Economics of Fertilizer Application to Maize in North China

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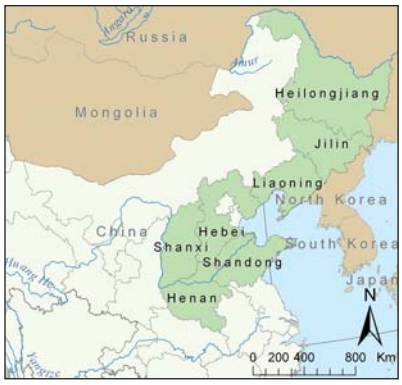

Results from field trials conducted for three years in seven provinces in North China's maize production area showed that average yield responses to fertilizer N, P and K were 1.89, 0.95 and 0.97 t/ha, respectively. Economic returns with N and P fertilization increased with increase in yield responses and fertilizer prices, but those with K fertilization decreased with increase in K prices. Use of Nutrient Expert® led to higher grain yields and farmer profits.

As one of the most important crops used as food, forage, and a raw material for industry, maize plays an important role in food security. Ranked as the most widely planted crop in China, its planting area occupied 29.5% of the food crops in the country with 32.5 million ha in 2010 (China Agriculture Yearbook, 2011). Maize in China is mainly planted in the Northeast (Heilongjiang, Jilin and Liaoning) and North Central regions (Hebei, Henan, Shandong and Shanxi), which represents 61% of the total maize planting area in China.

Fertilizers play an important role in increasing food production and maintaining food security in China. However, their excessive and unbalanced use has become a common issue in China (He et al., 2009). Nutrient Expert® (NE), a new easy-to-use, interactive and computer-based nutrient decision support system developed by the International Plant Nutrition Institute (IPNI) to rapidly provide nutrient recommendations for an individual farmer field in the presence or absence of soil testing data, has proven to be a successful method in maintaining grain yields and increasing nutrient use efficiency (Chuan et al., 2013ab; Xu et al., 2013). However, due to the variability in yield responses, grain prices and fertilizer costs, it is also important to evaluate and compare the economics of fertilizer application in maize in China under different yield responses and price/cost scenarios. We conducted this study to determine: (1) yield responses to fertilizer N, P and K application, (2) economic returns from N, P and K fertilizers application, and (3) economic returns based on current and some anticipated yield response, fertilizer rate, crop price and fertilizer price scenarios in maize production areas in North China.

On-farm trials were conducted in Northeast and North Central China from 2010 to 2012 on 374 farms. Specifically, on-farm trials were conducted in Heilongjiang (43) Jilin (58), Liaoning (41), Hebei (49), Henan (112), Shandong (33), and Shanxi (37) provinces, respectively. Five treatments were laid out in every field trial with plot areas ranging between 40 and 90 m^2. Treatments included: (a) NE, where fertilizer application rates (kg/ha) ranged from 110 to 231 N, 31 to 89 P_2O_5, and 28 to 108 K_2O, respectively; (b) 0-N or N omission plot, where only P and K were applied; (c) 0-P or P omission plot, where only N and K were applied; (d) 0-K or K omission plot, where only N and P were applied; and (e) FP or farmers' fertilization practice, where fertilizer rates were determined and applied by farmers. Fertilizer rates (kg/ha) in FP treatments ranged from 48 to 460 N, 0 to 252 P_2O_5, and 0 to 177 K_2O, respectively,

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; 1US$ = 6 Yuan.

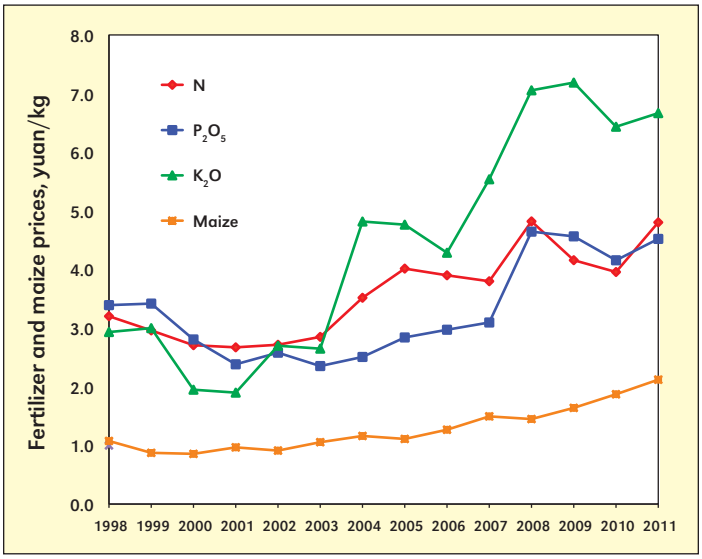

Figure 1. Variability in maize and fertilizer N, P and K prices in China since 1998.

across different experimental farms. Fertilizer sources were urea, triple superphosphate or diammonium phosphate, and potassium chloride or potassium sulfate. Maize varieties were chosen by farmers and planting densities ranged from 55,000 to 75,000 plants/ha. Summer maize was irrigated only once during the whole growing period (i.e., after seeding), while spring maize was completely rainfed. Farmers did the weeding and pest/disease control. At maturity, grain yields were determined from a 20 to 50 m^2 harvest area and recorded at a standard moisture content of 15.5%.

Yield responses due to N, P and K fertilizers were calculated from yield differences between NE and different omission treatments. Economic returns, expressed as value to cost ratio (VCR, yuan/yuan), were calculated by first multiplying crop price and yield response and then dividing the value by costs of applied N, P and K fertilizers. We also estimated VCRs at three fertilizer price scenarios, viz., (a) current scenario, where we used the averaged price across 2010 to 2012, (b) 150% and (c) 200% of current prices at three different yield responses (with 25th, 50th, and 75th percentiles representing low, medium and high yield responses, respectively). The corresponding maize prices used were estimated based on corresponding relationships developed between maize price and fertilizer price with data from **Figure 1**. The following relationships were obtained between prices for maize (Y) and N, P and K fertilizers, respectively.

Field Validation of Nutrient Expert® for maize in Henan, China.

$Y = 0.4385 \times e^{0.2945*N}$ (R^2=0.6531)
$Y = 0.089 \times P^2 - 0.2713 \times P + 1.1426$ (R^2=0.5996)
$Y = 0.678 \times 2e^{0.1339K}$ (R^2=0.802)

Yield Responses

Since yield responses to fertilizer N, P and K applications across seven different provinces did not differ much between NE and FP, only yield responses from NE plots are presented here. Averaged across seven provinces, yield with treatment NE was 10.1 t/ha, while yield losses of 1.89 (range 0.34 to 7.9), 0.95 (range 0.01 to 5.4) and 0.97 (range 0.01 to 4.1) t/ha occurred without N, P and K applications, respectively. Data indicated large variability in and high maize yield responses to N, P and K fertilization.

Economic Returns

Economic returns followed trends quite similar to yield responses. Data indicated that VCRs of N, P and K ranged between 0.5 to 12.1, 0.1 to 43.7, and 0 to 18.6, respectively. This suggested that on average for every yuan invested in fertilizer N, P and K, an additional maize value of 2.8, 7.8 and 4.6 was produced across 374 sites in seven provinces (**Figure 2**). Although yield responses followed as N > K > P, VCRs followed as P > K > N. Higher VCR values from P related well with lower P application rate (57 kg P_2O_5/ha) and lower P fertilizer prices compared with N and K fertilizer rates and prices. Although N response was almost twice the P response, higher N rate (three times the P rate) resulted in lower VCR for N fertilization. Among the 374 field trials, 30, 39 and 43 sites from N, P and K applications, respectively, had VCR<1.0, accounting for about 8, 10 and 11% of the total observation sites. This suggested that under current nutrient management practices and market situation, about 30% of the sites in North China have unfavorable economic returns from fertilizing maize.

Economic Returns Under Anticipated Price and Crop Response Scenarios

Values of VCR for N fertilization ranged from 4.3 to 12.3 for NE and 2.2 to 8.6 for FP treatments (**Table 1**). The VCR values in FP occupied 50 to 70% of those from NE for same

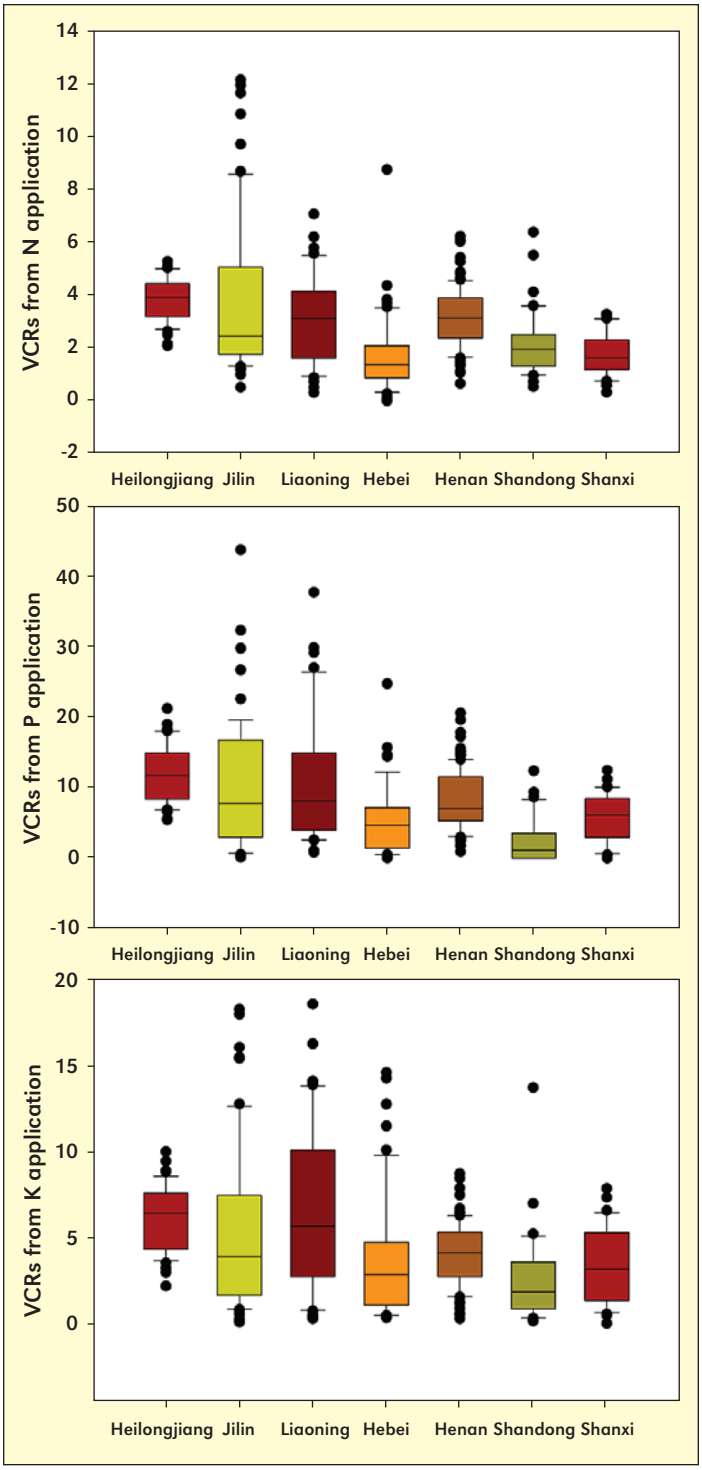

Figure 2. Variability in value to cost ratios (VCR) with N (top), P (middle) and K (bottom) fertilization in maize based on actual rates and prices of fertilizer and maize crop across seven provinces in North China. Fertilizer prices used were 3.96, 4.8 and 5.28 yuan/kg N, 4.16, 4.52 and 4.91 yuan/kg P_2O_5, and 6.43, 6.67 and 6.92 yuan/kg K_2O, and maize prices used were 1.87, 2.12 and 2.39 yuan/kg for 2010, 2011 and 2012. *Data source: China Agriculture Products and Profits Compilation.* Boxes represent data within the first and third quartiles (interquartile range). The thin line denotes the second quartile or median. Lines extending beyond the interquartile range denote the 10th to 90th percentile of the data. Statistical outliers are plotted as individual points outside these lines.

Table 1. Value to cost ratio for maize fertilization at different actual crop response levels (25th, 50th and 75th percentile) and fertilizer application rates under current and anticipated costs of fertilizers. North China.

	Nutrient Expert			Farmer Practice		
	25th*	50th	75th	25th	50th	75th
N response, kg/ha	1,076	1,748	2,537	937	1,652	2,347
N rate, kg/ha	110	150	190	190	220	250
Cost of N (4.8) and maize (2.12), yuan/kg**	4.3	5.1	5.9	2.2	3.3	4.1
Cost of N (7.2) and maize (4.02), yuan/kg	5.5	6.5	7.5	2.8	4.2	5.2
Cost of N (9.6) and maize (8.83), yuan/kg	9.0	10.7	12.3	4.5	6.9	8.6
P response, kg/ha	455	805	1301	381	714	1,163
P_2O_5 rate, kg/ha	50	60	70	80	100	120
Cost of P_2O_5 (4.5) and maize (2.12), yuan/kg	4.3	6.3	8.7	2.2	3.3	4.5
Cost of P_2O_5 (6.8) and maize (3.39), yuan/kg	4.6	6.7	9.3	2.4	3.6	4.8
Cost of P_2O_5 (9.0) and maize (5.96), yuan/kg	6.0	8.8	12.3	3.1	4.7	6.4
K response, kg/ha	403	835	1,328	381	759	1,234
K_2O rate, kg/ha	60	70	80	0	30	60
Cost of K_2O (6.7) and maize (2.12), yuan/kg	2.1	3.8	5.3	-	8.0	6.5
Cost of K_2O (10.0) and maize (2.59), yuan/kg	1.7	3.1	4.3	-	6.5	5.4
Cost of K_2O (13.3) and maize (4.05), yuan/kg	2.0	3.6	5.0	-	7.7	6.2

*25th, 50th and 75th denote respective percentiles.
**Fertilizer prices chosen were current, 150%, and 200% of the current prices, and maize prices were calculated from the correlation equations given in the text.

class of yield responses. The higher VCR values in NE were due to the higher yield responses and optimized lower N application rates. The values of VCR increased with increase in both yield responses and N fertilizer prices. These results clearly show that N is being over applied to most maize fields in China.

Values of VCR for P fertilization ranged from 4.3 to 12.3 for NE and 2.2 to 6.4 for FP treatments (**Table 1**). The VCR values with P fertilization in NE were more than two times that in FP treatment for same class of yield responses and for similar reasons (higher yield responses and optimized lower P application rates). Again, the VCR values increased with both yield responses and P fertilizer prices. Interestingly, the VCR values from 75th percentile yield responses in FP achieved comparable VCR values from the 25th percentile yield responses in NE. Like N, the data on VCR for P clearly indicates that P fertilizer is being over applied to maize in China.

The VCR values for K fertilization were quite different from those of N and P (**Table 1**). In the 25th percentile, no K fertilizer was applied in FP, so no observations for VCR occurred under this scenario. Although higher VCRs were achieved by FP with less K fertilizer input, NE-based K application with right rates could still obtain favorable VCRs over 1.7. Unlike with N or P fertilization, VCR values decreased with increase in K fertilizer prices, and the 75th percentile yield response could not achieve a better VCR than 50th percentile yield response due to 50 kg/ha more K_2O input. This was probably because the increase in maize price could not keep up with the rapid increase in the price of potash (**Figure 1**).

The above results and discussion on VCRs were merely from the applications of N, P and K under different scenarios. However, based on the actual yield and profitability scenario observed across 374 observations, NE was able to achieve a grain yield of 10.3 t/ha and a net profitability of 18,903 yuan/ha with 157-56-67 kg N-P_2O_5-K_2O/ha input, while FP achieved a grain yield of 9.99 t/ha and a net profitability of 18,154 yuan/ha with 225-61-47 kg N-P_2O_5-K_2O/ha input. The net increase in profitability of NE over FP was 748 yuan/ha, of which one-third was from fertilizer saving and two-thirds was from the increase in grain yield. It is not a big profit under the current smallholding situation, but is a considerable number under large scale farming system in the near future.

Summary

Maize yield responses to N, P and K fertilization were highly variable across different provinces in China. Average yield responses to fertilizer N, P and K were 1.9, 0.95 and 0.97 t/ha across seven provinces. The VCRs for fertilizer N, P and K ranged between 0.5 to 12.1, 0.1 to 43.7, and 0 to 18.6, respectively. Omission of N, P and/or K resulted in losses of both yield and profitability. Economic returns from N and P fertilization increased with increase in yield responses and fertilizer prices, but those from K fertilization decreased with increase in K prices. All of the VCRs were higher than 2.0 when yield responses were over the 25th percentile for N and P fertilizers, and those for NEs were much higher than FP. Although profitability in the FP treatment with less K input was higher than in NE treatment under K application, the optimized Nutrient Expert®-based fertilizer recommendation proved to be a successful nutrient decision support tool leading to higher grain yield and profitability. BC

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