PERFORMANCE OF NEW CORN NITROGEN RATE GUIDELINES

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Introduction

In fall 2005 the Department of Soil Science unveiled a nitrogen (N) rate guideline tool to aid producers in determining a N fertilizer rate for corn that is appropriate for their economic situation. This tool is called the maximum return to nitrogen (MRTN) approach. MRTN 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, an 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.
- ➢ 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.

In early 2006 with high N fertilizer prices and less than desirable corn prices, many farmers were interested in using the MRTN approach as a means to improve economic profitability. However, because the concept was new many were reluctant to fully embrace the approach, but were interested in trying it. Thus, in 2006 many on-farm plots were established throughout the state with the objective to verify the performance of the MRTN approach.

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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

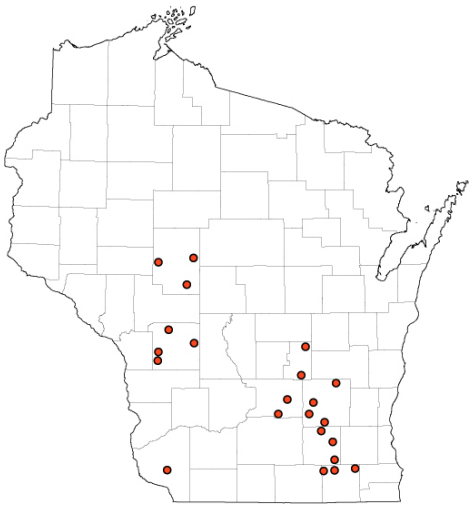

Figure 1. Location of the 22 MRTN on-farm verification plots in 2006.

University of Wisconsin faculty and staff were involved in conducting these on-farm plots in cooperation with participating farms. Twenty-two plots were located throughout the state (Figure 1). Soybean was the previous crop for 13 locations and corn for nine 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.

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 14, 16, 20, and 21 were tile drained. No sites were irrigated. Three sites had a history of manure application within three years prior to the study year. Site 3 had 6,000 gal/a of manure applied the first and second year prior to the study; site 15 had 5 T/a of manure applied the second and third year prior to the study; and site 31 had 1,530 gal/a applied the third year prior to the study.

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 $3.00/bu and the price of N varied: $0.15/lb, $0.30/lb, and $0.45/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

Maximum grain yield and the amount of N needed to reach that yield is given in Table 2 and Figure 2. Figure 2 shows that using a yield goal approach for making a N recommendation for maximum yield most often results in over application of N and subsequently results in an economic loss to the grower. Additionally, fertilizing for maximum yield is not profitable because there are diminishing returns on the last increments of N applied.

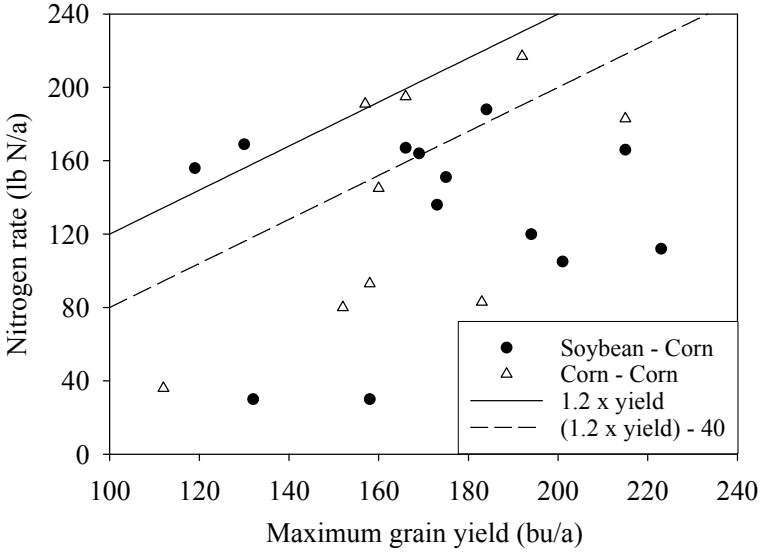

Figure 2. Nitrogen rate needed to obtain maximum grain yield. The lines represent the N application rate recommendation that results from using a yield goal based approach for both corn after corn (1.2 x yield) and corn after soybean (1.2 x yield – 40).

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 was no tilled or 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 to 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 41, 50, and 55% of the time for the 0.05, 0.10, and 0.15 price ratios, respectively. For corn following soybean N was under applied 38, 46, and 54% of the time for the 0.05, 0.10, and 0.15 price ratios, respectively; while for corn following corn N was under applied 45, 56, and 56% 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 (Table 3) at the 0.05 price ratio. The economic loss caused by under or over application of N is balanced at the 0.10 and 0.15 price ratios (Tables 4 and 5). Overall the MRTN approach provides an N rate that is on average balancing economic losses and, thus, maximizing return on the investment in N fertilizer.

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 36% of the time, was greater than the MRTN range 28% of the time, and was less than the MRTN range 36% of the time. The MRTN range encompassed the EONR 18 and 23% of the time for the 0.10 and 0.15 price ratios, respectively. Fifty and 45% of the time EONR was greater than the MRTN range for the 0.10 and 0.15 price ratios, respectively. The MRTN range was less than EONR 32 and 32% 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 99% with a range of 97 to 100%. As the price ratio increases, the average relative yield decreases to 97 % 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 (45% of the time) that loss is small (0 to 1%) and infrequently (14% of the time) the loss is greater (9 to 11%).

If the preplant nitrate test (PPNT) is used to adjust N rates, over applications of N at the 0.05 price ratio can be reduced. However when N rates are already being reduced with the 0.10 and 0.15 price ratios, using the PPNT to further reduce N rates would often result in under application of N at the sites in this database.

For all three sites that had a manure history, the MRTN N rate would have resulted in an over application of N. At site 3, which was a sandy site, there was no PPNT credit, hence there was no way to predetermine that this site would have a minimal yield response to N. For site 31 there was a 19 lb N/a credit; taking that credit would have reduced the amount of N that was over applied, but over application would have still occurred. The PPNT was not taken for site 15.

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. When evaluating these 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

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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, surface residue cover at planting, preplant nitrate test (PPNT) N credit, plateau N rate (PNR) and corn yield at PNR (max. yield) for 22 on-farm MRTN evaluation trials in Wisconsin, 2006.

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	PNR	Yield @ PNR
				%					%	lb N/a	lb N/a	bu/a
PREVIOUS CROP = SOYBEAN												
Very high	Monroe	1	Jackson sil	3.5	AA	Sub-Surf	Sidedress	NT	70	7	136	173
	Monroe	4	Downs sil	2.0	AA	Sub-Surf	Sidedress	NT	55	1	167	166
	Walworth	16	Plano sil	3.9	UAN-28	Sub-Surf	Sidedress	NT	50	3	120	194
	Dodge	20	Pella sicl	3.8	AA	Sub-Surf	Sidedress	CP F	5	20	105	201
	Columbia	24	Plano sil	3.4	UAN-28	SB/Inc	Preplant	CP F	10	31	112	223
High	Green Lake	9	Kidder fsl	1.8	AA	Sub-Surf	Sidedress	Yes	n.d. #	0	151	175
	Jefferson	14	Keowns sil	4.7	UAN-28	Sub-Surf	Sidedress	NT	50	0	164	169
	Walworth	17	Dodge sil	1.6	UAN-28	Sub-Surf	Sidedress	NT	45	0	188	184
Medium	Clark	5	Withee sil	3.6	AN	SB/NoInc	Preemerge	D S	30	37	30	158
	Clark	6	Flambeau l	3.2	AN	SB/NoInc	Preemerge	D S	30	0	30	132
Non irrigated	Monroe	2	Tarr s	0.7	AA	Sub-Surf	Sidedress	D S	15	0	156	119
Sands &	Monroe	3	Impact s	1.1	AA	Sub-Surf	Sidedress	NT	n.d.	0	169	130
Loamy sands	Columbia	23	Salter ls	1.4	UAN-28	Sub-Surf	Sidedress	CP F	40	0	166	215
PREVIOUS CROP = CORN												
Very high	Walworth	15	Plano sil	2.5	UAN-28	Sub-Surf	Sidedress	CP F	30	n.d.	93	158
	Dodge	21	Mayville sil	2.3	UAN-32	Sub-Surf	Sidedress	CP F	30	0	195	166
	Dodge	22	Elburn sil	2.5	UAN-28	Sub-Surf	Sidedress	D S	10	18	191	157
	Grant	31	Rozetta sil	2.3	Urea	SB/Inc	Preplant	CP F	25	19	83	183
High	Green Lake	10	Kidder l	1.6	Urea-I	SB/NoInc	Sidedress	NT	n.d.	0	217	192
	Dodge	19	Mendota sil	3.2	UAN-28	Sub-Surf	Preemerge	NT	80	35	183	215
Medium	Clark	8	Flambeau l	3.2	AN	SB/NoInc	Preemerge	DT F	25	9	36	112
	Jefferson	12	Wasepi sl	5.6	UAN-28	Sub-Surf	Preemerge	CP F	35	0	145	160
	Jefferson	13	Wasepi sl	5.6	UAN-28	Sub-Surf	Sidedress	CP F	35	0	80	152

† VH, very high; H, high; M, medium; s/ls, sands and loamy sands non-irrigated.
‡ sil, silt loam; sicl, silty clay loam; fsl, fine sandy loam; l, loam; ls, loamy sand; s, sand; sl, sandy loam.
§ AA, anhydrous ammonia; UAN, urea-ammonium nitrate; AN, ammonium nitrate; Urea-I, urea with Agrotain.
¶ Sub-Surf, subsurface; SB, surface broadcast; Inc, incorporated; NoInc, not incorporated.
* CP F, chisel plow fall; D S, disk spring; DT F, deep till fall; NT, no till; Yes, tillage occurred but not described.
# n.d., not determined

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 22 on-farm MRTN trials in Wisconsin, 2006.

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	1	160	173	129	173	31	0	-4.65
		4	160	165	161	165	-1	0	0.15
		16	160	194	115	194	45	0	-6.75
		20	140	201	105	201	35	0	-5.25
		24	140	223	107	223	33	0	-4.95
	High	9	160	175	144	175	16	0	-2.40
		14	160	168	163	169	-3	-1	-2.55
		17	160	182	180	184	-20	-2	-3.00
	Medium	5	90	158	30	158	60	0	-9.00
		6	90	132	30	132	60	0	-9.00
	Sands/loamy sands	2	140	118	151	119	-11	-1	-1.35
		3	140	127	169	130	-29	-3	-4.65
		23	140	213	136	213	4	0	-0.60
Corn	Very high	15	165	158	93	158	72	0	-10.80
		21	165	163	187	166	-22	-3	-5.70
		22	165	156	180	157	-15	-1	0.75
		31	165	183	82	183	83	0	-12.45
	High	10	190	187	217	192	-27	-5	-10.95
		19	190	215	179	215	11	0	-1.65
	Medium	8	120	112	36	112	84	0	-12.60
		12	120	158	138	160	-18	-2	-3.30
		13	120	152	80	152	40	0	-6.00
			Average N rate guideline under applied (n = 9)				-16	-2	-3.40
			Average N rate guideline over applied (n = 13)				44	0	-6.62

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 22 on-farm MRTN trials in Wisconsin, 2006.

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	1	130	173	122	173	8	0	-2.40
		4	130	161	150	165	-20	-4	-6.00
		16	130	194	110	194	20	0	-6.00
		20	115	201	105	201	10	0	-3.00
		24	115	223	101	223	14	0	-4.20
	High	9	130	173	137	174	-7	-1	-0.90
		14	130	163	156	168	-26	-5	-7.20
		17	130	173	172	183	-42	-10	-17.40
	Medium	5	60	158	30	158	30	0	-9.00
		6	60	132	30	132	30	0	-9.00
	Sands/loamy sands	2	120	114	144	118	-24	-4	-4.80
		3	120	126	0	116	120	10	-6.00
		23	120	211	127	212	-7	-1	-0.90
Corn	Very high	15	135	158	93	158	42	0	-12.60
		21	135	155	179	165	-44	-10	-16.80
		22	135	150	169	156	-34	-6	-7.80
		31	135	183	80	183	55	0	-16.50
	High	10	155	179	217	192	-62	-13	-20.40
		19	155	212	170	214	-15	-2	-1.50
	Medium	8	105	112	36	112	69	0	-20.70
		12	105	154	132	159	-27	-5	-6.90
		13	105	152	80	152	25	0	-7.50
			Average N rate guideline under applied (n = 11)				-28	-5.5	-8.24
			Average N rate guideline over applied (n = 11)				38	0.9	-8.81

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 22 on-farm MRTN trials in Wisconsin, 2006.

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	1	115	172	114	172	1	0	-0.45
		4	115	158	140	163	-25	-5	-3.75
		16	115	194	105	193	10	1	-1.50
		20	100	198	105	201	-5	-3	-6.75
		24	100	223	96	222	4	1	1.20
	High	9	115	170	131	173	-16	-3	-1.80
		14	115	158	149	167	-34	-9	-11.70
		17	115	167	164	182	-49	-15	-22.95
	Medium	5	50	158	30	158	20	0	-9.00
		6	50	132	30	132	20	0	-9.00
	Sands/loamy sands	2	110	111	136	117	-26	-6	-6.30
		3	110	125	0	116	110	9	-22.50
		23	110	210	117	211	-7	-1	0.15
Corn	Very high	15	120	158	93	158	27	0	-12.15
		21	120	148	171	164	-51	-16	-25.05
		22	120	146	158	155	-38	-9	-9.90
		31	120	183	78	183	42	0	-18.90
	High	10	135	173	217	192	-82	-19	-20.10
		19	135	207	160	213	-25	-6	-6.75
	Medium	8	95	112	36	112	59	0	-26.55
		12	95	151	125	158	-30	-7	-7.50
		13	95	152	80	152	15	0	-6.75
			Average N rate guideline under applied (n = 12)				-32	-8.3	-10.20
			Average N rate guideline over applied (n = 10)				31	1.1	-10.56

Table 6. Yield loss incurred by using the MRTN approach at several N:corn price ratios for 22 on-farm MRTN trials in Wisconsin, 2006.

		N: corn price ratio					
		0.05		0.1		0.15	
	PNR yield †	Yield	Relative yield ‡	Yield	Relative yield	Yield	Relative yield
	bu/a	bu/a	%	bu/a	%	bu/a	%
1	173	173	100	173	100	172	99
4	166	165	99	161	97	158	95
16	194	194	100	194	100	194	100
20	201	201	100	201	100	198	99
24	223	223	100	223	100	223	100
9	175	175	100	173	99	170	97
14	169	168	99	163	96	158	93
17	184	182	99	173	94	167	91
5	158	158	100	158	100	158	100
6	132	132	100	132	100	132	100
2	119	118	99	114	96	111	93
3	130	127	98	126	97	125	96
23	215	213	99	211	98	210	98
15	158	158	100	158	100	158	100
21	166	163	98	155	93	148	89
22	157	156	99	150	96	146	93
31	183	183	100	183	100	183	100
10	192	187	97	179	93	173	90
19	215	215	100	212	99	207	96
8	112	112	100	112	100	112	100
12	160	158	99	154	96	151	94
13	152	152	100	152	100	152	100
Average relative yield			99		98		97
Standard deviation of average			0.80		2.39		3.64
Maximum relative yield			100		100		100
Minimum relative yield			97		93		89
Median relative yield			100		99		97

† PNR yield, maximum yield obtained at the site.

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