Dr. Shutian Li visits an on-farm potato research site in northwest China.

Identifying Yield and Nutrient Gaps for Potato Production in Northwest China

By Shutian Li and Ping He

China's potato production is presently near 100 million t, which positions the country as the world's leading potato-growing nation. The northwestern region of China produces more than 30% of its annual harvest (MOA, 2014). Recently, the government of China launched a strategy meant to promote the consumption (and hence production) of potato in the hopes of solidifying the crop's place as the fourth most consumed staple food crop behind rice, wheat, and corn. Although China's northwest has great productive capacity, more information about the region's attainable yield is needed to determine how it can best support this policy-driven increase in potato demand.

Crop yield gaps can be calculated if one has knowledge of both the maximum attainable yield and the actual (on-farm) yield. Maximum attainable yield is achieved under field conditions when all the management factors are effectively managed. The difference in attainable yield and actual yield provides a realistic estimate of the yield gap that could be closed through improved management practices.

In northwest China, on-farm yield data from the Ministry of Agriculture shows an increasing trend between 1982 to 2014 (**Figure 1**). These data are similar to data collected by other farm surveys that are generally used to estimate actual yields (Haverkort et al., 2014; Svubure et al., 2015). The most recent 5-year (2010-2014) yield averages that combine rain-fed and irrigated potato production were 14.2, 16.7, 10.3, and 20 t/ha for the Inner Mongolia Autonomous Region (IMAR), Gansu, Ningxia, and Qinghai, respectively.

Maximum attainable yield can be estimated by several methods such as crop model simulation, field experiments, maximum farmer yields based on surveys, and yield contests amongst farmers (Lobell et al., 2009; van Ittersum et al., 2013). The International Plant Nutrition Institute (IPNI) used multiple-year field experimental data to analyze attainable yields of potato as well as yield responses to N, P, and K fertilization. This included a total of 288, 170, 84, and 114 on-farm trials conducted between 2002 and 2013 in the IMAR and the provinces of Gansu, Ningxia, and Qinghai (**Table 1**). Each trial had an optimum (OPT) nutrient recommendation treatment developed using the Agro Services International (ASI) "systematic approach" (Hunter, 1980; Portch and Hunter, 2002), as well as corresponding nutrient omission treatments (i.e., OPT-N, OPT-P, and OPT-K). Due to the arid climatic conditions in northwest China, it is reasonable to assume that reaching the 90th percentile yield

A yield and nutrient gap analysis for potato helps to evaluate the yield-limiting nutrient factors within northwestern China, and identifies the solutions to improving tuber yields to realistically attainable levels.

KEYWORDS:
attainable yield; yield gap; nutrient gap; balanced fertilization; partial factor productivity

ABBREVIATIONS AND NOTES:
N = nitrogen; P = phosphorus; K = potassium.

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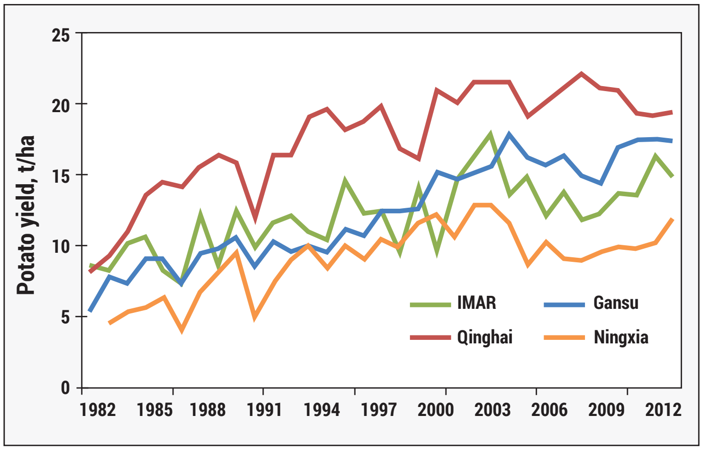

Figure 1. Trends in farmers' potato yield for the Inner Mongolia Autonomous Region (IMAR) and three provinces in northwestern China, MOA (1982-2014).

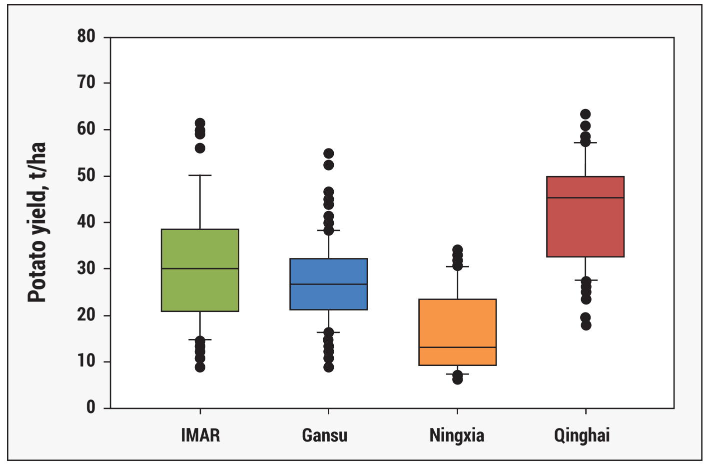

Figure 2. Box plots showing the distribution of yields within different regions of northwest China resulting from the application of optimum fertilizer NPK treatments (box indicates 25th, 50th and 75th percentiles; error bars indicate 10th and 90th percentiles; solid circles indicate 5th and 95th percentiles).

threshold under a OPT treatment would mark the maximum attainable yield.

Identifying Attainable Potato Yields

The network of field trials found good responses to applied NPK throughout northwest China. IMAR and Qinghai were most responsive, Ningxia was least responsive, and Gansu generated intermediate nutrient responses. The marginal nutrient responses in Ningxia point to a relatively small benefit from applied nutrients, and further suggests a need for the region's growers to focus on improving their management of factors other than NPK fertilization (e.g., water management) in order to make the investment in fertilizer more effective.

The distribution of potato yields obtained with soil test-based OPT treatments varied considerably within and across regions (**Figure 2**). In IMAR, Gansu, Ningxia, and Qinghai, the respective average yields were 31.1, 26.9, 16.4, and 42.4 t/ha, maximum yields were 61.2, 54.9, 34.3, and 69 t/ha, and the 90th percentile yields (maximum attainable yields for this study) were 50.1, 37.8, 30.3, and 56.6 t/ha.

Yield Gaps

This information about on-farm and attainable yields indicates that there is considerable potential to increase potato productivity in all four regions studied. However, the magnitude of the yield increase required to narrow the yield gap differed significantly across regions (**Figure 3**). For example, in IMAR, Gansu, Ningxia, and Qinghai, yields would need to increase by 165%, 70%, 112%, 121% to reach a threshold equal to 75% of attainable yield.

Nutrient Gaps

Adequate and balanced nutrient input is one of the most important factors that can contribute to the narrowing of any yield gap. In order to assess how current on-farm fertilization practices are impacting the size of each region's yield gaps, the amounts of N, P, and K fertilizer (i.e., nutrient gaps) needed to reach the 75% attainable yield threshold were estimated. The nutrient gaps were calculated by dividing the size of the yield gap by the partial factor productivity (PFP) obtained for each nutrient at the 25th, 50th, and 75th percentiles, which represent a low, medium, and high nutrient use efficiency scenario, respectively (**Table 2**). PFP was calculated as potato tuber yield obtained under an OPT treatment divided by the amount of nutrient applied. PFP is an established nutrient performance indicator that provides a measure of the crop responsiveness to applied nutrients. For each scenario, a nutrient gap was calculated by dividing the

Table 1. Characteristics of the selected field trials conducted by the IPNI cooperative research network between 2002 and 2013.

Items	IMAR	Gansu	Ningxia	Qinghai
Potato areas, ha	512,000	665,000	171,000	90,000
Number of trials	288	170	84	114
Number of trials with irrigation	216	75	26	73
Soil type	Chestnut soil	Loess	Desert grey soil	Chestnut soil/Sierozem
Growth period	May-Sep	Apr-Oct	Apr-Sep	May-Sep
Annual rainfall, mm	211-549 (370)[a]	300-558 (424)	195-366 (318)	352-523 (425)
N rate, kg/ha	45-450 (200)	37-240 (172)	90-150 (116)	27-248 (186)
P_2O_5 rate, kg/ha	30-250 (99)	38-225 (97)	45-225 (125)	35-276 (93)
K_2O rate, kg/ha	30-338 (139)	30-210 (91)	45-300 (154)	84-203 (123)

[a]: Numbers in the parenthesis represent the average.

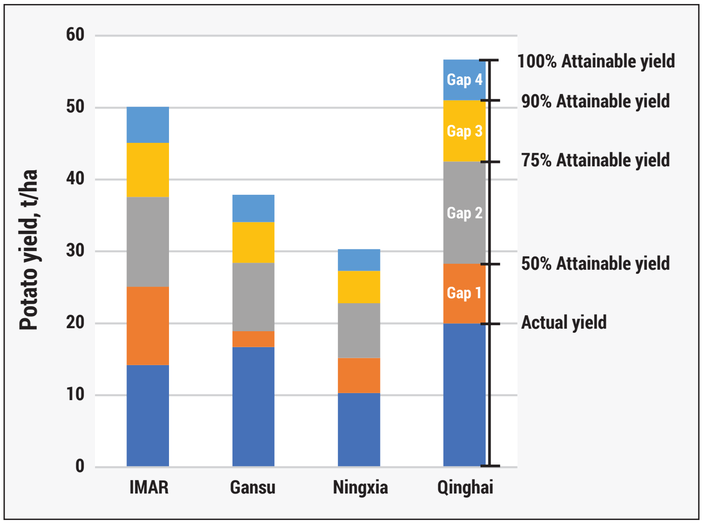

Figure 3. Potato yields need to move within 50%, 75%, 90%, and 100% of attainable yield.

yield gap by the PFP.

Compared with data for recent three-year average rates of fertilizer application by potato farmers (NDRC, 2014), in order to close the yield gap, N rates in IMAR, Gansu, Ningxia, and Qinghai need to increase by 68 to 102%, 36 to 61%, 30 to 56%, 49 to 81%, respectively (**Table 2**). Similarly for P, rates need to increase by 64 to 102%, 21 to 44%, 71 to 123%, 22 to 38%. Given the generally low K rates being used across northwest region, K rates need to increase several-fold in order to reduce the nutrient gap and improve productivity to near the 75% attainable yield threshold.

Considering the total combined NPK fertilizer rates for these regions, a 90 to 134% increase is recommended for IMAR, 43 to 69% for Gansu, 68 to 111% for Ningxia, and 48 to 84% for Qinghai.

Conclusions

High yield responses to N, P, and K application provide the opportunities to close the large yield gaps through balanced crop nutrition. Closing the yield gap to 75% of the attainable yield is a realistic goal that translates into 20 to 36.6 t/ha increases in tuber yields, which is the expected response to the application of 43 to 134% more NPK compared to current practice. **BC**

Example Nutrient Gap Calculation

Nutrient: Nitrogen
Region: IMAR
Yield Threshold: 75% Attainable Yield = 37,609 kg/ha
Average on-farm yield = 14,179 kg/ha
PFP at low scenario, where tuber yield is 30,677 kg/ha and N rate is 250 kg/ha

1. PFP_N (kg/kg) = Tuber yield (kg/ha) / N applied (kg/ha)
= 30,677 / 250
= 123 kg/kg

2. Yield gap (kg/ha) = 37,609 – 14,179
= 23,430 kg/ha

3. Nutrient Gap_N (kg/ha) = Yield Gap (kg/ha) / PFP_N
= 23,430 / 123
= 191 kg/ha

Table 2. Projected nutrient gaps necessary to close yield gaps to 75% of attainable yields.

	IMAR (n=288)[1]	Gansu (n=170)	Ningxia (n=84)	Qinghai (n=114)
PFP_N scenarios[2]	N gaps, kg/ha			
Low	191	94	137	129
Medium	155	76	88	102
High	127	56	74	78
On-farm N rate[3]	188	155	243	161
PFP_P scenarios	P_2O_5 gaps, kg/ha			
Low	95	59	135	60
Medium	69	40	89	45
High	60	29	77	35
On-farm P rate	94	134	110	159
PFP_K scenarios	K_2O gaps, kg/ha			
Low	133	61	163	98
Medium	106	37	130	58
High	84	27	75	48
On-farm K rate	28	5	13	22
PFP_{NPK} scenarios	$N+P_2O_5+K_2O$ gaps, kg/ha			
Low	416	204	407	286
Medium	330	154	343	215
High	279	126	249	164
On-farm NPK rate	310	294	366	341

[1] Number of observations.
[2] Calculated under low (25th percentile), medium (50th percentile), and high (75th percentile) scenarios of PFP.
[3] Recent three-year average fertilizer rates applied by potato farmers (NDRC, 2014).

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