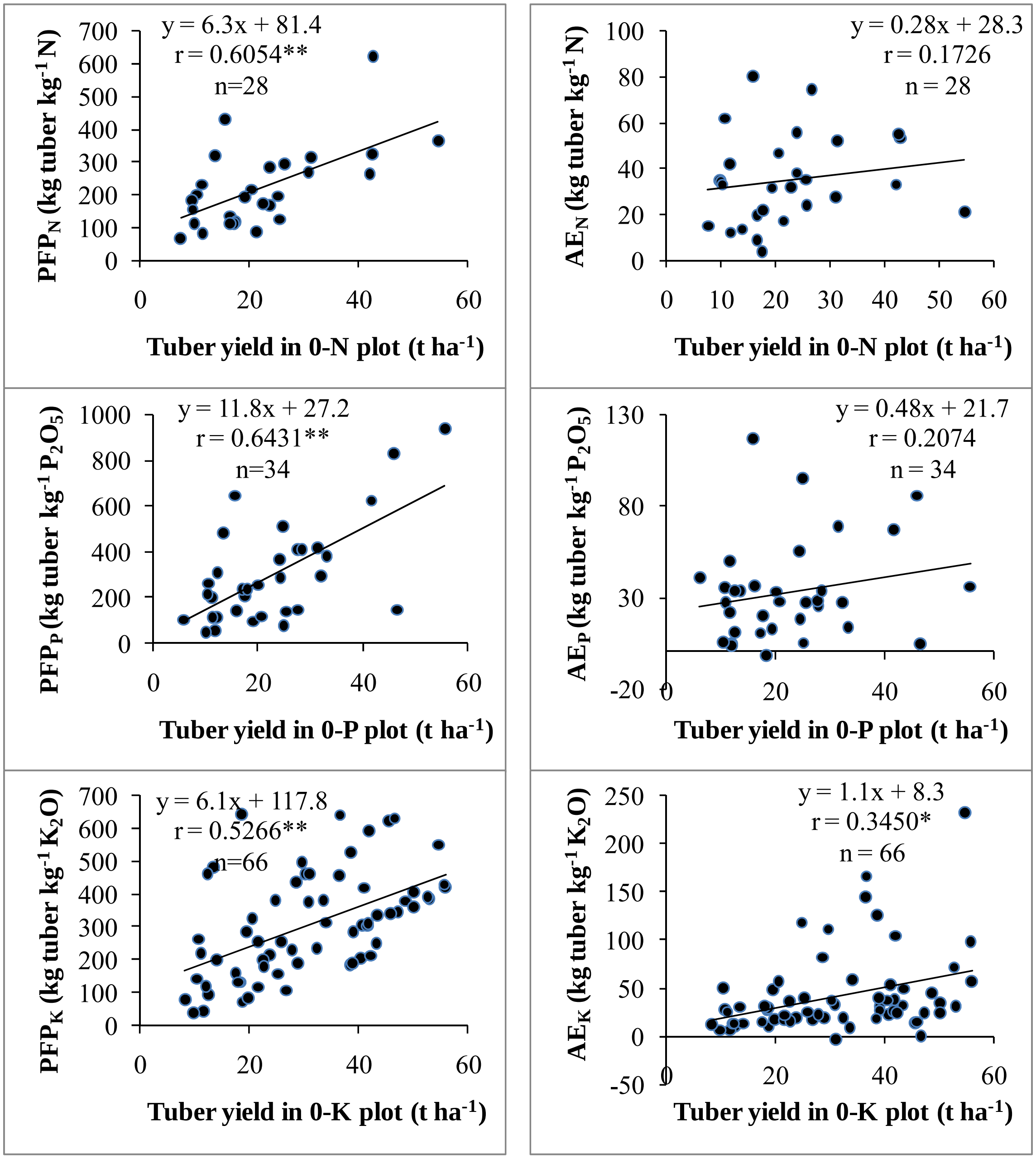

Figure 2. Relationship between tuber yield of nutrient omission plots and PFP (left) and AE (right)

Agronomic evaluation of NMP

Results indicated that NMP show advantages in yield, economic returns and nutrient use efficiency (Table 3). The tuber yields of NMP plots increased over FP by 4.0% to 22.1%. Nutrient AE under NMP was greater than that of FP at almost all sites and the benefit from NMP was 20 to 500 US$ ha^{-1} more than that from FP. Future work should focus on the better understanding of nutrient cycling in potato systems in order to develop the best nutrient management practice.

Table 3 Comparison between best nutrient management practice (NMP) and farmer's practices (FP)

Location	Year	Treat.	N	P_2O_5	K_2O	Yield †	Yield increase		AE_N	Benefit‡
			kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	%	kg kg^{-1}N	US$ ha^{-1}
Jishishan,	2004	NMP	120	120	150	35350 a	6333	21.8	74	1915
Gansu		FP	60	30	0	29017 b			43	1680
Zhangjiachuan,	2006	NMP	104	72	68	29583 a	5347	22.1	55	3479
Gansu		FP	104	0	0	24236 b			22	2978
Wuchuan,	2006	NMP	125	125	100	14200 a	900	6.8	33	728
IMAR		FP	60	18	0	13300 a			40	708
Wuchuan,	2006	NMP	250	225	200	31500 a	1900	6.4	24	1666
IMAR		FP	141	51	0	29600 b			23	1491
Huzhu,	2007	NMP	158	75	135	17893 a	696	4.0	3	997
Qinghai		FP	240	52	90	17197 a			0	944
Xining,	2007	NMP	158	75	135	30893 a	3393	12.3	35	1865
Qinghai		FP	240	52	90	27500 b			9	1631
Huaxian,	2007	NMP	181	322	225	47916 a	2083	4.5	33	2823
Shaanxi		FP	194	504	225	45833 b			20	2583
Mizhi, Shaanxi	2007	NMP	307	322	225	26527 a	4027	17.9	17	1331
		FP	358	0	0	22500 b			15	1312

†: Means in the same location followed by the same letter are not significantly different at $P<0.05$.

‡: Subtract the total cost of N, P, and K fertilizer from the total production value of potato tubers.

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