Understanding Potato Yield and Economic Responses to Fertilizer

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Researchers established a network of field trials in northwest China designed to test the response of potato to N, P, and K fertilizer and the crop sensitivity to price fluctuations.

NPK fertilization responses are commonly significant and economic for this important production center.

In response to expanding consumer demand, China's potato production is by far the world's largest. China's production reached 88 million t in 2011 (China Agriculture Statistics Data, 2011), which is nearly four times the 23.3 M t produced in the U.S. and Canada (USDA, 2015). China's semi-arid northwest produces 34% of its total potato crop annually. For the northwest, potato remains both a primary economic and staple food crop.

Potato usually takes up much more N and K than P (Perrenoud, 1993; Fageria et al., 1997; Westermann, 2005). Inadequate N can lead to reduced growth and yield while excessive N leads to delayed maturity, reduced uptake efficiency, and can increase the potential for environmental issues associated with leaching or runoff (Kumar et al., 2007a). Although potato requires less P than N and K, P promotes the development of large tubers (Kumer et al., 2007b). These are well-known facts concerning potato crop nutrition, but in northwest China a lack of specific information on potato yield response to fertilizer application creates a general knowledge gap concerning the main nutrient limitations as well as best management practices for the crop. As part of the IPNI national cooperative research network, on-farm field trials were arranged in Inner Mongolia Autonomous Region (IMAR), and the northwestern provinces of Ningxia, Qinghai, and Gansu between 2002 and 2011 to address this knowledge gap.

Each trial tested a recommended (OPT) practice and a series of nutrient omission plots (i.e., OPT-N, OPT-P, OPT-K). Nutrient application within the OPT was recommended after soil testing according to the ASI procedure (Portch and Hunter, 2002). Descriptions of soil testing data and field trial information are summarized in **Table 1** and **Table 2**.

Table 1. Important soil properties (mean +/- standard deviation) prior to trial establishment.

Soil parameters	N trials	P trials	K trials
Soil texture	Sandy loam, loam	Sandy loam, loam	Sandy loam, loam
pH in water (1:2.5)	8.3 ± 0.3	8.2 ± 0.2	8.2 ± 0.2
Soil organic matter, g/kg	10.0 ± 5.0	9.0 ± 5.0	9.0 ± 5.2
Mineral N, mg/L	29 ± 22	27 ± 22	26 ± 21
Available P, mg/L	18 ± 9	18 ± 8	18 ± 8
Available K, mg/L	99 ± 36	100 ± 34	99 ± 33

Table 2. Summarized details of field trials conducted in northwest China.

Variable	IMAR	Qinghai	Gansu	Ningxia
Cultivar	Zihuabai	Xiazhai-65	Longshu-3	Qingshu-168
Planting date	May 5-20	Apr. 19-29	Mar. 30-Apr. 17	Apr. 22
Harvest date	Sep. 12-15	Sep. 15	Sep. 22	Oct. 7
Plant density/ha	40,000-50,000	40,000-50,000	40,000-50,000	40,000-50,000
	------------ Nutrient used in OPT, kg/ha ------------			
N	45-300	136-214	75-225	150
P_2O_5	30-250	60-172	60-150	150-225
K_2O	30-225	84-225	60-150	150-300

Yield Responses

The trials found large tuber yield responses to fertilizer nutrients, but responses varied significantly across sites and years (**Figure 1**). In summary, 42 of 44 trials had significant (p<0.05) yield increases for N, 37 of 49 trials for P, and 65 of 80 trials for K. Average yield responses to N, P, and K were 5,660 kg/ha (25%), 3,970 kg/ha (18%), 5,340 kg/ha (18%), respectively. Thus, N was the most yield limiting followed by K and P.

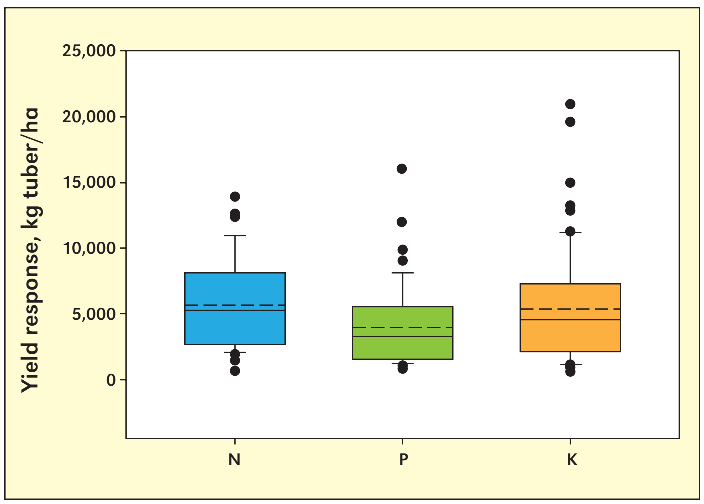

Figure 1. Variability of yield response among 44 data points for N, 49 data points for P, and 80 data points for K collected from studies across northwest China. The boundary of the box closest to zero indicates the 25th percentile, a black line within the box marks the median, a short dash line marks the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Error bars above and below the box indicate the 90th and 10th percentiles and outliers are black dots.

Economic Analysis for Fertilizer Application

Application of N, P, and K fertilizer resulted in average

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium. 1US$ = 6.5 Chinese Yuan.

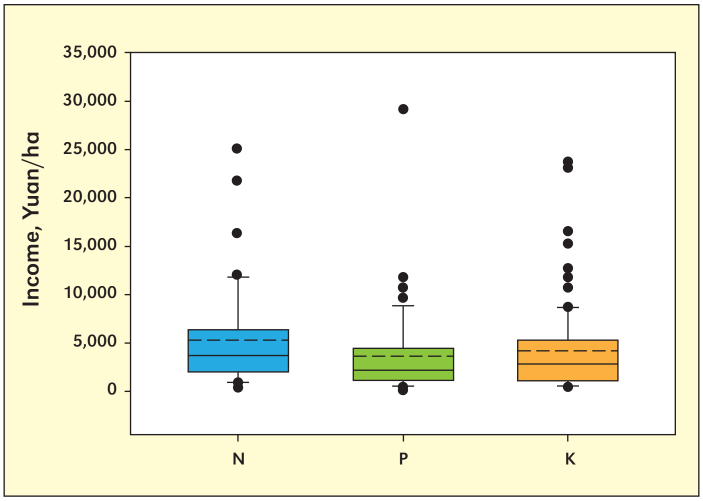

Figure 2. Variability of income by fertilizer application among 44 data points for N, 49 data points for P, and 80 data points for K collected from studies across northwest China. The boundary of the box closest to zero indicates the 25th percentile, a black line within the box marks the median, a short dash line marks the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Error bars above and below the box indicate the 90th and 10th percentiles and outliers are black dots.

incomes of 5,220, 3,680, and 4,140 Yuan/ha, showing more benefit from N and K than P fertilizer (**Figure 2**).

The value-to-cost ratio (VCR = benefit from fertilization/fertilizer cost) represents the economic return of a unit invested, in this case, N, P, or K fertilizer. The VCR for N, P, and K ranged between 2.0 to 34.4, 1.1 to 59.3, and 1.6 to 39.6 with the respective averages being 9.3, 12.7, and 8.8 (**Figure 3**). The wide variability in VCR is a reflection of the range of yield responses obtained; however, it is apparent that any investment in fertilizer, regardless of nutrient, contributed to the profitability of potato production.

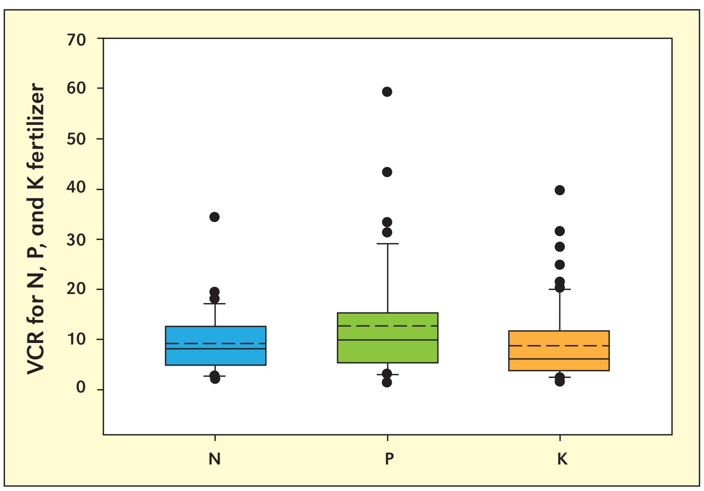

Figure 3. Variability of value-to-cost ratio (VCR) among 44 data points for N, 49 data points for P, and 80 data points for K collected from studies across northwest China. The boundary of the box closest to zero indicates the 25th percentile, a black line within the box marks the median, a short dash line marks the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Error bars above and below the box indicate the 90th and 10th percentiles and outliers are black dots.

Table 3. Critical yield response (VCR=1) at various scenarios of fertilizer rate and price for profitable income.

		---------- kg N/ha ----------				
		100	150	200	250	300
--- Yuan/kg N ---		----- Critical yield response, kg/ha -----				
2011 price	4.80	716	1,075	1,433	1,791	2,149
25% increase	6.00	896	1,343	1,791	2,239	2,687
50% increase	7.20	1,075	1,612	2,149	2,687	3,224
		---------- kg P_2O_5/ha ----------				
		45	60	90	120	150
--- Yuan/kg P_2O_5 ---		----- Critical yield response, kg/ha -----				
2011 price	4.52	304	405	607	810	1,012
25% increase	5.65	379	506	759	1,012	1,265
50% increase	6.78	455	607	911	1,214	1,518
		---------- kg K_2O/ha ----------				
		90	120	150	180	225
--- Yuan/kg K_2O ---		----- Critical yield response, kg/ha -----				
2011 price	6.67	896	1,195	1,493	1,792	2,240
25% increase	8.34	1,120	1,494	1,867	2,241	2,801
50% increase	10.01	1,345	1,793	2,241	2,689	3,362

The potato tuber price was 0.67 Yuan/kg, the lowest between 2002-2011.

In order to evaluate the effect of price fluctuation on VCR, multiple fertilizer price scenarios were tested to represent current and future prices (i.e., low, medium, high, high x 1.25, and high x 1.5). This economic analysis was evaluated within three yield response and fertilizer rate scenarios (i.e., low, medium, and high) represented by the 25, 50, and 75 percentiles (**Figure 1**).

Under a less responsive scenario, (2,700, 1,500, and 2,100 kg/ha) and low application rate (120-62-90 kg N-P_2O_5-K_2O/ha) VCR was 1.6, 1.7, and 1.1, respectively, at the highest fertilizer price/lowest potato tuber price simulation. Given the same prices, at the high response scenario, (8,000, 5,410, and 6,890 kg/ha) and high rate (210-115-150 kg N-P_2O_5-K_2O/ha) VCR was 2.6, 3.4, and 2.1, respectively. **Figure 4** provides the results of the mid-response/mid-rate scenario. The data demonstrated a >75% probability of profitability from N, P, or K fertilization within northwest China potato fields, and that profits will rise with increased yield response.

The critical yield response (VCR=1) where fertilizer investment cost was equal to return was also calculated using different scenarios of fertilizer rate and price, based on the lowest tuber price between 2002 to 2011 (**Table 3**). These critical yield responses to fertilizer further demonstrate that more response to K, compared to P or N, will be expected for profitable income. If fertilizer price increased 50% above the low of 2011, use of the high fertilization rate (300-150-225 kg N-P_2O_5-K_2O/ha) generated respective critical yield responses for N, P, and K of 3,224, 1,518, and 3,362 kg/ha. This suggested that 73%, 76%, and 60% of trials would be profitable with application of N, P, and K, respectively. If the calculation were based on low price of 2011 and the same high fertilization, 89%, 94%, and 74% of trials could be profitable.

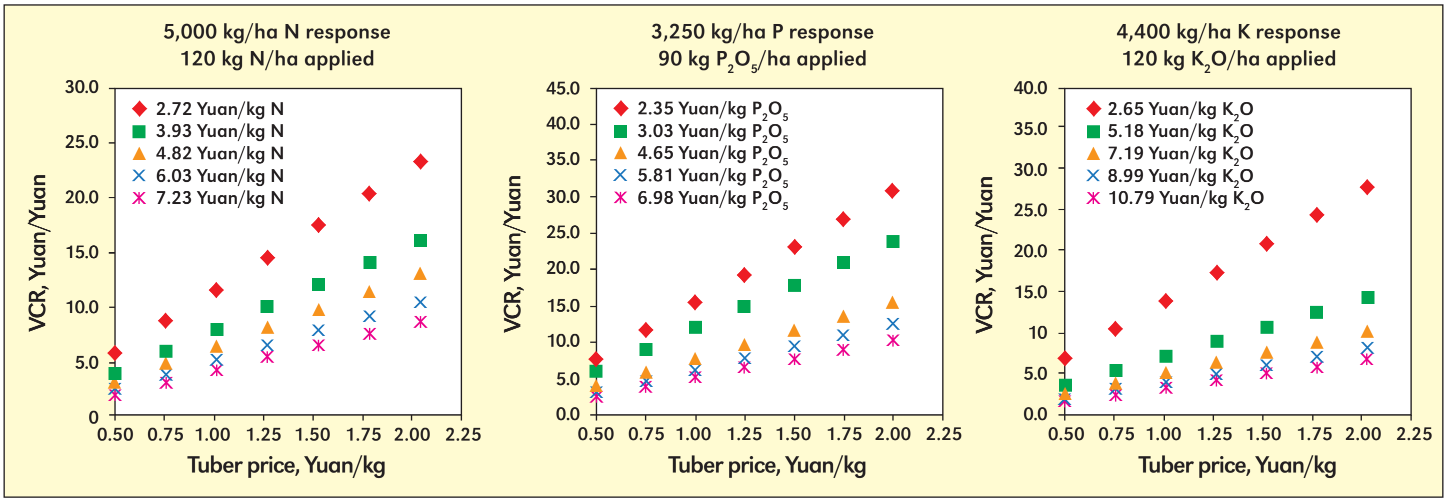

Figure 4. Expected value-to-cost ratio (VCR) changes with fertilizer and tuber price fluctuations under the middle yield response/fertilization scenario.

Conclusions

Nitrogen was the main yield-limiting nutrient for potato production in northwest China followed by K, and then P. Application of N, P, or K fertilizer can be profitable in the region in the face of fluctuating crop and fertilizer prices. A host of factors ranging from marketing to food policy can have an effect on fertilizer and tuber prices. Increased demand for potato will require higher yields and careful fertilization. A 4R Nutrient Stewardship approach integrated with other practices like water management will be required to increase yield response and profit. Future work should focus on 4R nutrient management integrated with other agronomic practices to further improve yield responses and profitability. BC

IPNI/S.Li

Comparison of potato growth between the NPK optimum (OPT) treatment and the K omission (OPT-K) treatment in Gansu province.

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