Maize Response to Balanced Fertilizer Application in Northwest China

By Shutian Li, Jiyun Jin, Yu Duan, Tianwen Guo, Yan Zhang, and Youhong Li

On-farm trials determined the effect of K fertilization on maize production within a region that has typically relied on N and P alone. Balanced use of N, P, and K fertilizer generated an average yield increase of 1.2 t/ha and was shown to improve farm income by USD 300/ha when compared to common farmer practice. This case of long-term use of N and P in the absence of K illustrates the seriousness of nutrient imbalance in this and other regions of China.

Spring maize is one of the main crops in China's northwest region. In 2010, total maize production taken from an area of 5.4 M ha within the provinces of Gansu, Inner Mongolia, Xinjiang, and Ningxia was nearly 30 M t (MOA, 2010) with an average yield of 5,540 kg/ha. Fertilizer use in the northwest has been inadequate for years—mainly because of economic constraints. Therefore, little information is available on nutrient-limiting factors and the economic value of balanced fertilizer application to maize grown in the region.

Since 2003, IPNI has conducted a series of field experiments in collaboration with the provincial Soil and Fertilizer Institutes to evaluate the response of spring maize to N, P, and K fertilizer application. A total of 16 field trials were conducted—six in Gansu province, four in Xinjiang, four in Inner Mongolia, and two in Ningxia. **Table 1** shows some chemical properties of soils at these sites before the field trials began. All trials had four treatments including an optimum (OPT) NPK treatment recommended by the Agro Services International (ASI) soil testing and fertilizer recommendation procedure (Portch and Hunter, 2005) based on target yields in the different locations, and three nutrient omission plots (OPT-N, OPT-P, and OPT-K.) All experiments were set up in a randomized complete block design with three replications. Economic comparisons were made between the OPT and FP treatments at some sites in Gansu and Xinjiang.

Results

Maize yields varied greatly for different years and sites (**Figure 1**). Nitrogen was the main nutrient limitation since the crop gave significant responses in 12 of the 16 sites-years (**Table 2**). Although available P in most soils was above 10 mg/L, a deficient level for the soil testing system used, application of P fertilizer still increased maize yields significantly at 9 of the 16 sites. This response to P reflects the high rates of N being applied. Similarly, K application increased maize yields at 7 of the 16 sites. Interestingly, no significant relationship existed between the relative yields of maize in the OPT-P and OPT-K plots (i.e., the ratio of yield in either the OPT-P or OPT-K plot to the yield in the OPT plot) and soil test P and K (**Figure 2**). This is most likely due to the impact of other confounding factors such as high levels of soil P or the climatic conditions.

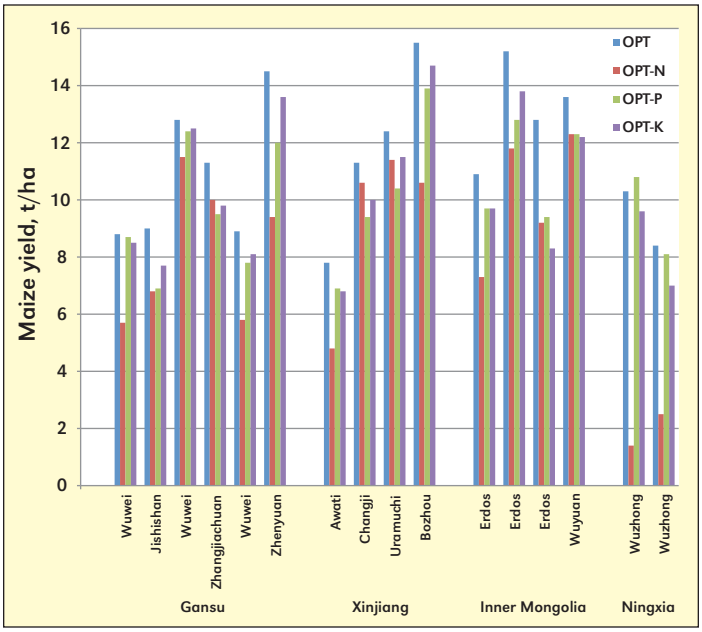

Figure 1. Average maize yields in different treatments at different sites within Gansu, Xinjiang, Inner Mongolia, and Ningxia.

The agronomic efficiencies of N (AE_N), P_2O_5 (AE_P), and K_2O (AE_K) averaged 13.4 (range 2.8 to 32.7), 12.8 (-5.1 to 28.5), and 13.9 (1.6 to 35.6) kg/kg, respectively. These values were slightly higher than those reported for China (i.e., 12.2 kg/kg,

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; OPT = optimum NPK treatment; FP = farmer practice; M = million; USD = US Dollar; RMB = Chinese Yuan.

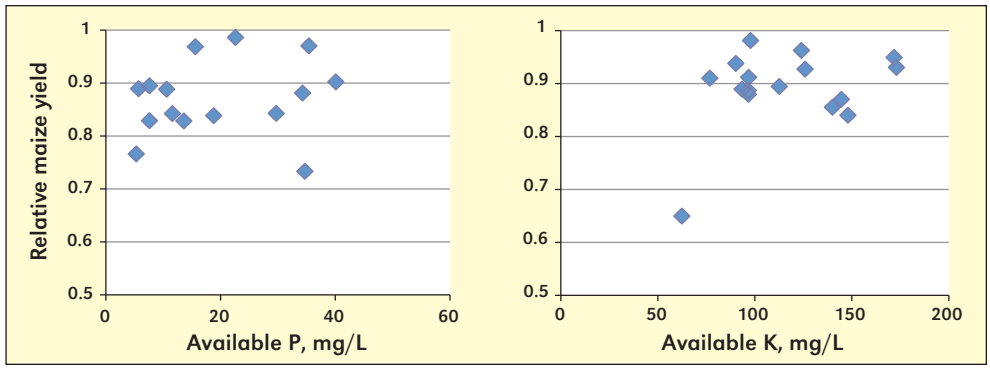

Figure 2. Relationship between relative yield of maize in the OPT-P and OPT-K plots (i.e. ratio of yield in OPT-P or OPT-K plot to the yield in the OPT plot) with available soil P (left) and exchangeable soil K (right) for 16 site-years.

Table 1. Some chemical properties of soils at the experimental sites.

Locations	Year	pH	OM, %	N, mg/L	P, mg/L	K, mg/L
Wuwei, Gansu	2003	7.9	0.75	14.5	22.6	124
Jishishan, Gansu	2004	7.6	0.12	81.4	5.3	140
Wuwei, Gansu	2006	7.8	0.85	4.3	15.6	98
Zhangjiachuan, Gansu	2006	8.2	0.85	0.0	11.6	144
Wuwei, Gansu	2007	8.2	0.93	23.1	34.3	96
Zhenyuan, Gansu	2007	8.1	0.78	13.4	7.6	90
Awati, Xinjiang	2005	8.0	1.41	47.0	5.7	97
Changji, Xinjiang	2006	8.2	1.17	21.3	13.6	93
Uramuchi, Xinjiang	2007	8.5	1.29	25.3	18.8	126
Bozhou, Xinjiang	2009	8.3	0.53	56.2	7.6	172
Erdos, Inner Mongolia	2009	8.8	0.24	16.2	10.6	97
Erdos, Inner Mongolia	2010	8.7	0.24	11.2	29.7	77
Erdos, Inner Mongolia	2011	8.5	0.18	16.7	34.7	62
Wuyuan, Inner Mongolia	2011	8.7	0.24	55.3	40.1	113
Wuzhong, Ningxia	2006	8.2	0.38	15.0	50.6	173
Wuzhong, Ningxia	2007	8.1	0.23	10.3	35.4	148

Table 2. Yield response to N, P, and K fertilizer applications and agronomic efficiencies (AE) of macronutrients.

Location	Yield response, %			AE, kg/kg		
	N	P	K	N	P_2O_5	K_2O
Wuwei, Gansu	55.3	1.4	3.9	10.5	1.0	4.4
Jishishan, Gansu	32.4	30.5	16.9	12.2	17.5	21.7
Wuwei, Gansu	11.5	3.2	1.9	4.9	2.7	1.6
Zhangjiachuan, Gansu	12.5	18.7	14.9	4.2	11.9	12.2
Wuwei, Gansu	52.8	13.5	9.7	11.4	14.1	8.7
Zhenyuan, Gansu	55.0	20.6	6.6	22.9	16.6	6.0
Awati, Xinjiang	60.5	12.4	13.7	15.1	11.5	31.3
Changji, Xinjiang	6.2	20.7	12.4	2.8	27.3	35.6
Uramuchi, Xinjiang	8.3	19.3	7.8	4.5	19.0	12.0
Bozhou, Xinjiang	46.0	11.7	5.3	21.7	15.5	17.4
Erdos, Inner Mongolia	49.3	12.6	12.7	14.1	11.6	13.7
Erdos, Inner Mongolia	28.2	18.6	9.9	12.4	19.9	7.6
Erdos, Inner Mongolia	39.4	36.4	53.9	13.4	28.5	24.9
Wuyuan, Inner Mongolia	11.0	10.8	11.8	5.0	11.1	8.0
Wuzhong, Ningxia	607	-4.3	7.5	32.7	-5.1	8.0
Wuzhong, Ningxia	235	3.1	19.0	26.1	1.4	9.9
Average	81.9	14.3	13.0	13.4	12.8	13.9

11.5 kg/kg, and 10.4 kg/kg for N, P_2O_5, and K_2O, respectively) by Jin (2012). Thus it would appear that the crop response to nutrients in northwest China is higher than the national average. This could be attributed to the lower soil organic matter (and soil fertility) in the northwest compared to other regions of China. But the low soil fertility in this region is also a result of the lack of significant nutrient accumulation in these soils compared to other intensive agricultural regions within China (Li and Jin, 2011).

The pattern of macronutrient accumulation by maize grown in Inner Mongolia is shown in **Figure 3**. Most of the accumulation (80% for N, 92% for P, and 85% for K) occurred within 80 days after sowing (tasseling stage), after which the accumulated nutrients (especially N and P) were rapidly transferred to the seeds. These trends suggest that the application of macronutrients needs to be done earlier in the season to match plant demand.

Using examples from Gansu and Xinjiang, the OPT increased grain yields by an average of 1,207 kg/ha, and farmer's income by more than USD 300/ha, when compared to FP (**Table 3**). Again, this difference can be attributed to a traditional reliance on under- or over-application of N and P, and the fact that most farmers ignore K application for their maize crops.

These results illustrate three clear recommendations to maize growers in northwest China: 1) addition of K to N and P fertilizers is critical to optimizing yields and profits; 2) the large variability in crop response to all nutrients indicates the

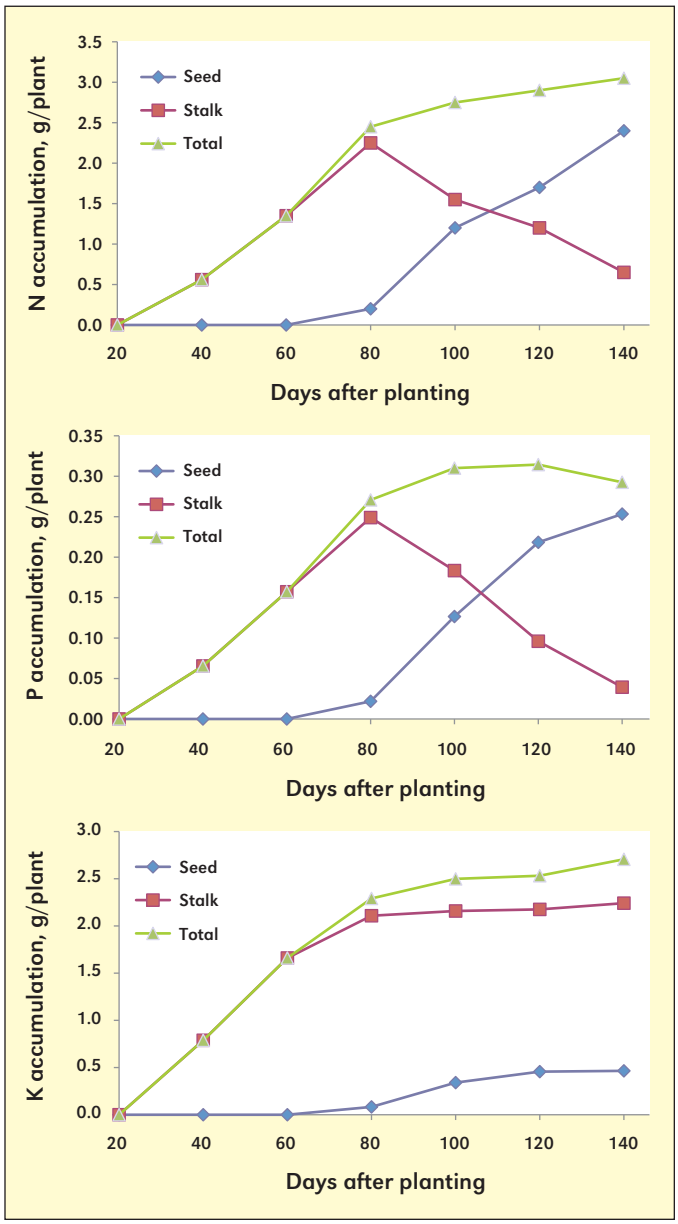

Figure 3. Accumulation of N, P, and K by maize in Inner Mongolia.

Table 3. Comparison of optimum NPK (OPT) and farmer practices (FP) in Gansu and Xinjiang.

Location	Year	Treatment	N	P_2O_5 kg/ha	K_2O	Mean yield†, t/ha	Cost‡, USD/ha	GRF§, USD/ha
Gansu	2006	OPT	225	120	150	12.0a	393	3,807
		FP	300	150	0	11.3b	350	3,617
Gansu	2007	OPT	300	120	150	13.2a	447	4,161
		FP	450	120	0	11.9b	431	3,734
Gansu	2007	OPT	300	120	150	10.4a	447	3,181
		FP	450	120	0	9.5a	431	2,894
Gansu	2007	OPT	225	150	150	11.3a	420	3,544
		FP	150	120	0	9.4b	215	3,073
Gansu	2007	OPT	225	150	150	14.5a	420	4,667
		FP	225	150	0	12.7b	296	4,159
Gansu	2007	OPT	300	120	150	8.9a	447	2,663
		FP	450	120	0	7.9b	431	2,336
Gansu	2009	OPT	225	120	90	9.0a	344	2,816
		FP	150	105	0	8.2b	201	2,659
Gansu	2009	OPT	225	90	60	9.4a	292	2,989
		FP	150	120	0	9.0a	215	2,937
Xinjiang	2006	OPT	232	70	34	11.3a	259	3,691
		FP	274	172	0	11.0a	351	3,489
Xinjiang	2009	FP+K	192	138	225	16.6a	448	5,375
		FP	192	138	0	14.4b	261	4,783
Xinjiang	2007	FP+K	192	138	90	9.8a	336	3,081
		FP	192	138	0	8.8b	261	2,821
Xinjiang	2008	FP+K	192	138	225	16.6a	448	5,375
		FP	192	138	0	14.6b	261	4,845
Xinjiang	2010	FP+K	192	138	225	13.8a	448	4,385
		FP	192	138	0	12.4b	261	4,082

†For each location, mean yields followed by the same letter are not significantly different at $p<0.05$.
‡Total costs (USD) of N, P, and K fertilizers: N = \$0.72/kg, P_2O_5 = \$0.89/kg, K_2O = \$0.83/kg. (1 USD = 6.30 RMB)
§GRF = gross return to fertilizers; Maize price = \$0.35/kg.

desperate need to develop fertilizer recommendation tools that consider more than just a soil test; and 3) the rates of N and P applied by farmers in northwest China are very high given the yield responses obtained and this needs to change to avoid unnecessary losses in profitability and as well as negative environmental impacts. BC

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References

Jin, J.Y. 2012. J. Sci. Food Agric. 92:1006–1009.

Li, S. and J.Y. Jin. 2011. Scientia Agricultura Sinica 44(20):4207-4229 (in Chinese).

MOA. 2010. China Agriculture Statistical Report. China Agriculture Press.

Portch, S. and A. Hunter. 2005. Special Publication No.5, PPI/PPIC China program.

Crop Nutrient Deficiency Photo Contest Entries Due December 11

December 11, 2012, is the deadline for entries in the annual IPNI contest for photos showing nutrient deficiencies in crops. An individual can submit an entry for each of the four nutrient deficiencies categories: nitrogen (N), phosphorus (P), potassium (K), and other (i.e. secondary nutrients and micronutrients).

Preference is given to original photos with as much supporting/verification data as possible. Cash prizes are offered to First Place (USD 150) and Second Place (USD 75) in each of the four categories, plus a Grand Prize of USD 200 will be awarded to the photo selected as best over all categories. Entries can only be submitted electronically to the contest website: www.ipni.net/photocontest. BC