Characterization of nitrogen use strategies in commercial maize hybrids

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Introduction:

- Despite current interest in developing ‘nitrogen use efficient’ maize hybrids, there are relatively few published reports of variation for responses to N in modern commercial hybrids.
- This information is of critical importance for developing product concepts (e.g. NUE transgenes) for improved nitrogen use in maize production.
- In 2006 – 2010, we evaluated 58 hybrids (locally-adapted hybrids with various biotech traits) under six levels of N to determine the means and ranges for key N use traits like grain yield at low N and response to N fertilizer.

Research approach:

- This experiment was conducted over five years at the University of Illinois Department of Crop Sciences Research and Education Center at Champaign-Urbana, IL. The soil type was a Drummer-Flanagan soil association (Typic Endoaquolls) with adequate P and K fertility.
- In each year, a random collection of locally-adapted commercial maize hybrids (Table 1) were planted in a split-block field design (main plot = N rate) with four replications.
- The experiments were planted in an approximate one-month window ranging from April 24th (2006) to May 27th (2009). The plots were overplanted and thinned to a final population of 79,000 plants ha^{-1}.
- Fertilizer treatments consisted of $(NH_4)_2SO_4$ (21-0-0-24S) incorporated in a diffuse band between the rows at V3-V4. Six fertilizer rates were used (0 – 280 kg N ha^{-1}) in 56 kg N ha^{-1} increments.

Table 1. Commercial hybrids evaluated for their N responses.

Entry	Brand	Hybrid (Year)	Entry	Brand	Hybrid (Year)
1	Agrigold	A6467 (2006)	44	DEKALB	DKC65-44 (2008)
2	Asgrow	RX756 (2006)	45	Pioneer	32B83 (2008)
3	Beck's	5827 (2006)	46	Pioneer	33D14 (2008)
4	Crow's	7655 (2006)	47	Pioneer	33F88 (2008)
5	DEKALB	DKC57-79 (2006)	48	Pioneer	33H29 (2008)
6	DEKALB	DKC58-80 (2006)	49	Pioneer	33W84 (2008)
7	DEKALB	DKC60-18 (2006)	50	DEKALB	DKC61-19 (2009)
8	DEKALB	DKC60-19 (2006)	51	DEKALB	DKC61-33 (2009)
9	DEKALB	DKC61-22 (2006)	52	DEKALB	DKC61-69 (2009)
10	DEKALB	DKC61-54 (2006)	53	DEKALB	DKC62-54 (2009)
11	DEKALB	DKC63-75 (2006)	54	DEKALB	DKC63-42 (2009)
12	DEKALB	DKC64-77 (2006)	55	DEKALB	DKC65-44 (2009)
13	FS	FS 6755 (2006)	56	DEKALB	DKC65-63 (2009)
14	Golden Harvest	H-8991 (2006)	57	FS	FS 61BV3 (2009)
15	Mycogen	2P781 (2006)	58	Pioneer	32B83 (2009)
16	Mycogen	2P788 (2006)	59	Pioneer	33D14 (2009)
19	Pioneer	33N11 (2006)	60	Pioneer	33F88 (2009)
20	Agrigold	A6467 (2007)	61	Pioneer	33H29 (2009)
21	Asgrow	RX674 (2007)	62	Pioneer	33W84 (2009)
22	Asgrow	RX785 (2007)	63	Pioneer	34A89 (2009)
23	Asgrow	RX832 (2007)	64	Pioneer	35K04 (2009)
24	Beck's	5827 (2007)	65	DEKALB	DKC59-35 (2010)
25	DEKALB	DKC57-79 (2007)	66	DEKALB	DKC61-19 (2010)
26	DEKALB	DKC60-18 (2007)	67	DEKALB	DKC61-21 (2010)
27	DEKALB	DKC61-66 (2007)	68	DEKALB	DKC61-22 (2010)
28	DEKALB	DKC63-39 (2007)	69	DEKALB	DKC61-33 (2010)
29	DEKALB	DKC63-74 (2007)	70	DEKALB	DKC61-69 (2010)
30	FS	FS 6996 (2007)	71	DEKALB	DKC61-72 (2010)
31	Great Heart	HT-188 (2007)	72	DEKALB	DKC63-42 (2010)
32	Midwest	79880B (2007)	73	DEKALB	DKC63-84 (2010)
33	Pioneer	33N11 (2007)	74	DEKALB	DKC65-63 (2010)
34	Pioneer	34P88 (2007)	75	FS	FS 61BV3 (2010)
35	Agrigold	A6457 (2008)	76	Golden Harvest	H-9014 (2010)
36	Agrigold	A6639 (2008)	77	Mycogen	2K679 (2010)
37	Asgrow	RX785 (2008)	78	Mycogen	2T784 (2010)
38	Beck's	5387 (2008)	79	Pioneer	P1184XR (2010)
39	Beck's	6733 (2008)	80	Pioneer	P1236XR (2010)
40	DEKALB	DKC61-19 (2008)	81	Pioneer	P32B83 (2010)
41	DEKALB	DKC61-69 (2008)	82	Pioneer	P33W80 (2010)
42	DEKALB	DKC62-29 (2008)	83	Pioneer	P33W84 (2010)
43	DEKALB	DKC64-24 (2008)	84	Pioneer	P34A89 (2010)

Objective: Characterize genetic variation for response of grain yield to nitrogen fertilizer in commercial maize hybrids.

Effect of year on average N response curve:

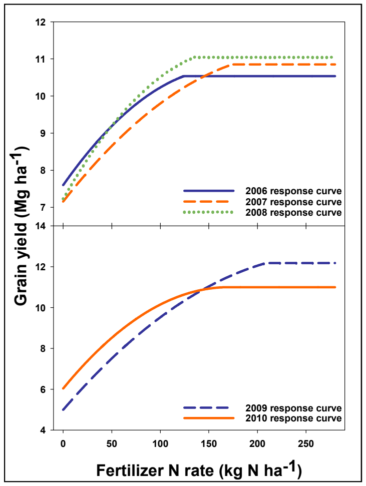


Table 2. Means for check plot yield (grain yield at 0 kg N ha^{-1}), initial N response (difference between 0 and 56 kg N ha^{-1}), and maximum grain yield predicted by a quadratic with plateau regression model. Yields expressed in Mg ha^{-1} at 0% moisture concentration. Genetic ranges for each year are shown in parentheses below each mean.

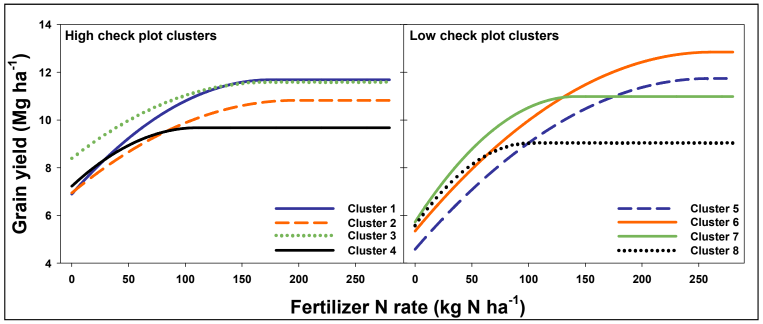
Year	Check plot yield	Initial N response	Maximum yield
	-------------- Mg ha^{-1} -------------		
2006	7.5	2.1	10.5
	(6.2-9.1)	(1.2-3.2)	(8.4-12.3)
2007	7.1	1.9	10.9
	(5.7-8.5)	(0.5-2.7)	(10.1-12.1)
2008	7.1	2.6	11.1
	(5.7-8.4)	(1.8-3.4)	(8.7-12.1)
2009	5.0	2.6	12.2
	(4.1-5.9)	(1.9-3.1)	(10.6-13.3)
2010	5.9	3.2	11.0
	(4.9-7.1)	(1.7-4.1)	(9.3-12.0)

Figures 1A-1B. Quadratic with plateau regression models for each of the five years included in this study. Each curve represents the average N response across all hybrids evaluated in that year.

Results and discussion

- 2006, 2007, and 2008 had higher check plot yields (7.1 – 7.5 Mg ha^{-1}), compared to 2009 and 2010 (5.0 – 5.9 Mg ha^{-1}) (Figures 1A-1B, Table 2).
- Despite the pronounced effect of environment on check plot yield, similar genetic ranges for check plot yield occurred in each year (Table 2). The average genetic range for check plot yield was 2.5 Mg ha^{-1}.
- Initial N response (difference between 0 and 56 kg N ha^{-1}) exhibited an average genetic range of 1.9 Mg ha^{-1} (Table 2).
- Initial N response was negatively correlated with check plot yield ($r = -0.44$; $P < 0.0001$) (data not shown).

Cluster analysis of N responses:



Figures 2A-2B. Quadratic with plateau regression models for each of the eight clusters identified by hierarchical cluster analysis. Clusters 1-4 (Fig. 2A) had high check plot yields (> 6.0 Mg ha^{-1}) while clusters 5-8 had low check plot yields (< 6.0 Mg ha^{-1}).

Results and discussion

- Hierarchical cluster analysis (Ward’s minimum variance approach) was used to group hybrids with similar N responses using check plot yield, initial N response, and maximum grain yield as variables.
- Check plot yield distinguished clusters 1-4 (mean = 7.3 Mg ha^{-1}) from clusters 5-8 (mean = 5.3 Mg ha^{-1}) (Figures 2A-2B, Table 3).
- Clusters 1-3 reached similar maximum yields, but differed in check plot yield (Δ = 1.6 Mg ha^{-1}) and initial N response (Δ = 1.2 Mg ha^{-1}). Clusters 1, 2, and 4 had similar check plot yields (mean = 6.9 Mg ha^{-1}), but differed in their initial N responses and maximum yields (Figures 2A-2B, Table 3).
- Clusters 5 and 6 are populated by hybrids grown in 2009, but differ in check plot yield (Table 3). Initial N responses were similar, but cluster 6 achieved a greater maximum yield as a result of its increased check plot yield (Figure 2B).
- In the present year of this study (2010), the top three yielding hybrids were in cluster 1 (high check plot yield with large initial response to N) (data not shown), demonstrating the importance of this N use strategy to high grain yields.

Table 3. Means for each of the eight clusters identified by hierarchical cluster analysis. Maximum yields estimated using a quadratic with plateau regression model. Yields expressed in Mg ha^{-1} at 0% moisture concentration.

Cluster	# of hybrids	Check plot yield	Initial N response	Maximum yield	2006	2007	2008	2009	2010
		-------------- Mg ha^{-1} -------------			# of hybrids from each year				
1	10	6.7	3.2	11.7	1	1	3	0	5
2	25	6.9	2.2	10.9	7	10	4	0	4
3	10	8.3	2.0	11.6	3	2	5	0	0
4	8	7.2	1.8	9.7	5	2	1	0	0
5	7	4.6	2.6	11.6	0	0	0	7	0
6	8	5.4	2.5	12.8	0	0	0	8	0
7	9	5.6	3.8	11.0	0	0	1	0	8
8	5	5.6	2.7	9.3	1	0	1	0	3

Conclusions:

1. Check plot yield is a key determinant of hybrid maize grain yield, and is affected by both genetics and environment.
2. For years such as 2009, in which N loss dominates, selection of hybrids with a high check plot yield contributes to a high overall grain yield.
3. The most desirable N use strategy incorporates a combination of high check plot yield and a large response to N fertilizer, yet these hybrids are relatively rare.