Yield Responses and Potassium Use Efficiency for Winter Wheat in North-Central China

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Field experiments were conducted to study yield responses and K use efficiency parameters for wheat in three provinces across three years in North Central China. Results indicate that K application increased grain yield and profit for wheat in most cases. Determination of K use efficiency parameters demonstrated that there is potential to optimize K use efficiency further with best nutrient management practices.

Wheat (Triticum aestivum L.) is one of most important cereal crops in China, and K fertilizer applications have played a major role in increasing wheat yield. However, wheat production sometimes is limited because farmers give little attention to K application. Due to the limited potash resources in China and increasing fertilizer cost, efficient application of K is very important for high yield in wheat production. Understanding the yield responses, profitability and K use efficiency parameters of potassium application is essential for the further improvement of K use efficiency for high yielding wheat production systems.

To evaluate K responses on winter wheat in North-Central China, field experiments were carried out for nine sites/years in farmer fields in Hebei, Shandong and Shanxi provinces from 2006 to 2009. The trial soils were fluvo-aquic, brown and calcic cinnamon soils for Hebei, Shandong and Shanxi respectively. Prior to sowing, soil samples (0-20 cm) were collected and analyzed for nutrient status. Soil nutrients were determined with procedures applied by the National Laboratory of Soil Testing and Fertilizer Recommendation using the method described by Porch and Hunter (2002). Winter wheat was sown at the beginning of October and harvested in mid-June of the next year. Each experiment was designed in a randomized complete block with three replications of two treatments: with K application, and without K. Urea, single super phosphate and potassium chloride were selected as fertilizer sources. All other limiting nutrients in addition to K were applied using a rate suited to eliminate limitations on yield (**Table 1**).

About one half to one third of N, and all the P and K fertilizer, were applied as basal before sowing and the remaining N was applied as topdressing in early spring before the tillering stage of winter wheat. Irrigation, insect-control, inter-row tillage and other management activities were conducted according to farmers' practice. At harvest time, aboveground biomass including straw and grain yield were recorded. Seed and straw samples were randomly collected and oven-dried at 60° for determination of dry matter weight, and analyzed for total K. Plant samples were digested using wet oxidation with H_2SO_4

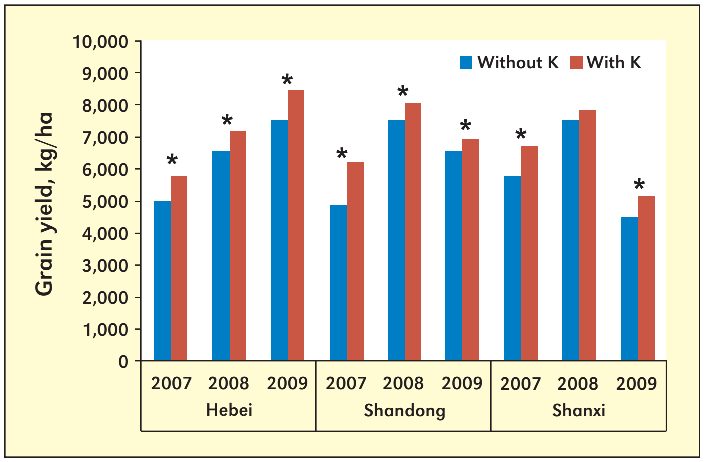


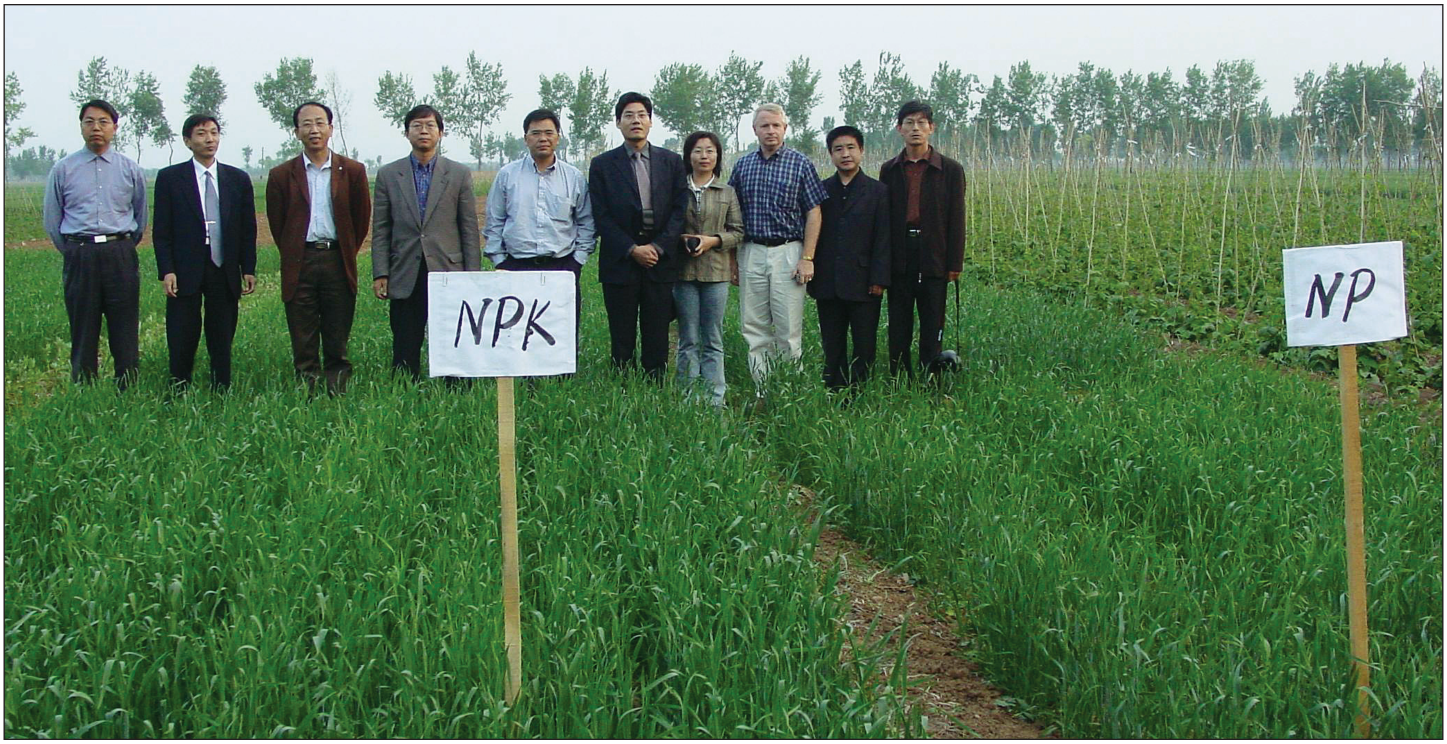
Figure 1. Grain yield of wheat in different sites/years as influenced by K application (the year of 2007, 2008 and 2009 in horizontal Axis indicated the wheat was harvested in June of 2007, 2008 and 2009, the same as below; the symbol * label above individual column indicates significance at P<0.05 between treatments without K and with K with t test analysis).

Abbreviations and notes:

Table 1. Fertilizer application rates and agro-chemical properties of tested soils.

Province	Location	Year	N rate	P_2O_5 rate	K_2O rate	pH	OM	NO_3^--N	NH_4^+-N	P	K
			---------- kg/ha ----------				%	-------------- mg/L --------------			
Hebei	Xinji	2007	180	100	75	8.4	0.70	ND[1]	4.9	22	78
	Xinji	2008	180	75	120	8.4	0.53	23.4	23.4	43	72
	Xinji	2009	180	60	90	8.3	0.49	23.9	10.6	18	50
Shandong	Haiyang	2007	240	30	120	7.9	1.17	3.5	8.9	59	45
	Qingzhou	2008	210	75	60	8.2	1.01	17.6	5.4	25	83
	Qingzhou	2009	240	75	90	7.7	0.80	20.6	12.2	28	75
Shanxi	Linfen	2007	195	90	150	8.1	0.35	3.1	20.5	21	72
	Linfen	2008	180	150	120	8.3	0.65	ND	0	29	266
	Linfen	2009	210	105	90	8.3	1.03	12.0	9.7	32	79

[1]ND-no data



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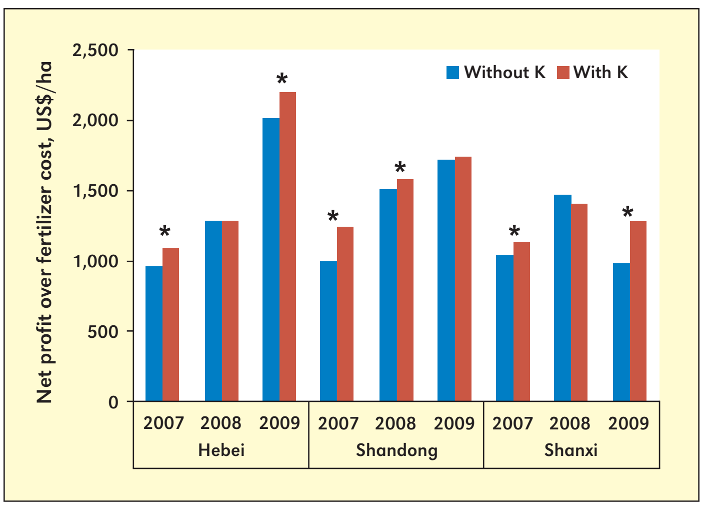

Figure 2. Net profit over fertilizer cost for wheat in different sites/ years as influenced by K application (the symbol * label above individual column indicates significance at P<0.05 between treatments without K and with K with t test analysis).

and H_2O_2. Total K was analyzed by flame spectrophotometers (Analysis Approach of Soil Agro-chemical Analysis, 2000).

Yield Responses to K Application

K application increased grain yields of wheat significantly in all sites except Shanxi in 2008. The yield responses to K application were 763 kg/ha (13%), 657 kg/ha (10%) and 889 kg/ha (11%) in 2007, 2008 and 2009 in Hebei, 1320 kg/ha (21%), 562 kg/ha (7%) and 378 kg/ha (5%) in 2007, 2008 and 2009 in Shandong, 857 kg/ha (13%), 379 kg/ha (5%) and 645 kg/ha (13%) in 2007, 2008 and 2009 in Shanxi, respectively (**Figure 1**). The low yield response to K application for Shanxi in 2008 was at the site with a very high soil K level, and the

Table 2. Fertilizer and crop prices used in profit analysis for Figure 2.

Province	Year	Wheat	N	P_2O_5	K_2O
		- - - - - - - - - - - - -	RMB/kg	- - - - - - - - - - - - -	
Hebei	2007	1.56	3.91	4.38	4.33
	2008	1.60	5.65	8.13	8.67
	2009	2.00	4.35	6.25	7.33
Shandong	2007	1.60	3.40	4.50	3.40
	2008	1.60	4.80	7.60	6.70
	2009	2.00	3.90	4.17	6.70
Shanxi	2007	1.44	3.90	5.20	3.70
	2008	1.65	5.70	7.60	9.00
	2009	2.00	3.70	7.30	7.00

1 US$=6.9 RMB

largest yield response to K application in Shandong in 2007 was related to very low soil test K level (**Table 1**). Therefore, to some extent, yield response was inversely related to soil fertility, in that yield response was low when soil test was high, and visa versa. These results have also been used to develop a fertilizer recommendation method based on yield response for use under conditions when soil testing is not available (Pampolino et al., 2011; He et al., 2012).

Profitability from K Application

Generally, the net profitability over fertilizer cost from K application followed similar trends to grain yields (**Figure 2**). In most cases (six out of nine), K application significantly increased net profitability by 12% in 2007 and 8% in 2009 in Hebei, 20% in 2007 and 5% in 2008 in Shandong, and 9% and 23% in 2007 and 2009 in Shanxi, respectively. There existed some variability across years and sites due to the changes in

Table 3. Potassium use efficiency parameters for wheat in different sites/years.

Province	RE (%)			AE (kg/kg K_2O)			PFP (kg/kg K_2O)		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
Hebei	47	35	47	10.2	5.5	9.9	77	60	94
Shandong	42	38	52	11.0	9.4	4.2	52	134	77
Shanxi	41	35	27	5.7	3.2	11.1	45	66	61

crop price and fertilizer cost. Comparatively, good profitability was observed in the year 2009 with good crop prices and moderate fertilizer cost, and low profitability in 2008 in Hebei and Shanxi was related to low crop prices and high fertilizer cost (**Table 2**). In this case, the farmers could decide how much K fertilizer was needed to obtain a good profit from K application.

K Use Efficiency

Nutrient use efficiency can be expressed by crop recovery efficiency (RE), agronomic efficiency (AE), and partial factor productivity (PFP) (Fixen, 2007). AE refers to the crop yield increase per unit nutrient applied, RE refers to the increase in plant nutrient uptake per unit nutrient applied, and PFP refers to the crop yield per unit nutrient applied. Measurements of RE, AE, and PFP for applied K resulted in large location-to-location variability. Mean RE values across three years were 47%, 44% and 34% for Hebei, Shandong and Shanxi, respectively. Mean AE values were 8.5 kg/kg, 8.2 kg/kg and 6.7 kg/kg, while mean PFP values were 77.kg/kg, 88 kg/kg, and 57 kg/kg for Hebei, Shandong and Shanxi, respectively. The different values for K nutrient use efficiency were related to how much fertilizer was used and how much grain yield or yield increase was obtained by K application. For example, the very high PFP value of 134 kg/kg in 2008 in Shandong was due to the relatively low K application rate (60 kg K_2O/ha) and very high grain yield (**Figure 1**).

In summary, K application increased wheat grain yield, and net profitability in most cases in North Central China. The average yield response to K application was less than 1 t/ha, and K use efficiency parameters of RE, AE and PFP were relatively low. Therefore, further best management practices (BMPs), such as 4R nutrient stewardship of right source at the right rate, right time and right place should be integrated into common practices to improve fertilizer use efficiency for wheat. BC

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