VERIFYING NITROGEN APPLICATION RATES FOR CORN

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Introduction

The price of fertilizer nitrogen (N) has increased substantially over the past three months and ranges from $0.37 to 0.60/lb N with anhydrous ammonia at the lower end of the range and poly coated urea (ESN®) at the upper end of the range. Many dealerships are expecting the price of N fertilizer to increase as we move towards planting. With the increasing N prices, questions are being asked regarding how much N should be applied to maximize economic return in corn production. As of mid-December 2007, the price of corn was between $3.80 to $4.25/bu depending on contract, location, etc. Thus, the N:corn price ratio varies from 0.09 to 0.16. These price ratios do not differ substantially from the price ratios that were prevalent in winter 2005/2006.

The maximum return to N (MRTN) tool that was released in 2006 can be used to determine an appropriate N rate for corn with fluctuating N and corn prices. Current N fertilizer and grain prices suggest lower N fertilizer rates should be applied to maximize economic return. The object of this project was to evaluate how the MRTN N rate guidelines performed in 2007.

The MRTN tool will be described briefly; for more details please see Laboski et al. (2006) and Laboski (2006).

The new N rate guidelines for Wisconsin are provided in Table 1. In order to determine the N application rate using this table, one must first know:

- ✓ Soil yield potential. All soils in Wisconsin have been classified into yield potential categories based on the soil's rooting depth, water holding capacity, drainage, and length of growing season. Soil yield potentials can be found in UWEX publication A2809 "Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin".
- ✓ Previous crop.
- ✓ N:corn price ratio. This is the price of N per pound divided by the price of corn per bushel.

Using these three pieces of information, a N rate can be identified that will, on average, maximize economic return to N (MRTN). A range of N rates that will produce economic profitability within one dollar per acre of the maximum can also be identified. Guidelines for choosing which part of the range to use are provided in the list below.

- ➢ If there is > 50% residue cover at planting, use the upper end of the range.
- ➢ When corn follows small grains on medium and fine textured soils, the mid-to-low end of the profitable range is most appropriate.
- ➢ If 100 % of the N will come from organic sources, use the top end of the range. In addition, up to 20 lb N/a in starter fertilizer may be applied in this situation.
- ➢ For medium and fine textured soils with: < 2% organic matter, use the high end of the range; > 10 % organic matter, use the low end of the range.
- ➢ For coarse textured soils with: < 2% organic matter, use the high end of the range; > 2 % organic matter, use the mid to low end of the range.

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- If a medium yield potential soil is irrigated, use the rates suggested for high yield potential soils.
- If there is a likelihood of residual N (carry over N), then use the low end of the range or use the high end of the range and subtract preplant nitrate test (PPNT) credits.

Table 1. Suggested N application rates for corn at different N:corn price ratios.

Soil and Previous Crop	N:Corn Price Ratio ($/lb N:$/bu)			
	0.05	0.10	0.15	0.20
	lb N/a (Total to Apply) [3]			
HIGH/V. HIGH YIELD POTENTIAL SOILS				
Corn, Forage legumes, Leguminous vegetables, Green manures[4]	165[1] (135-190)[2]	135 (120-155)	120 (100-135)	105 (90-120)
Soybean, Small grains[5]	140 (110-160)	115 (100-130)	100 (85-115)	90 (70-100)
MEDIUM/LOW YIELD POTENTIAL SOILS				
Corn, Forage legumes, Leguminous vegetables, Green manures[4]	120 (100-140)	105 (90-120)	95 (85-110)	90 (80-100)
Soybean, Small grains[5]	90 (75-110)	60 (45-70)	50 (40-60)	45 (35-55)
IRRIGATED SANDS AND LOAMY SANDS				
All crops[4]	215 (200-230)	205 (190-220)	195 (180-210)	190 (175-200)
NON-IRRIGATED SANDS AND LOAMY SANDS				
All crops[4]	120 (100-140)	105 (90-120)	95 (85-110)	90 (80-100)

[1] Rate is the N rate that provides the maximum return to N (MRTN).
[2] Range is the range of profitable N rates that provide an economic return to N within $1/a of the MRTN.
[3] These rates are for total N applied including N in starter fertilizer and N used in herbicide applications.
[4] Subtract N credits for forage legumes, leguminous vegetables, green manures, and animal manures. This includes 1st, 2nd, and 3rd year credits where applicable. Do not subtract N credits for leguminous vegetables on sand and loamy sand soils.
[5] Subtract N credits for animal manures and 2nd year forage legumes.

Methods and Materials

University of Wisconsin faculty and staff were involved in conducting these on-farm plots in cooperation with participating farms. Thirteen plots were located throughout the state (Figure 1). Soybean was the previous crop for seven locations and corn for six locations (Table 2). Very high, high, and medium yield potential soils were represented along with non-irrigated sands/loamy sands. Site selection criteria included:

a) Previous crops: corn, soybean, vegetable crops, or small grains.
b) Avoid sites with first or second year corn after alfalfa or a forage legume.
c) Avoid sites where manure or other organic N sources have been applied in the last three years.
d) Uniform soils typically used for corn production.

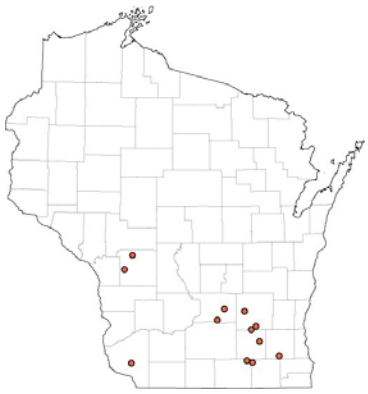

Figure 1. Locations of the thirteen MRTN on-farm verification plots in 2007.

The experimental design was a randomized complete block with three replications. The plot size was flexible in that any number of rows or length was acceptable. However, the harvested area was the same for all replications at a location. The treatments were: medium yield potential soils (MYPS): 0, 40, 80, 120, 160 lb N/a; high yield potential soils (HYPS): 0, 40, 80, 120, 160, 200 lb N/a. Nitrogen source, application method, and application timing were chosen to minimize N losses at each site (Table 2).

An adapted corn hybrid was planted at each site. Routine soil samples were collected prior to planting and analyzed for P, K, pH, and organic matter (OM). Preplant nitrate (PPNT) samples were also collected to a depth of two feet.

Site characteristics such as county, soil yield potential, soil name, OM content, surface residue at planting, tillage, and PPNT N credit are provided in Table 2. Sites 37, 39, and 40 were tile drained. No site was irrigated or had a history of manure application within the previous three years.

Grain yield response to N fertilizer was fit with quadratic plateau, linear plateau, and quadratic models. The model with the best R^2 was chosen to represent the yield response. The economic optimum N rate (EONR) for each site was calculated based on N:corn price ratios of 0.05, 0.10, and 0.15. For all price ratios the price of corn was set at $4.00/bu and the price of N varied: $0.20/lb, $0.40/lb, and $0.60/lb for 0.05, 0.10, and 0.15 price ratios, respectively. Performance of MRTN was assessed by using the yield response function to determine the yield that would have been obtained if different N rates were applied.

Results and Discussion

The agronomic optimum N rate (AONR) is the amount of fertilizer N needed to maximize grain yield. AONR and the yield at AONR (maximum yield) is given in Table 2. On high and very high yield potential soils, the AONR ranged form 26 to 157 lb N/a for corn following soybean and 93 to 171 lb N/a for corn following corn.

The economic optimum N rate (EONR) is the N rate where the net return on the investment in N is maximized. The yield at EONR can be less than the maximum yield, but depends upon the shape of the response curve for a field and the N:corn price ratio that is being considered. The effectiveness of the MRTN approach in accurately predicting the EONR for each site for 0.05, 0.10, and 0.15 N:corn price ratios is provided in Tables 3, 4, and 5, respectively. In the comparisons, the MRTN N rate was chosen based upon soil yield potential, previous crop, and the guidelines for selecting which portion of the MRTN range to use. Thus, if a site had greater than 50 % residue cover the top end of the range was chosen for the comparison as opposed to the actual MRTN rate. This distinction is import because it represents the decision that a grower would make based on Table 1 and the guidance points that follow.

In Tables 3 through 5, the MRTN N rate for each N:corn price ratio is provided along with the yield obtained at the N rate. This is compared to the observed EONR for each site at the same N:corn price ratio. The columns labeled "Difference (MRTN – EONR)" are the difference in N rate and yield obtained for each N rate; a negative number in either of these columns indicates that the MRTN approach would have resulted in an under application of N and yield loss, while a positive number indicates that MRTN would have resulted in an over application of N and sometimes a slight increase in yield. The economic column is the economic loss caused by either under or over application of N; whereby both yield lost/gained and cost of N applied or not applied are factored in.

For all sites, N was under applied 23, 31, 46 % of the time for the 0.05, 0.10, and 0.15 price ratios, respectively. For corn following soybean N was under applied 43 % of the time at each price ratios; while for corn following corn N was under applied 0, 17, and 50 % of the time for the 0.05, 0.10, and 0.15 price ratios, respectively. Greater economic loss occurred because of over application of N compared to under application (Tables 3 and 4) at the 0.05 and 0.10 price ratios. The economic loss caused by under or over application of N is more balanced at the 0.15 price ratio (Table 5). Overall the MRTN approach provides a N rate that is somewhat greater than the amount of N needed to economic yields.

In the previous comparison, single N rates were compared to each other. Another way to compare each site's EONR with MRTN is determine how often the EONR was within the MRTN range for each price ratio. At the 0.05 price ratio, the MRTN range encompassed the EONR 46 % of the time and the MRTN range was greater then the EONR 54 % of the time. The MRTN range encompassed the EONR 46 and 23 % of the time for the 0.10 and 0.15 price ratios, respectively. Eight and 38 % of the time EONR was greater than the MRTN range for the 0.10 and 0.15 price ratios, respectively. The MRTN range was greater then EONR 46 and 38 % of the time for the 0.10 and 0.15 price ratios, respectively. For each site, if a range of N rates that produces an economic return within $1/a of the EONR were calculated, the range would often over lap with the published MRTN range.

Growers are often concerned with yield loss from reduced N rates. Table 6 provides relative yield obtained using the MRTN approach at each N:corn price ratio, where relative yield is defined as the yield obtained as a percent of the maximum yield at the site. The average relative yield over all sites at the 0.05 price ratio is 100 % with a range of 99-100 %. As the price ratio increases, the average relative yield decreases to 98 % at the 0.15 price ratio. When using MRTN to reduce N rates in an effort to improve profitability, there is a risk for yield loss. At the 0.15 price ratio, often (54 % of the time) that loss is small (0-1 %) and infrequently (15 % of the time) the loss is greater (6 to 9 %).

Sites 48 and 49 were part of the same experiment at Lancaster Ag Research Station which was set up to assess the effect of N timing on EONR. Some plots had ammonium nitrate broadcast at planting and the other plots had ammonium nitrate knifed in at sidedress. The yield obtained at each rate of N applied was not significantly different between N timings with an average AONR of 106 lb N/a (Figure 2).

In an experiment at Arlington Ag Research Station the effect of level of weed control on grain yield and EONR was determined in 2006 and 2007 (Figure 3) (Boerboom et al., 2008). In 2006 when weeds were controlled with a preemergence herbicide or postemergence herbicide when weeds were four inches tall, the EONR was in similar for all price ratios. In 2007, waiting to control weeds until they were four inches tall resulted in EONR that were 38 lb N/a higher on

average than when weeds were controlled preemergence for all price ratios. Weather conditions and N mineralization potential in the field impact these results. In both 2006 and 2007, waiting to control weeds until they were 12 inches tall caused yield losses at N rates that maximized yield with good weed control. When weeds were controlled at the 12 inch height, yield could be recovered with high N application rates. If N fertilizer is $0.50/lb N and at least 100 lb of N is needed to recover yield, the cost of late weed control is $50/a. Clearly, timely herbicide application is more economical. Failure to control weeds resulted in yield losses that could not be recovered regardless of the amount of N applied.

Conclusions

These data are likely quite representative of the range of response to applied N that occurs on Wisconsin farms because the data set represents a range of soils, use of field scale equipment, and typical grower practices. Timing of N application did not impact EONR; however this was studied at only one location. Timely weed control is important for high N use efficiency and economic crop production.

When evaluating this data, it must be kept in mind that these are the results from just one year at each site. Year-in and year-out the EONR, for a given price ratio, will vary at a location. Until soil N mineralization can be accurately predicted, it will continue to be difficult to predetermine the exact amount of N that will be needed by a corn crop in a given year. The power of the MRTN approach is that it pulls data from multiple locations over multiple years to arrive at a best estimate of profitability by balancing economic losses from over and under application of N.

Acknowledgments

A special thank you to everyone who contributed to making these on-farm plots a success including: Bill Halfman, Matt Hanson, Kevin Shelley, Tim Wood, and all the farmers who participated. The laboratory analyses for were paid for by the Nutrient Management UW-Extension self directed team. Data analysis was supported by non-point source funding.

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Table 2. Previous crop, soil yield potential, county, and soil name/texture, soil organic matter content (OM), N source, N application method, N timing, tillage, residue, and agronomic optimum N rate (AONR) and corn yield at AONR (max. yield) for 13 on-farm MRTN evaluation trials in Wisconsin, 2007.

Soil yield potential	County	Site i.d.	Soil name and texture†	OM	N Source‡	N application method§	N application timing	Tillage¶	Residue	PPNT N credit	AONR	Yield @ AONR
				%					%	lb N/a	lb N/a	bu/a
PREVIOUS CROP = SOYBEAN												
Very high	Columbia	33	Plano sil	3.5	UAN-28	Sub-Surf	Preplant	CP F	10	8	44	228
	Dodge	40	Pella sicl	4.0	AN	Sub-Surf	Sidedress	CP F	20	0	157	167
	Jefferson	42	Del Rey sil	2.8	UAN-28	Sub-Surf	Sidedress	NT	20	73	148	166
	Monroe	45	Jackson sil	3.3	AA	Sub-Surf	Sidedress	NT	60	30	26	158
High	Jefferson	39	Keowns sil	4.4	UAN-28	Sub-Surf	Sidedress	NT	40	0	98	173
	Columbia	47	Griswold sil	3.4	UAN-28	Sub-Surf	Sidedress	NT	40	0	63	143
Non irrigated Sands & Loamy sands	Monroe	46	Tarr s	1.0	AA	Sub-Surf	Sidedress	NT	35	0	131	77
PREVIOUS CROP = CORN												
Very high	Jefferson	37	Milford sil	5.4	UAN-28	Sub-Surf	Sidedress	RT	50	47	160	171
	Dodge	41	Plano sil	3.2	UAN-28	Sub-Surf	Planting	NT	80	0	171	173
	Grant	48	Rozetta sil	2.0	AN	SB/NoInc	Planting	CP F	30	22	93	211
	Grant	49	Rozetta sil	2.0	AN	Sub-Surf	Sidedress	CP F	30	22	112	206
High	Waukesha	38	Dodge sil	1.6	UAN-28	Sub-Surf	Sidedress	NT	60	0	150	192
Medium	Jefferson	43	Wasepi sl	1.8	UAN-28	Sub-Surf	Sidedress	NT	60	45	94	180

† sil, silt loam; sicl, silty clay loam; s, sand; sl, sandy loam.
‡ AA, anhydrous ammonia; AN, ammonium nitrate; UAN, urea-ammonium nitrate.
§ SB/NoInc, surface broadcast no incorporation; Sub-Surf, subsurface.
¶ CP F, chisel plow fall; NT, no till; RT, ridge till.

Table 3. MRTN N rate guideline and observed economic optimum N rate (EONR) and yield at MRTN and EONR at the **0.05 N:Corn price ratio** and difference between EONR and MRTN N rate, yield, and economic return for 13 on-farm MRTN trials in Wisconsin, 2007.

Previous crop	Soil yield potential	Site i.d.	MRTN rate guideline		Observed EONR		Difference (MRTN minus EONR)		
			N rate	Yield	N rate	Yield	N rate	Yield	Economic†
			lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	$/a
Soybean	Very high	33	140	228	42	228	98	0	-19.60
		40	140	166	144	167	-4	-1	-3.20
		42	140	166	141	166	-1	0	0.20
		45	160	158	26	158	134	0	-26.80
	High	39	140	173	98	173	42	0	-8.40
		47	140	142	61	142	79	0	-15.80
	Non irrigated Sands & Loamy sands	46	120	77	123	77	-3	0	0.60
Corn	Very high	37	190	171	160	171	30	0	-6.00
		41	190	172	163	172	27	0	-5.40
		48	165	211	91	211	74	0	-14.80
		49	165	206	108	206	57	0	-11.40
	High	38	190	192	150	192	40	0	-8.00
	Medium	43	140	180	94	180	46	0	-9.20
			Average N rate guideline under applied (n = 3)				-3	0	-0.74
			Average N rate guideline over applied (n = 10)				63	0	-11.74

† Based on $0.20/lb N fertilizer and $4.00/bu corn.

Table 4. MRTN N rate guideline and observed economic optimum N rate (EONR) and yield at MRTN and EONR at the **0.10 N:Corn price ratio** and difference between EONR and MRTN N rate, yield, and economic return for 13 on-farm MRTN trials in Wisconsin, 2007.

Previous crop	Soil yield potential	Site i.d.	MRTN rate guideline		Observed EONR		Difference (MRTN minus EONR)		
			N rate	Yield	N rate	Yield	N rate	Yield	Economic†
			lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	$/a
Soybean	Very high	33	115	228	41	228	74	0	-29.60
		40	115	164	131	166	-16	-2	-1.60
		42	115	162	135	166	-20	-4	-8.00
		45	130	158	26	158	104	0	-41.60
	High	39	115	173	98	173	17	0	-6.80
		47	115	142	59	142	56	0	-22.40
	Non irrigated Sands & Loamy sands	46	105	75	115	76	-10	-1	0.00
Corn	Very high	37	155	168	160	171	-5	-3	-10.00
		41	155	172	154	172	1	0	-0.40
		48	135	211	88	211	47	0	-18.80
		49	135	206	104	206	31	0	-12.40
	High	38	155	192	150	192	5	0	-2.00
	Medium	43	120	180	94	180	26	0	-10.4
			Average N rate guideline under applied (n = 4)				-13	-2	-4.25
			Average N rate guideline over applied (n = 9)				40	0	-14.02

† Based on $0.40/lb N fertilizer and $4.00/bu corn.

Table 5. MRTN N rate guideline and observed economic optimum N rate (EONR) and yield at MRTN and EONR at the **0.15 N:Corn price ratio** and difference between EONR and MRTN N rate, yield, and economic return for 13 on-farm MRTN trials in Wisconsin, 2007.

Previous crop	Soil yield potential	Site i.d.	MRTN rate guideline		Observed EONR		Difference (MRTN minus EONR)		
			N rate	Yield	N rate	Yield	N rate	Yield	Economic†
			lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	$/a
Soybean	Very high	33	100	228	39	228	61	0	-36.60
		40	100	161	118	164	-18	-3	-1.20
		42	100	157	129	165	-29	-8	-14.60
		45	115	158	26	158	89	0	-53.40
	High	39	100	173	98	173	2	0	-1.20
		47	100	142	57	142	43	0	-25.8
	Non irrigated Sands & Loamy sands	46	95	73	107	75	-12	-2	-0.80
Corn	Very high	37	135	156	160	171	-25	-15	-54.80
		41	135	169	146	171	-11	-2	-1.40
		48	120	211	86	210	34	0	-20.40
		49	120	206	101	205	19	0	-11.40
	High	38	135	181	150	192	-15	-9	-27.00
	Medium	43	110	180	94	180	16	0	-9.60
			Average N rate guideline under applied (n = 6)				-18	-7	-16.37
			Average N rate guideline over applied (n = 7)				38	0	-21.54

† Based on $0.60/lb N fertilizer and $4.00/bu corn.

Table 6. Relative grain yield obtained by using the MRTN guideline approach at several N:corn price ratios for 13 on-farm MRTN trials in Wisconsin, 2007.

		N: corn price					
		0.05		0.10		0.15	
Site i.d.	AONR yield †	Yield	Relative yield ‡	Yield	Relative yield	Yield	Relative yield
	bu/a	bu/a	%	bu/a	%	bu/a	%
33	228	228	100	228	100	228	100
40	167	166	99	164	98	161	96
42	166	166	100	162	98	157	95
45	158	158	100	158	100	158	100
39	173	173	100	173	100	173	100
47	143	142	99	142	99	142	99
46	77	77	100	75	97	73	95
37	171	171	100	168	98	156	91
41	173	172	99	172	99	169	98
48	211	211	100	211	100	211	100
49	206	206	100	206	100	206	100
38	192	192	100	192	100	181	94
43	180	180	100	180	100	180	100
Average relative yield			100		99		98
Standard deviation of average			0.43		1.07		3.02
Maximum relative yield			100		100		100
Minimum relative yield			99		97		91
Median relative yield			100		100		99

† AONR yield, maximum yield obtained at the agronomic optimum N rate at the site.
‡ Relative yield, yield obtained using the MRTN rate for a given price ratio as a percent of the AONR yield achieved at the site.

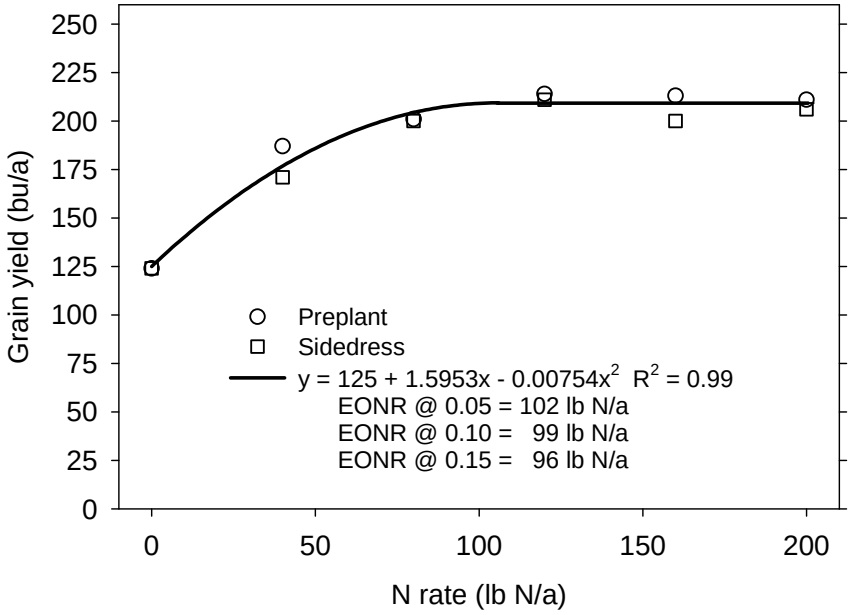

Figure 2. Effect of N application timing (preplant vs. sidedress) on grain yield.

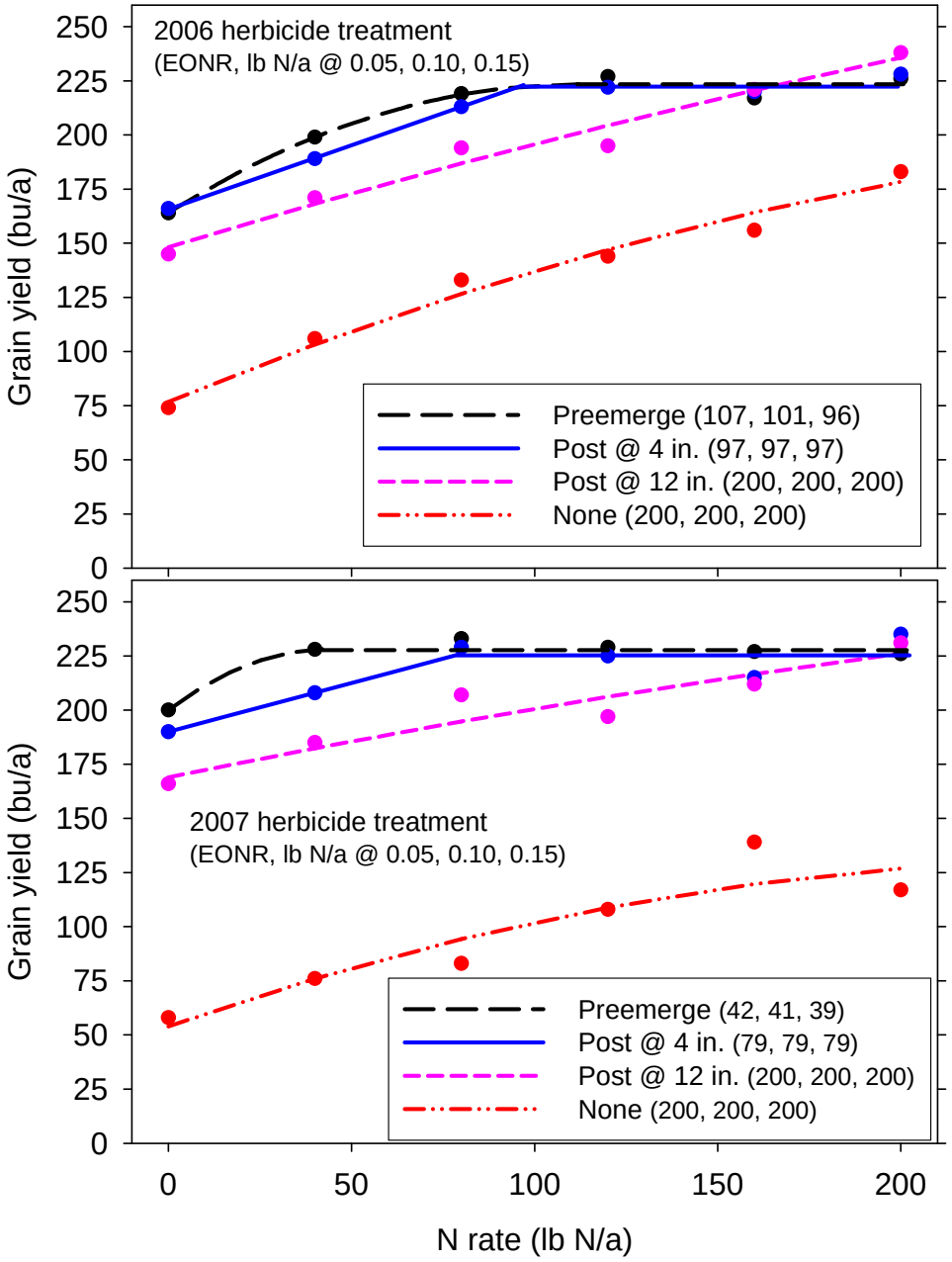

Figure 3. Effect of four levels of weed control (Preemerge = weed-free conditions; Post @ 4 in. = postemergence control when weeds were 4 inches tall; Post @ 12 in., postemergence control when weeds were 12 in. tall; and none = no weed control) on corn grain yield and economic optimum N rate (EONR) at 0.05, 0.10, and 0.15 N:corn price ratios in 2006 and 2007. In the legend, the numbers in parenthesis are the EONRs at 0.05, 0.10, and 0.15 N:corn price ratios.