Nutrient Management within a Wheat-Maize Rotation System

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Shanxi Province's maize and wheat rotation contributes greatly to national food security. This study examined the implications of inadequate or imbalanced fertilization within the two cycles of this crop rotation.

Maize and wheat are the two major crops in Shanxi Province located in north central China. The crop rotation of wheat and maize is a particularly dominant cropping system for Shanxi's southern regions – an area that occupies 720,000 ha. Nutrient management on farmland plays an important role in crop production and environmental protection. However, the fertilizer decision-making process for many farmers is limited due to little understanding of soil nutrient status. This lack of understanding can lead to excessive or insufficient use of mineral fertilizer.

To maintain the sustainability of agricultural development, it is necessary to explore the benefits of fertilizer application through an improved nutrient management system. This study was conducted at the monitored village of Nanma in Shanxi to develop such an approach within the wheat/maize cropping system.

The field experiment was established in October 2005. The site had a semi-arid, monsoonal climate with an average annual rainfall of 498 mm, an average temperature of 12.6 °C, and a frost-free period of about 195 days. Soil at the site was classified as a calcic cinnamon soil with loamy texture. Prior to the experiment, soil samples (0 to 20 cm) were collected to analyze residual soil nutrients after a previous soybean crop. Soil nutrients were determined according to procedures applied by the National Laboratory of Soil Testing and Fertilizer Recommendation (Jin and Zhang, 1996). The physical and chemical properties of the test soil are given in **Table 1**.

The experiment was designed in a randomized complete block with six treatments and four replicates. Treatments included a zero fertilizer check (CK), a soil test-based balanced "optimum" nutrient application (OPT), and a series of nutrient omission treatments including OPT-N, OPT-P, OPT-K, and OPT-Zn. Urea, single superphosphate, potassium chloride, and zinc sulfate were selected as fertilizer sources. In each rotation of wheat and maize, all P, K, and Zn fertilizer and 180 kg N/ha was applied on winter wheat, while only 195 kg N/ha was applied on summer maize to corresponding treatment at jointing stage. The complete fertilizer application scheme is outlined in **Table 2**. Crop planting and harvest details are given in **Table 3**. Irrigation, insect-control, inter-row tillage, and other management activities were conducted according to farmer practice. After each harvest, soil samples (0 to 20 cm) and plant samples were collected and analyzed for total N, P, and K. Plant samples were digested using wet oxidation with H_2SO_4 and H_2O_2. Total N was determined using the Kjeldahl method, P was determined by vanadomolybdate yellow color development, and K was analyzed by flame spectrophotometers (Analysis Approach of Soil Agro-chemical Analysis, 2000).

Crop yield results indicate large variation between treatments (**Table 4**). Balanced fertilization produced the highest yields, while treatments omitting N, or fertilizer altogether, were the least productive. Yields within N omission plots declined between the first and third crops indicating a significant decrease in soil N supply capacity. This effect is easily observed in the photos taken during the jointing stage of the first and third crops (see next page).

Yields from the fourth crop (maize) were obviously higher across all treatments compared to the first maize crop. Ample rains amounting to 273 mm, or 72% of the year's total, fell during the summer maize growing

Table 1. Soil physical and chemical properties as tested in October 2005.

pH	OM, %	Ca	Mg	K	NH_4-N	P	S	B	Cu	Fe	Mn	Zn
		- mg/L -										
8.3	0.65	2,964	373	266	0.0	29	2.7	0.8	1.8	4.2	0.15	1.7
Critical value		401	122	78	50	12	12	0.20	1.0	1.0	5.0	2.0

Abbreviations and notes for this article: N= nitrogen; P = phosphorus; K = potassium; Zn = zinc; H_2SO_4 = sulfuric acid; H_2O_2 = hydrogen peroxide.

Table 2. Fertilizer treatment design for wheat and maize in 2005-2007.

	Nutrient application, kg/ha			
Treatments	N	P_2O_5	K_2O	Zn
OPT	375[1]	150	200	15
OPT-N	0	150	200	15
OPT-P	375[1]	0	200	15
OPT-K	375[1]	150	0	15
OPT-Zn	375[1]	150	200	0
CK	0	0	0	0

[1]180 kg N/ha applied on wheat, and 195 kg N/ha applied on maize.

Table 3. Schedule of crop planting and harvests.

Year	Crop/ Variety	Seeding rate	Seeding date	Harvest date
2005/06	Wheat/ Jinmai 81	225 kg/ha	Oct. 12, 2005	June 15, 2006
2006	Maize/ Jindan 958	45,000 plants/ha	June 15, 2006	Oct. 10, 2006
2006/07	Wheat/ Jinmai 81	225 kg/ha	Oct. 10, 2006	June 12, 2007
2007	Maize/ Zhengdan 958	45,000 plants/ha	June 17, 2007	Oct. 16, 2007

Plot size was 5 m × 5.3 m, or 26.5 m^2.

Table 4. Yields of four successive crops of wheat and maize in 2005-2007.

	2005-2006				2006-2007			
	Wheat grain yield		Maize grain yield		Wheat grain yield		Maize grain yield	
Treatments	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
OPT	7,307 a	100	6,073 a	100	7,792 a	100	8,033 a	100
OPT-N	5,192 c	71	3,814 c	63	3,596 c	46	5,561 b	69
OPT-P	6,824 b	93	5,503 b	91	6,354 b	82	7,887 a	98
OPT-K	6,804 b	93	5,755 b	95	7,450 a	96	7,898 a	98
OPT-Zn	7,020 ab	96	6,015 ab	99	7,525 a	97	7,568 a	94
CK	4,932 c	68	3,302 d	54	3,437 c	44	5,738 b	71

Treatments with the same letter do not differ at the α=0.05 level.

Table 5. Net returns of four successive crops in 2005-2007.

	2005-2006		2006-2007	
Treatments	Wheat profit	Maize profit	Wheat profit	Maize profit
	-------------------- US$/ha --------------------			
OPT	1,146 a	957 a	1,308 a	1,568 a
OPT-N	821 c	668 c	532 d	1,158b
OPT-P	1,158 a	857 b	1,117 b	1,537 a
OPT-K	1,149 a	902 b	1,340 a	1,540 a
OPT-Zn	1,095 a	947 ab	1,259 a	1,471 a
CK	986 b	578 d	716 c	1,195 b

Net return was calculated by differences between yield values and fertilizer costs only. Treatments with the same letter do not differ at the α=0.05 level.

season. This timely rainfall increased the yield potential of all treatments including those showing an apparent decline in productivity (i.e., OPT-N, OPT-P, and CK). Yield differences between the OPT and OPT-K treatments were significant in the first two crops (first rotation), but not in the following two crops (second rotation). Yield differences between the OPT and OPT-Zn treatments were not significant in all crops.

Crop profitability mirrored the yield responses, with the OPT treatment being most remunerative (**Table 5**). Although profitability of OPT treatment sometimes was slightly lower than that of OPT-P treatment (first crop) or OPT-K treatment (third crop) in a single season, the profitability differences between treatments of OPT and OPT-P (first crop) or OPT and OPT-K (third crop) were not statistically significant, and profitability of OPT treatment was always the highest within the rotation of wheat and corn (data not shown). Profitability was consistently lowest in OPT-N or CK plots and returns from these two treatments, as well as the OPT-P treatment, appeared to decrease throughout the duration of the study. The difference in profits between the OPT and OPT-P treatment was significant for the second and third crops. Differences between the OPT and the OPT-K or OPT-Zn were not significant.

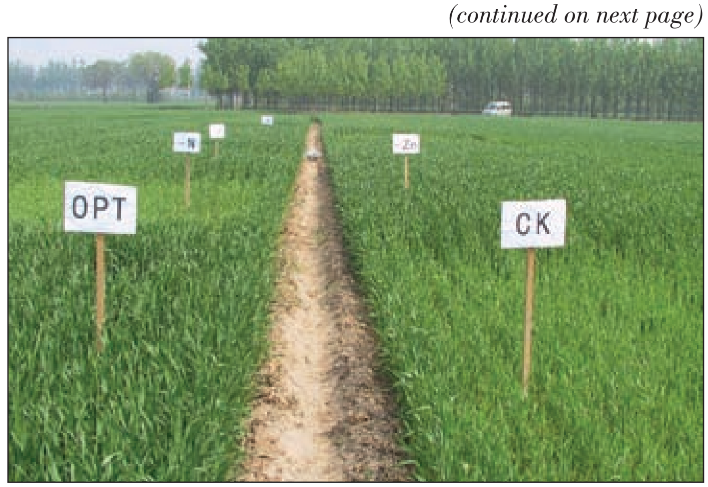
Nutrient uptake was almost always highest under the OPT applied in each cropping season (**Table 6**). Single crop nutrient use efficiency, especially N, was calculated throughout the study. Considering the first wheat/maize rotation, use efficiency of N, P, and K fertilizer was 39%, 14%, and 9%, respectively. The second rotation figures were 62%, 17%, and 21%, respectively.

Nutrient balances for N, P, and K were severely negative with omission of single nutrients, or all nutrients entirely (**Table 7**). The OPT treatment maintained a balance for N, generated a P surplus, but still resulted in a serious soil K deficit due to a significant increase in K uptake by crops. The K balance would be highly dependent upon the degree of crop residue recycling as a large portion of this K deficit could be eliminated given a continual recycling of straw materials. In this study, field management was conducted according to farmer practice, thus crop residue recycling was not considered.

In summary, balanced fertilization is essential for optimizing yields, increasing profits, and improving fertilizer use efficiency. This study outlines a rational fertilization strategy able to improve the economic outlook of this wheat-maize system. The above results from this study have several implications for nutrient management. 1) Balanced fertilization

(continued on next page)

At jointing stage in the first crop (April 6, 2006), this photo shows dark green color in the OPT, OPT-P, OPT-K, and OPT-Zn plots, while wheat was pale green and grew slowly in the OPT-N and CK plots. These plots exhibited insufficient soil N supply capacity.



At jointing stage in the third crop (April 29, 2007), the plots show similar effects as in the first crop. However, N deficiency symptoms are more severe in the OPT-N and CK plots than in the OPT plot.

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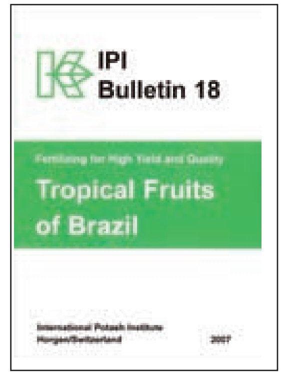

The International Potash Institute (IPI) has released a new 233-page bulletin titled *Fertilizing for High Yield and Quality: Tropical Fruits of Brazil.* It discusses the cultivation, mineral nutrition, and fertilization of 11 widely grown perennial, tropical fruits. Brazil is one of the world's major producers of tropical fruit. While much of the information and data is from Brazil, there are also cross references to production systems in other tropical climates…making the observations applicable to other parts of the world. The book is in English.

Content of the bulletin features 11 tropical fruits: acerola, banana, cashew, citrus, coconut, guava, mango, papaya, passion-fruit, pineapple, and soursop. Each chapter contains a brief overview of the geography of the area where the fruit is grown, the characteristics of the climate and soil, and recommendations for soil preparation and amelioration. The function of each nutrient for the given fruit is discussed, and a description of the visible symptoms caused by their deficiency provided. The authors emphasize fertilization practices for the various phases of plant development from nursery to production, with particular attention to irrigation (including fertigation).

The original version of the book (in Portuguese) was edited by Dr. Lindbergue Araújo Crisóstomo, EMBRAPA Center for Tropical Agro-Industry at Fortaleza (Brazil), together with Dr. Alexey Naumov, IPI Coordinator for Latin America and Associate Professor at the Faculty of Geography of Lomonosov Moscow State University (Russia). The English version is edited by A.E. Johnston of Rothamsted Research at Harpenden (United Kingdom).

The book (Bulletin No. 18: Tropical Fruits of Brazil) is available for purchase at US$14.00. To order a copy, look for "publications" at the IPI website: **>http://www.ipipotash.org/publications/detail.php?i=245<**

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is a very important measure to maintain the sustainability of agricultural development. 2) Nutrient application should pay attention to crop rotation and crop sequence. Thus, N should be applied within each non-legume cropping season, while P application in one cropping season may be enough to fulfill the requirements for the wheat and maize grown. 3) Best management practices for fertilizer should consider integration of fertilizer, water, and other cultivation practices.

Table 6. Responses of nutrient uptakes of four crops to successively fixed fertilization in the rotation of wheat and maize in 2005-2007.

	Nutrient uptake in 2005-2006, kg/ha						Nutrient uptake in 2006-2007, kg/ha					
	Wheat (first crop)			Maize (second crop)			Wheat (third crop)			Maize (fourth crop)		
Treatments	N	P	K	N	P	K	N	P	K	N	P	K
OPT	163	31	147	191	23	189	184	28	194	209	27	148
OPT-N	104	23	88	105	16	118	59	12	69	100	15	90
OPT-P	158	26	143	182	19	154	151	20	148	214	23	131
OPT-K	150	27	141	188	22	180	182	26	176	212	25	130
OPT-Zn	159	28	143	171	20	180	172	27	176	209	24	138
CK0	97	21	82	83	12	109	75	16	65	101	17	91
Efficiency[1], %	33	8	4	44			69	12	11	56		
Efficiency[2], %				39	14	9				62	17	21

Efficiency[1] denote the nutrient use efficiency of a single crop; Efficiency[2] denote the nutrient use efficiency of the wheat/maize rotation.

Table 7. Balance sheet of nutrients of four crops (two rotations) from 2005 to 2007.

	Nutrient uptake, kg/ha			Nutrient input, kg/ha			Balance, kg/ha		
Treatments	N	P	K	N	P	K	N	P	K
OPT	747	109	678	750	132	332	3	23	-346
OPT-N	368	66	364	0	132	332	-368	66	-32
OPT-P	705	89	576	750	0	332	45	-89	-244
OPT-K	732	101	627	750	132	0	18	31	-627
OPT-Zn	712	100	637	750	132	332	38	32	-305
CK0	357	66	346	0	0	0	-357	-66	-346

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