Evaluation of In-season Nitrogen Management for Summer Maize in the North China Plain

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Field experiments tested N fertilizer at different rates and ratios of basal:topdress application. A total N rate of 120 to 180 kg/ha was shown to maximize grain yield and, with split application, reduce N inputs by 25 to 50% compared to typical farm practice within the North China Plain.

The North China Plain (NCP) is one of the most important areas for summer maize production in China. The crop grows from the middle of June to the end of September and high yields in this intensively farmed region have been obtained over the past 2 decades through excessive N fertilization (He et al., 2009; Ju et al., 2009). This results in the accumulation of soil N as leachable NO_3^-, which risks groundwater pollution and low NUE by crops (Cui et al., 2009; Zhao et al., 2010). At present, typical farmer practice is to apply all their N fertilizer at once, either as a basal application before planting or as topdressing during the 7-leaf stage. Neither of these patterns of N application can provide a soil N supply that is in synchrony with crop N demand.

It is essential to develop appropriate N management methods that can overcome any environmental problems or low NUE that results from excessive N application. It is also important to promote the development of sustainable agricultural production within this region. The most logical approach to increasing NUE is to combine applications of basal N and topdressed N at critical growth stages that coincide with crop N demand and seasonal soil N supply. High-yielding maize varieties show increased N uptake after anthesis, and the 8 to 10-leaf stages are critical times for topdressed N (Barbieri et al., 2008). Since current N management practices for summer maize in this region are not tailored to these growth requirements, this study evaluated in-season N management based on grain yield and crop N uptake, and provides a theoretical base for reducing N application and enhancing NUE in the NCP.

Field experiments were conducted simultaneously on farms near the cities of Hengshui and Xinji (37°N, 115°E), in Hebei province, from July to October 2009. The two sites were approximately 25 km apart, and had similar climatic conditions. The previous crop at both sites was winter wheat. In Hengshui, the soil texture was clay loam, and the chemical properties in the 0 to 20 cm soil profile were: pH 8.4; organic matter 13.4 g/kg; Olsen-P 8.9 mg/kg; and NH_4OAc-K 103 mg/kg. Before planting, the NH_4^+-N content in the 0 to 20, 20 to 40, 40 to 60, 60 to 80, and 80 to 100 cm soil layers were 3.1, 0.9, 2.5, 13.2, and 10.0 mg/kg, respectively, and NO_3-N content were 12.2, 11.6, 12.7, 7.2, and 6.3 mg/kg, respectively. In Xinji, the soil texture was sandy loam, and the chemical properties in the 0 to 20 cm soil profile were: pH 8.6; organic matter 0.82 g/kg; Olsen-P 6.2 mg/kg; and NH_4OAc-K 97 mg/kg. Before planting, the NH_4^+-N content in the 0 to 20, 20 to 40, 40 to 60, 60 to 80, and 80 to 100 cm soil layers was 1.2, 1.2, 1.1, 1.0, and 0.8 mg/kg, respectively, while the NO_3-N contents were 14.8, 11.9, 10.4, 7.8, and 6.1 mg/kg, respectively.

Common abbreviations and notes: N = nitrogen; P = phosphorus; NUE = nitrogen use efficiency; NH_4OAc-K = ammonium acetate-extractable K; NH_4^+ = ammonium; NO_3^- = nitrate; RE = recovery efficiency; AE = agronomic efficiency; HI = harvest index.

Besides a zero-N control, seven N treatments varied the amount and/or ratio of basal: top-dressed N (**Table 1**). A 0:240 treatment (i.e. 0 kg basal and 240 kg topdressed) was designed to simulate the N application pattern commonly used by farmers. Basal N (urea) was broadcast before planting followed by 600 m^3/ha of irrigation water; while topdressed N was applied at the V10 (10-leaf) stage. Before planting, all plots received 90 kg P_2O_5/ha and 90 kg K_2O/ha. All winter wheat residues were left on the field. The maize variety was Zhengdan 958.

Table 1. Experimental design for nitrogen applied to summer maize (Hengshui and Xinji, Hebei).

Treatment	Basal	Topdress	Topdress date
	---------- kg/ha	----------	
N0	0	0	-
N120 (0:120)[a]	0	120	June 25
N120 (30:90)	30	90	June 25
N120 (60:60)	60	60	June 25
N180 (0:180)	0	180	June 25
N180 (45:135)	45	135	June 25
N180 (90:90)	90	90	June 25
N240 (0:240)[b]	0	240	July 17

[a] Values in the parenthesis indicate basal:topdress N rate.
[b] Farmers' practice treatment.

Grain Yield, Crop N Uptake and Utilization

In Hengshui, no significant difference in grain yield was found among N supplying treatments, and only the low rate of 120 kg N/ha was required to achieve the maximum grain yield (**Table 2**). Combining basal N with topdressed N promoted crop N uptake, RE_N, and AE_N; but did not impact HI or HI_N with the exception of the 0: 240 treatment, which generated a significantly lower HI than some treatments that received basal N.

The Xinji site was more responsive to N as all treatments receiving basal N out-yielded the control, and the 180 kg N/ha rate achieved the maximum grain yield (**Table 2**). When N was applied solely as a topdressing, no significant differences in grain yield were found among the N0, N120 (0:120), and N180 (0:180) treatments. Crop N uptake, RE_N, and AE_N showed similar trends to those observed in Hengshui. Treatments that received basal N showed higher HI values than the zero-N control, but there were no significant differences in HI_N except for the low HI_N value of the N240 (0:240) treatment.

At both sites, RE_N and AE_N increased along with basal N rate. Maize grown in Hengshui showed higher grain yield, crop N uptake, and NUE than in maize grown in Xinji; however, the HI and HI_N values were lower for maize grown in Hengshui (**Table 2**).

Nitrogen Balance

The initial N_{min}, apparent N mineralization, and crop N uptake in Hengshui were higher than those values obtained in Xinji (**Table 3**). Thus, indigenous N supply in Hengshui was higher than that in Xinji. Compared with treatments that only received top-dressed N at V10 stage, those that received both basal and top-dressed N showed reduced residual N_{min} after maturity. In Hengshui, soil residual N_{min} was higher in the N240 (0:240) treatment than in the N120 (0:120) treatment. In Xinji, however, no significant difference was found among the three N treatments that did not receive basal N. At both sites, the apparent N losses during the maize growing season increased with total N application rate. For treatments receiving the same amount of total N, the apparent N loss increased with topdress N rate, and these values were significantly higher in Xinji than in Hengshui.

Discussion and Conclusions

In this study, basal application of N did not affect grain yield when N was also being topdressed in Hengshui because of high indigenous N supply. In Xinji, the highest grain yield was achieved via application of N as basal and top-dressed fertilizer. This despite reports that indicate no basal N fertilizer is recommended to improve NUE when soil N indigenous supply is considered adequate (Zhao et al., 2012).

In Hengshui and Xinji, the total N rate of 120 and 180 kg N/ha—half applied basally and half topdressed—could meet the N demands of high yielding maize during the entire growing season. The optimal N application rates determined here for maximum grain yield indicate that N fertilizer could be reduced by more than 50% and 25% in one summer maize season in Hengshui and Xinji, respectively. Therefore the

Table 2. Maize grain yield, crop N uptake, nitrogen use efficiency (RE_N and AE_N), HI, and HI_N of different N treatments (Hengshui and Xinji, Hebei).

Sites	Treatment	Grain yield, kg/ha	Crop N uptake, kg N/ha	RE_N, %	AE_N, kg/kg	HI, %	HI_N, %
Hengshui	N0	7,384b[a]	179c	-	-	54.5a	60.2a
	N120 (0:120)	7,877ab	207b	23.6d	4.1b	54.2a	59.9a
	N120 (30:90)	8,181a	231ab	43.2b	6.6a	54.8a	60.7a
	N120 (60:60)	8,231a	247a	56.6a	7.1a	54.5a	60.6a
	N180 (0:180)	8,037ab	212b	18.6d	3.6bc	53.3ab	60.5a
	N180 (45:135)	8,088ab	217b	21.5d	3.9b	54.7a	62.9a
	N180 (90:90)	8,181a	239a	33.5c	4.4b	52.3ab	60.6a
	N240 (0:240)	8,074ab	240a	25.3d	2.9c	50.1b	57.1a
Xinji	N0	6,158c	103d	-	-	57.6a	70.1a
	N120 (0:120)	6,299c	124c	17.5e	1.2d	51.7b	63.9ab
	N120 (30:90)	6,908b	153a	41.9a	6.2ab	55.8a	67.3ab
	N120 (60:60)	6,769b	147ab	36.3b	5.1b	55.8a	65.2ab
	N180 (0:180)	6,677bc	137b	19.0e	2.9c	51.3b	64.0b
	N180 (45:135)	7,228ab	151ab	26.2c	5.9b	56.2a	68.8ab
	N180 (90:90)	7,435a	154a	28.3c	7.2a	56.6a	67.4ab
	N240 (0:240)	6,912b	155a	21.8d	3.1c	50.2b	62.4b

[a] Within each column, mean values followed by different letters are significantly different ($p < 0.05$).

Table 3. Nitrogen balance sheet for treatments applied during maize growing season (Hengshui and Xinji, Hebei).

		N output			N input		
Site	Treatment	N rate (1)	Initial Nmin[a] (2)	Apparent N mineralization (3)	Crop N uptake (4)	Residual Nmin[b] (5)	Apparent N loss (1)+(2)+(3)-(4)-(5)
Hengshui	N0	0	217	108	179c[d]	146d	0
	N120 (0:120)	120	217	108	207b	242b	-4d
	N120 (30:90)	120	217	108	231ab	237b	-22e
	N120 (60:60)	120	217	108	247a	218c	-20e
	N180 (0:180)	180	217	108	212b	257ab	36b
	N180 (45:135)	180	217	108	217b	256ab	32b
	N180 (90:90)	180	217	108	239ab	247b	19c
	N240 (0:240)	240	217	108	240ab	272a	54a
Xinji	N0	0	157	61	103c	114d	0
	N120 (0:120)	120	157	61	124b	155ab	51c
	N120 (30:90)	120	157	61	153a	131c	46c
	N120 (60:60)	120	157	61	147ab	138c	45c
	N180 (0:180)	180	157	61	137b	156ab	97b
	N180 (45:135)	180	157	61	151ab	149bc	96b
	N180 (90:90)	180	157	61	154a	143bc	93b
	N240 (0:240)	240	157	61	155a	165a	130a

[a] Initial N_{min}, soil mineral N in 0 to 100 cm soil layer before planting.
[b] Residual N_{min}, soil mineral N in 0 to 100 cm soil layer after harvest.
[c] Within each column, means followed by different letters are significantly different ($p < 0.05$).

apparent risk to N loss can be reduced if compared with traditional N fertilization practice. The question of whether N rates of 120 and 180 kg/ha can sustain high grain yields in the next crop season requires further study. However, for optimum N management, fertilizer applications should be tailored to each specific field or region, because N availability and N use vary according to crop growth, soil fertility, and soil texture. BC

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4R Nutrient Stewardship – Update

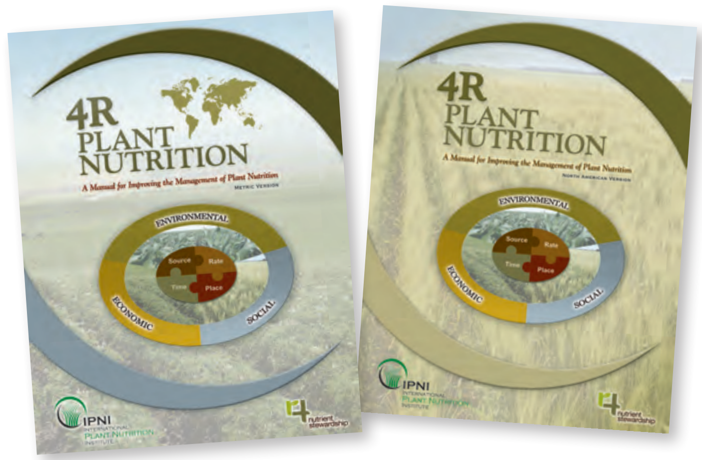
Metric Version of 4R Plant Nutrition Manual Now Available

In further support 4R Nutrient Stewardship and its approach to implementing fertilizer best management practices, the International Plant Nutrition Institute (IPNI) has released a second version of its 4R Plant Nutrition Manual—one that is fully metric.

This metric version is a follow-up to IPNI's initial release of the 4R Plant Nutrition Manual in March 2012, which was designed to fit a North American user through its predominant use of U.S. (Imperial) units.

4R Nutrient Stewardship is one of IPNI's core strategies to support agriculture's ability to meet the world's production needs in a sustainable manner. The 4R concept is simple—apply the right source of nutrient, at the right rate, at the right time, and in the right place—but the implementation is knowledge-intensive and site-specific. 4R Nutrient Stewardship also considers economic, social, and environmental dimensions of nutrient management and because of these considerations 4R Nutrient Stewardship has been recognized by the world's fertilizer industry as an essential approach to the ensuring sustainability of agricultural systems.

The 4R Plant Nutrition Manual includes chapters on the scientific principles behind each of the four R's or "rights". It discusses adoption of 4R practices on the farm, approaches to nutrient management planning, and measurement of sustainability performance. The manual is intended to help the reader adapt and integrate the fundamental 4R principles into a comprehensive method of nutrient management that meets the criteria of sustainability. A mix of learning modules and case studies demonstrate the universality of the 4R Nutrient Stewardship concept through its application to diverse cropping systems used within small enterprises, large commercial farms, and plantations.



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