# UPDATE ON NITROGEN USE EFFICIENCY OF CORN HYBRIDS WITH AND WITHOUT TRANSGENIC CORN ROOTWORM RESISTANCE

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## BACKGROUND

The number of acres planted to corn rootworm (*Diabrotica* spp.) (CRW) resistant corn (*Zea mays* L.) hybrids have increased in recent years. The CRW resistant corn hybrids may have a greater yield potential because of reduced stress from CRW larval feeding resulting in larger root systems. Many agronomists believe higher N rates are needed to achieve the greater yield potential associated with these hybrids. However, larger root systems of CRW resistant hybrids could result in greater N use efficiency and perhaps a reduced N fertilizer need compared to non-CRW resistant hybrids.

Corn yields have increased over time because of improved genetics and management (Duvick, 1984). O'Neill et al. (2004) found that newer corn hybrids exhibited greater grain yield response to applied fertilizer N and greater N fertilizer use efficiency compared to older (1970s) hybrids. Yields under N deficient conditions varied among individual hybrids and these yield differences were not related to hybrid era (older or newer), however. Their study included only two N rates (0 and 224 lb/a); thus, more detailed analysis regarding variability of the economic optimum N rate between hybrid eras could not be determined. Vanotti and Bundy (1994) reported that optimum N rates for corn were similar at high and low yield levels from a 24-yr corn N rate study conducted from 1967 to 1990 at Lancaster, Wisconsin. They concluded that conditions which promote high corn yields, such as adequate moisture and temperature, improve the efficiency of available N use by the crop and greater amounts of applied N are not needed. Whether the greater yield potential associated newer hybrids have a similar effect on N use efficiency and optimum N rates is unknown.

There is no record in the published literature of research focusing on the N use efficiency and N needs of CRW resistant vs. non-resistant corn hybrids. Research on the integration of corn hybrid traits, including CRW resistance, with various N management systems is in the preliminary stages at the University of Minnesota (Gyles Randall, personal communication). There has been some research conducted on the influence of N fertilizer on CRW larval feeding. Riedell et al. (1996) found that banded-split N applications resulted in a larger root system and greater tolerance to CRW larval feeding damage compared with broadcast-preplant N applications. However, Roth et al. (1995) found that N fertilizer timing (at planting, sidedress, or split) did not affect corn root damage ratings. In other research, leafy and non-leafy corn hybrids, which differ in their leaf canopy and root morphology, were found to respond similarly to N fertilizer (Costa et al., 2002; Subedi et al., 2006). The objective of this study is to determine if corn hybrids with the transgenic corn rootworm resistant gene vary in their N use efficiency and N need compared to non-resistant hybrids.

## MATERIALS AND METHODS

A field research study was conducted in 2008 and 2009 at the University of Wisconsin Agricultural Research Station at Arlington on a Plano silt loam soil (fine-silty, mixed, superactive, mesic Typic Argiudoll). The study was conducted in a new field each year to avoid previous year treatment effects and where corn was planted for several years to increase the probability of moderate to severe corn rootworm pressure. Treatments consisted of eight corn hybrids and six nitrogen rates in a factorial of corn hybrid and N rate in a randomized complete block design with four replications. A description of corn hybrids is shown in Table 1. The corn hybrids included two pairs of hybrid isolines with and without the corn rootworm resistance gene (hybrids 1 and 2; hybrids 3 and 4), two of the overall best non-rootworm resistant hybrids available in Wisconsin (hybrids 5 and 6), and two of the overall best rootworm resistant hybrids available in Wisconsin (hybrids 7 and 8). The goal of using a suite of hybrids is to reflect isoline differences as well as real-world choices that growers make when selecting a hybrid. Nitrogen fertilizer (as $NH_4NO_3$ in 2008 and UAN-28% in 2009) rates ranged from 0 to 200 lb N/acre in 40 lb N/acre increments and was applied early post-emergence broadcast (2008) or band-injected at about a 6-in. depth between rows (2009).

Soil test P and K levels were in the excessively high category according to Wisconsin nutrient guidelines (Laboski et al., 2006). Soil pH and organic matter values averaged 7.0 and 3.7%, respectively. The sites were chisel plowed in fall or spring and the seedbed was prepared for planting using a soil finisher in early May. Preplant soil nitrate test (PPNT) samples collected in spring indicated minimal carryover $NO_3$-N content in the soil profile (0-3 ft) from the previous year. Corn was planted in early May with 30-inch row spacing at 33,600 seeds/acre with 3-gal./a 10-34-0 pop-up starter fertilizer in the furrow (2008) or no starter fertilizer (2009) and 4.4 lb/acre of soil insecticide (Force 3G) in a T-band. Conventional herbicides were used to control weeds. Initial plot size was four-rows wide (10 ft.) and 25-ft long in 2008 and 40-ft long in 2009. Plot lengths were trimmed to 20-ft in 2008 and 30-ft in 2009 and corn plants within each plot were counted and thinned to a uniform stand density of about 30,350 plants/acre at the V4 to V5 corn growth stage. Corn rootworm ratings were determined by digging 20 roots of the standard nontransgenic hybrid (#6) planted without soil insecticide. Corn rootworm ratings were conducted in late July. The average rating was 1.12 in 2008 and 0.19 in 2009 using the 0 to 3 node-injury scale (Oleson et al., 2005).

At physiological maturity (2008) or within one week following several nights where low temperatures (26$^{o}$F) killed the corn plants, at which point not all plants had reached physiological maturity (2009), six corn plants were hand harvested from each plot to determine total biomass yield and N uptake in late September or early October. The ears (cob and grain) were removed, dried in a force-draft dryer at 160$^{o}$F, shelled, and dry weights of the cob and grain were recorded. Plants (excluding ears) were weighed, chopped, sub-sampled, dried, and dry weights were recorded. Corn grain yield was determined by harvesting all ears from the middle two rows from each plot using a plot combine in early November. A grain subsample was retained and will be analyzed for total N, NIR grain protein, oil, starch, and ethanol traits. Total corn biomass yield, and eventually N uptake, was determined using the harvest index (% of whole plant dry matter as grain) from the six plant sample and converting it based on the whole-plot grain yield. The purpose being to exploit the lower variability of the larger grain harvest area compared with the six-plant sample, and the fact that harvest index among plants within a given treatment is very consistent (D. Walters, personal communication). All tissue samples were ground to pass a 1-mm mesh screen, and were/will be analyzed for total N. Corn grain yields are reported at 15.5% moisture and corn silage yields are reported on a dry matter basis.

Data were analyzed using PROC MIXED for the appropriate experimental design (SAS Institute, 2002). Significant mean treatment differences were evaluated using Fisher's protected LSD test at the 0.10 probability level. Plateau N rate (PNR), economic optimum N rate (EONR), and grain yield or silage yield at PNR or EONR was determined using regression analysis (PROC REG or PROC NLIN). The EONR for corn grain reflects several N fertilizer to corn grain price ratios including 0.05, 0.10, 0.15, and 0.20 reflecting, for example $4.00/bu corn grain and $0.20, $0.40, $0.60, and $0.80/lb N fertilizer, respectively. The EONR for total corn biomass (silage) reflects several N fertilizer to corn silage price ratios including 0.002, 0.005, 0.007, and 0.009 reflecting, for example $86/dry ton corn silage and $0.20, $0.40, $0.60, and $0.80/lb N fertilizer, respectively.

## RESULTS AND DISCUSSION

The 2008 and 2009 growing seasons were very cool and dry except following heavy rainfall in early summer 2008 resulting in wet soil conditions which continued for about a 12-mo period. Total precipitation was generally below normal (i.e. 30-yr average) for most months of the 2008 and 2009 growing seasons. However, precipitation was 10.63-in. above normal in June and July 2008. Monthly average air temperature for May to October was 1.4$^{o}$F below normal in 2008 and 3.3$^{o}$F below normal in 2009.

The effect of corn hybrid and N rate on total corn biomass (silage) and grain yield in 2008 and 2009 was significant, but the hybrid by N rate interaction was not significant. Corn silage and grain yield response to applied N is shown graphically in Figs. 1 and 2, respectively. Regression models were calculated to determine silage and grain yield response to applied N for each hybrid in each year in order to more accurately identify the plateau N rate (PNR) at which yield was maximized. Based on the regression models, the PNR for maximizing silage yield averaged among hybrids was 189 lb N/acre with values ranging from 119 to 160 lb N/acre for individual hybrids in 2008 (Table 2). In 2009, the PNR for silage ranged from 95 to 165 lb N/acre for individual hybrids with a hybrid average of 126 lb N/acre (Table 2). The PNR for maximum grain yield averaged among hybrids was also higher in 2008 (177 lb N/a) compared with 2009 (157 lb N/a), with the PNR among individual hybrids ranging from 119 to 185 lb N/acre in 2008 and from 115 to 200 lb N/acre in 2009 (Table 3).

Corn N recommendations need to account for the cost of N fertilizer and the price of corn. Therefore, we determined the economic optimum N rate (EONR) and the yield at EONR for corn silage and grain at several N:corn price ratios based on the yield by N rate regression models (Tables 2 and 3). For example, at the 0.10 N:corn price ratio for corn ($0.40/lb N and $4/bu grain), the hybrid average EONR was 20 lb N/acre lower and yield at EONR was 29 bu/acre lower compared with the PNR in 2008. In general, the EONR and yield at EONR decreases as the N:corn price ratio increases.

Differences in the PNR for grain yield among hybrids with and without the CRW resistance gene was not apparent. For hybrids 1 and 2 with the same isoline with (#1) and without (#2) the CRW resistance gene, the PNR was higher for hybrid 1 (164 lb N/a) compared with hybrid 2 (131 lb N/a) in 2008, but was lower for hybrid 1 (149 lb N/a) compared with hybrid 2 (168 lb N/a) in 2009. For hybrids 3 and 4, which are the same isoline with (#3) and without (#4) the CRW resistance gene, the PNR was lower for hybrid 3 (128 lb N/a) compared with hybrid 4 (175 lb N/a) in 2008, but was higher for hybrid 3 (188 lb N/a) compared with hybrid 4 (172 lb N/a) in 2009. When evaluating the performance of individual hybrids in both years, hybrids 1 through 4 required less than 20 lb N/a more N to reach the PNR for silage in 2009 compared to 2008; while hybrids 5 and 8 required 49 and 57 lb N/a less N, respectively, in 2009 compared to 2008. The difference in the PNR for between years for grain, showed different patterns than silage. Hybrids 1, 4, 5, and 8 required less N in 2009 to reach the grain PNR compared to 2008 (< 25 lb N/a difference) and hybrids 2 and 3 needed 37 and 60 lb N/a more in 2009 compared to 2008.

The effect of hybrid on silage yield at the 0 lb N/acre rate was significant in 2008, but not 2009 (Table 4). For hybrids 3 and 4 , which are the same isoline with (#3) and without (#4) the CRW resistance gene in 2008, silage yield was significantly greater for hybrid 3 compared with hybrid 4. Silage yields were not significantly different for the other isoline/CRW trait or best hybrid/CRW trait comparisons. The effect of hybrid on grain yield at the 0 lb N/acre rate, relative total N uptake, relative silage yield, relative grain yield, or Δ yield was not significant in 2008 or 2009 (Table 4). We determined the lb N/acre applied per bu/acre near the average EONR at the 0.10 N:corn price ratio (160 lb N/a) and termed it as fertilizer N use efficiency ($FNUE_{160}$) where a smaller $FNUE_{160}$ value indicates more grain was produced per unit of N fertilizer applied at the 160 lb N/acre rate. The effect of hybrid on $FNUE_{160}$ was significant in 2008 and 2009 (Table 4). For hybrids with the same isoline but different CRW resistant traits (hybrids 1 vs. 2 and hybrids 3 vs. 4), there was only one instance in 2008 and 2009 where a significant difference in FNUE occurred. It took significantly less N to produce a bushel of corn at the 160 lb N/acre rate for hybrid 2 (without CRW resistance) where the FNUE was 0.80 lb N/bu compared with hybrid 1 (with CRW resistance) where the FNUE was 0.85 lb N/bu in 2009.

## SUMMARY

In the two years of this study, there some differences in the amount of N needed corn grain and silage produced between corn hybrids isolines with and without CRW resistance. Isolines with the CRW resistance trait to sometimes required less N than the isolines without the trait, but not always. The relative performance of a hybrid compared to it's isoline with regard to the amount of N needed was not consistent between years. The third and final year of this study is planned for 2010.

## REFERENCES

Costa, C., L.M. Dwyer, D.W. Stewart, and D.L. Smith. 2002. Nitrogen effects on grain yield and yield components of leafy and nonleafy maize genotypes. Crop Sci. 42:1556-1563

Duvick, D.N. 1984. Genetic contribution to yield gains of U.S. hybrid maize, 1930 to 1980. In Genetic contributions to yield gains of five major crop plants (W.R. Fehr, editor). Special Publication 7, pp. 15-47. CSSA. Madison, WI.

Laboski, C.A.M., J.B. Peters, and L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. Publ. A2809. Univ. of Wisconsin Ext., Madison.

Oleson, J.D., Y.L. Park, T.M. Nowatzki, and J.J. Tollefson. 2005. Node-injury scale to evaluate root injury by corn rootworms (Coleopter: Chrysomelidae). J. Econ. Entomol. 98:1-8.

O'Neill, P.M., J.F. Shanahan, J.S. Schepers, and B. Caldwell. 2004. Agronomic responses of corn hybrids from different eras to deficit and adequate levels of water and nitrogen. Agron. J. 96:1660-1667.

Riedell, W.E., T.E. Schumacher, and P.D. Evenson. 1996. Nitrogen fertilizer management to improve crop tolerance to corn rootworm larval feeding damage. Agron. J. 88:27-32.

Roth, G.W., D.D. Calvin, and S.M. Lueloff. 1995. Tillage, nitrogen timing, and planting date effects on western corn rootworm injury to corn. Agron. J. 87:189-193.

SAS Institute. 2002. SAS release 9.1. SAS Inst., Cary, NC.

Subedi, K.D., B.L. Ma, and D.L. Smith. 2006. Response of a leafy and non-leafy maize hybrid to population densities and fertilizer nitrogen levels. Crop Sci. 46:1860-1869.

Vanotti, M.B., and L.G. Bundy. 1994. An alternative rationale for corn nitrogen fertilizer recommendations. J. Prod. Agric. 7:243-249.

Table 1. Description of corn hybrid treatments used in the Bt corn hybrid x N response study at Arlington, 2008 and 2009. The corn hybrids include two pairs of hybrid isolines with and without the corn rootworm resistance gene (hybrids 1 and 2; hybrids 3 and 4), two of the overall best non-rootworm resistant hybrids available in Wisconsin (hybrids 5 and 6), and two of the overall best rootworm resistant hybrids available in Wisconsin (hybrids 7 and 8).

| Hybrid no. | Hybrid i.d. | Brand | Hybrid | Relative maturity (CRM) | Traits † |
|---|---|---|---|---|---|
| 1 | Bt-CR 1 | Pioneer | P35F44 | 105 | HX (CB & CRW); RR2; LL |
| 2 | Isoline 1 | Pioneer | P35F37 | 105 | RR2 |
| 3 | Bt-CR 2 | DeKalb | DKC52-59 | 102 | YG-VT3 (CB & CRW); RR |
| 4 | Isoline 2 | DeKalb | DKC52-62 | 102 | RR2 |
| 5 | Standard Bt-CB | Northrup King | N58-D1 | 107 | YG (CB) |
| 6 | Standard nontransgenic | 2008: Pioneer | 35A30 | 106 | None |
| | | 2009: Pioneer | 35F38 | 105 | None |
| 7 | Bt-CR (Mon863) 1 | 2008: Renk | R698RRYGRW | 104 | YG (CRW); RR |
| | | 2009: DeKalb | DKC55-24 (VT3) | 105 | YG-VT3 (CB & CRW); RR |
| 8 | Bt-CR (Mon863) 2 | Dairyland | Stealth-4006 | 106 | YG (CRW); RR2 |

† CB, corn borer; CRW, corn rootworm; HX, Herculex Xtra; LL, Liberty Link; RR, Roundup Ready; YG, Yield Guard;

Table 2. Regression models for the relationship between corn N rate (including 4 lb N/a in starter in 2008) and corn silage yield, and the economic optimum N rate (EONR) and silage yield at EONR at several N:corn price ratios for eight corn hybrids at Arlington, 2008 and 2009.

| | | | | N:Corn price ratio † | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plateau yield | | 0.002 | | 0.005 | | 0.007 | | 0.009 | |
| Year | Hybrid | N rate | Yield | EONR | Yield | EONR | Yield | EONR | Yield | EONR | Yield |
| | | lb/a | t/a | lb/a | t/a | lb/a | t/a | lb/a | t/a | lb/a | t/a |
| 2008 | 1 | 119 | 10.55 | 119 | 10.55 | 119 | 10.55 | 119 | 10.55 | 119 | 10.55 |
| | 2 | 133 | 10.86 | 133 | 10.86 | 133 | 10.86 | 133 | 10.86 | 133 | 10.86 |
| | 3 | 160 | 11.49 | 160 | 11.49 | 160 | 11.49 | 160 | 11.49 | 160 | 11.49 |
| | 4 | 143 | 10.49 | 143 | 10.49 | 143 | 10.49 | 143 | 10.49 | 143 | 10.49 |
| | 5 | 144 | 10.12 | 132 | 10.11 | 119 | 10.06 | 110 | 10.01 | 100 | 9.93 |
| | 6 | 129 | 11.83 | 129 | 11.83 | 129 | 11.83 | 129 | 11.83 | 129 | 11.83 |
| | 7 | 124 | 10.68 | 124 | 10.68 | 124 | 10.68 | 124 | 10.68 | 124 | 10.68 |
| | 8 | 154 | 10.64 | 142 | 10.53 | 131 | 10.50 | 124 | 10.45 | 117 | 10.40 |
| | Ave. | 189 | 10.89 | 177 | 10.88 | 158 | 10.82 | 146 | 10.74 | 133 | 10.64 |
| 2009 | 1 | 129 | 9.14 | 123 | 9.09 | 116 | 9.07 | 112 | 9.04 | 107 | 9.00 |
| | 2 | 145 | 9.31 | 135 | 9.22 | 126 | 9.19 | 120 | 9.15 | 113 | 9.10 |
| | 3 | 162 | 9.77 | 153 | 9.76 | 141 | 9.71 | 133 | 9.66 | 124 | 9.60 |
| | 4 | 161 | 9.35 | 159 | 9.46 | 148 | 9.42 | 140 | 9.38 | 132 | 9.32 |
| | 5 | 95 | 9.25 | 93 | 9.25 | 89 | 9.23 | 86 | 9.22 | 84 | 9.20 |
| | 6 | 165 | 9.44 | 152 | 9.31 | 141 | 9.28 | 134 | 9.23 | 127 | 9.18 |
| | 7 | 144 | 9.60 | 140 | 9.66 | 131 | 9.63 | 126 | 9.59 | 120 | 9.54 |
| | 8 | 97 | 9.23 | 94 | 9.23 | 90 | 9.21 | 87 | 9.20 | 84 | 9.17 |
| | Ave. | 126 | 9.30 | 123 | 8.50 | 115 | 8.47 | 111 | 8.44 | 106 | 8.40 |

† Example of N:corn price ratio: $86/dry ton corn silage and $0.20/lb N (0.002), or $0.40/lb N (0.005), or $0.60/lb N (0.007), or $0.80/lb N (0.009).

Table 3. Regression models for the relationship between corn N rate (including 4 lb N/a in starter in 2008) and corn grain yield, and the economic optimum N rate (EONR) and grain yield at EONR at several N:corn price ratios for eight corn hybrids at Arlington, 2008 and 2009.

| | | Plateau yield | | N:Corn price ratio † 0.05 | | 0.10 | | 0.15 | | 0.20 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Hybrid | N rate | Yield | EONR | Yield | EONR | Yield | EONR | Yield | EONR | Yield |
| | | lb/a | bu/a | lb/a | bu/a | lb/a | bu/a | lb/a | bu/a | lb/a | bu/a |
| 2008 | 1 | 164 | 227 | 155 | 227 | 146 | 226 | 137 | 225 | 128 | 223 |
| | 2 | 131 | 234 | 131 | 234 | 131 | 234 | 131 | 234 | 131 | 234 |
| | 3 | 128 | 250 | 128 | 250 | 128 | 250 | 128 | 250 | 128 | 250 |
| | 4 | 175 | 227 | 163 | 227 | 150 | 226 | 138 | 225 | 126 | 222 |
| | 5 | 130 | 212 | 124 | 211 | 118 | 211 | 112 | 210 | 107 | 209 |
| | 6 | 119 | 239 | 119 | 239 | 119 | 239 | 119 | 239 | 119 | 239 |
| | 7 | 130 | 230 | 130 | 230 | 130 | 230 | 130 | 230 | 130 | 230 |
| | 8 | 185 | 234 | 175 | 234 | 165 | 233 | 155 | 232 | 145 | 230 |
| | Ave. | 177 | 233 | 167 | 233 | 157 | 232 | 147 | 231 | 138 | 229 |
| 2009 | 1 | 149 | 194 | 142 | 194 | 136 | 193 | 130 | 192 | 123 | 191 |
| | 2 | 168 | 205 | 160 | 204 | 152 | 204 | 144 | 203 | 136 | 201 |
| | 3 | 188 | 216 | 178 | 216 | 168 | 215 | 159 | 214 | 149 | 212 |
| | 4 | 172 | 213 | 165 | 213 | 158 | 213 | 150 | 212 | 143 | 210 |
| | 5 | 115 | 188 | 112 | 188 | 108 | 188 | 104 | 187 | 100 | 187 |
| | 6 | 200 | 217 | 200 | 217 | 191 | 216 | 181 | 215 | 171 | 213 |
| | 7 | 172 | 211 | 164 | 210 | 157 | 210 | 149 | 209 | 142 | 207 |
| | 8 | 131 | 201 | 125 | 200 | 120 | 200 | 115 | 199 | 109 | 198 |
| | Ave. | 157 | 204 | 150 | 204 | 143 | 203 | 136 | 202 | 129 | 201 |

† Example of N:corn price ratio: $4.00/bu corn grain and $0.20/lb N (0.05), $0.40/lb N (0.10), $0.60/lb N (0.15), or $0.80/lb N (0.20).

Table 4. Effect of corn hybrid on silage yield without N ($SY_{noN}$), grain yield without N ($GY_{noN}$), relative total N uptake (RTN †), relative silage yield (RSY ‡), relative grain yield (RGY §), delta grain yield (Δ yield ¶), and fertilizer N use efficiency (FNUE #) at physiological maturity at Arlington, 2008 and 2009.

| Year | Hybrid | $SY_{noN}$ | $GY_{noN}$ | RTN | RSY | RGY | Δ yield | $FNUE_{160}$ |
|---|---|---|---|---|---|---|---|---|
| | | t/a | bu/a | ---------------- | % | ---------------- | bu/a | lb N/bu |
| 2008 | 1 | 8.0 bc †† | 155 | 54 | 75 | 68 | 74 | 0.74 abc |
| | 2 | 8.8 ab | 168 | 64 | 82 | 72 | 66 | 0.70 bcd |
| | 3 | 9.0 a | 175 | 61 | 77 | 70 | 77 | 0.67 d |
| | 4 | 7.7 c | 169 | 64 | 78 | 74 | 58 | 0.70 bcd |
| | 5 | 7.8 c | 142 | 57 | 76 | 66 | 74 | 0.79 a |
| | 6 | 8.1 bc | 144 | 48 | 68 | 60 | 96 | 0.69 cd |
| | 7 | 7.9 c | 163 | 54 | 73 | 68 | 77 | 0.75 ab |
| | 8 | 7.4 c | 152 | 50 | 66 | 66 | 79 | 0.70 bcd |
| | *p* | 0.06 | 0.22 | 0.42 | 0.26 | 0.56 | 0.55 | 0.04 |
| 2009 | 1 | 5.6 | 106 | | 61 | 54 | 91 | 0.85 a |
| | 2 | 6.0 | 117 | | 65 | 56 | 92 | 0.80 bc |
| | 3 | 6.8 | 127 | | 71 | 60 | 88 | 0.74 d |
| | 4 | 5.9 | 113 | | 63 | 53 | 102 | 0.76 d |
| | 5 | 5.8 | 102 | | 65 | 56 | 81 | 0.85 a |
| | 6 | 5.7 | 106 | | 59 | 48 | 114 | 0.77 cd |
| | 7 | 6.0 | 113 | | 63 | 54 | 97 | 0.76 d |
| | 8 | 6.0 | 123 | | 64 | 60 | 81 | 0.83 ab |
| | *p* | 0.41 | 0.30 | | 0.70 | 0.46 | 0.23 | <0.01 |

† RTN = (total N uptake in unfertilized treatment / total N uptake in 200 lb N/a treatment) x 100.
‡ RSY = (silage yield in unfertilized treatment / silage yield at 200 lb N/a treatment) x 100.
§ RGY = (grain yield in unfertilized treatment / grain yield at 200 lb N/a treatment) x 100.
¶ Δ yield = grain yield at 200 lb N/a – grain yield at 0 lb N/a.
# FNUE = (lb N/a applied / grain yield) at 160 lb N/a rate.
†† Mean values in columns for each year followed by the same letter are not significantly different at the 0.10 probability level using Fisher's protected LSD test.

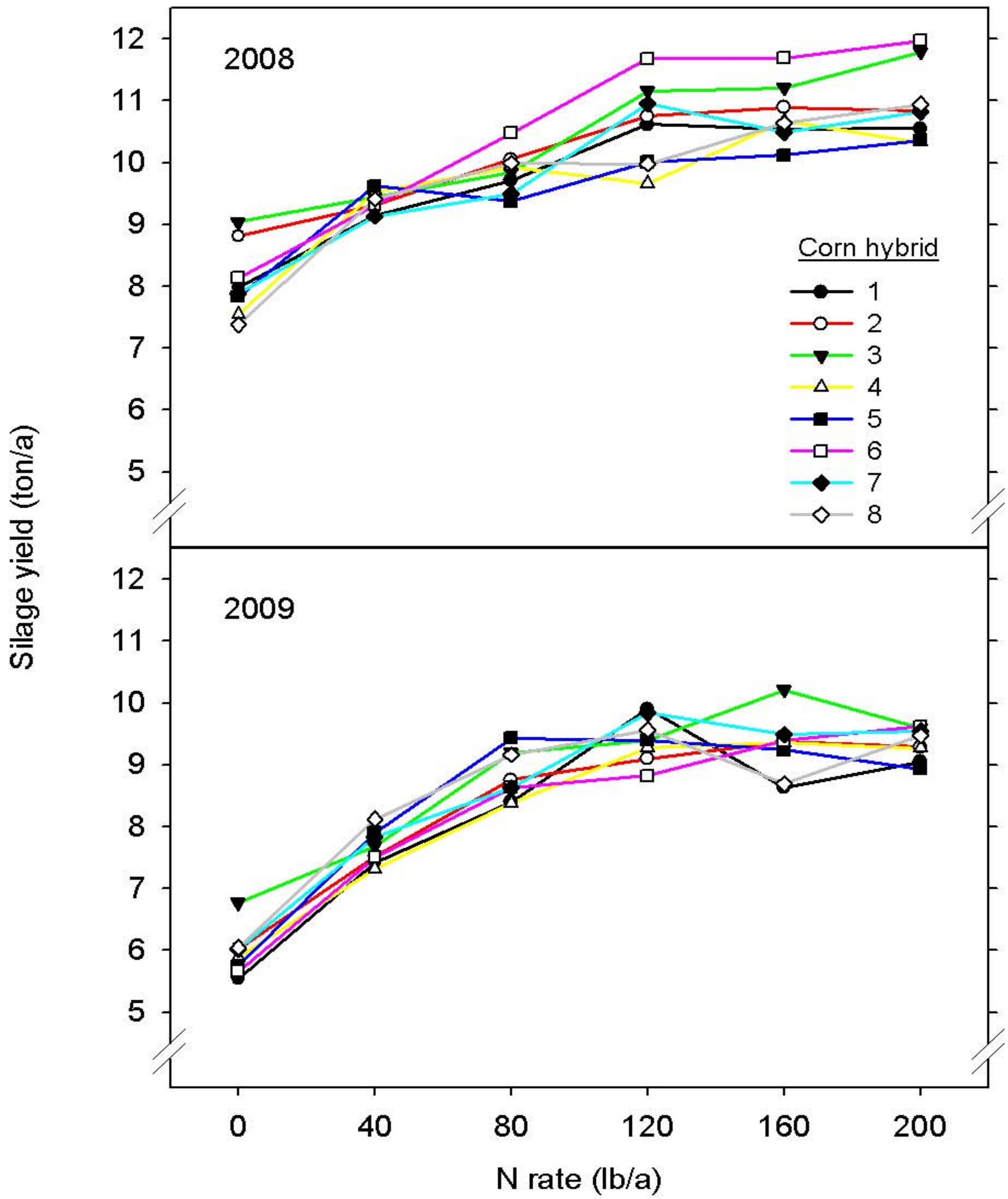


Fig. 1. Relationship between N rate and corn silage yield for eight corn hybrids at Arlington, WI, 2008 and 2009.

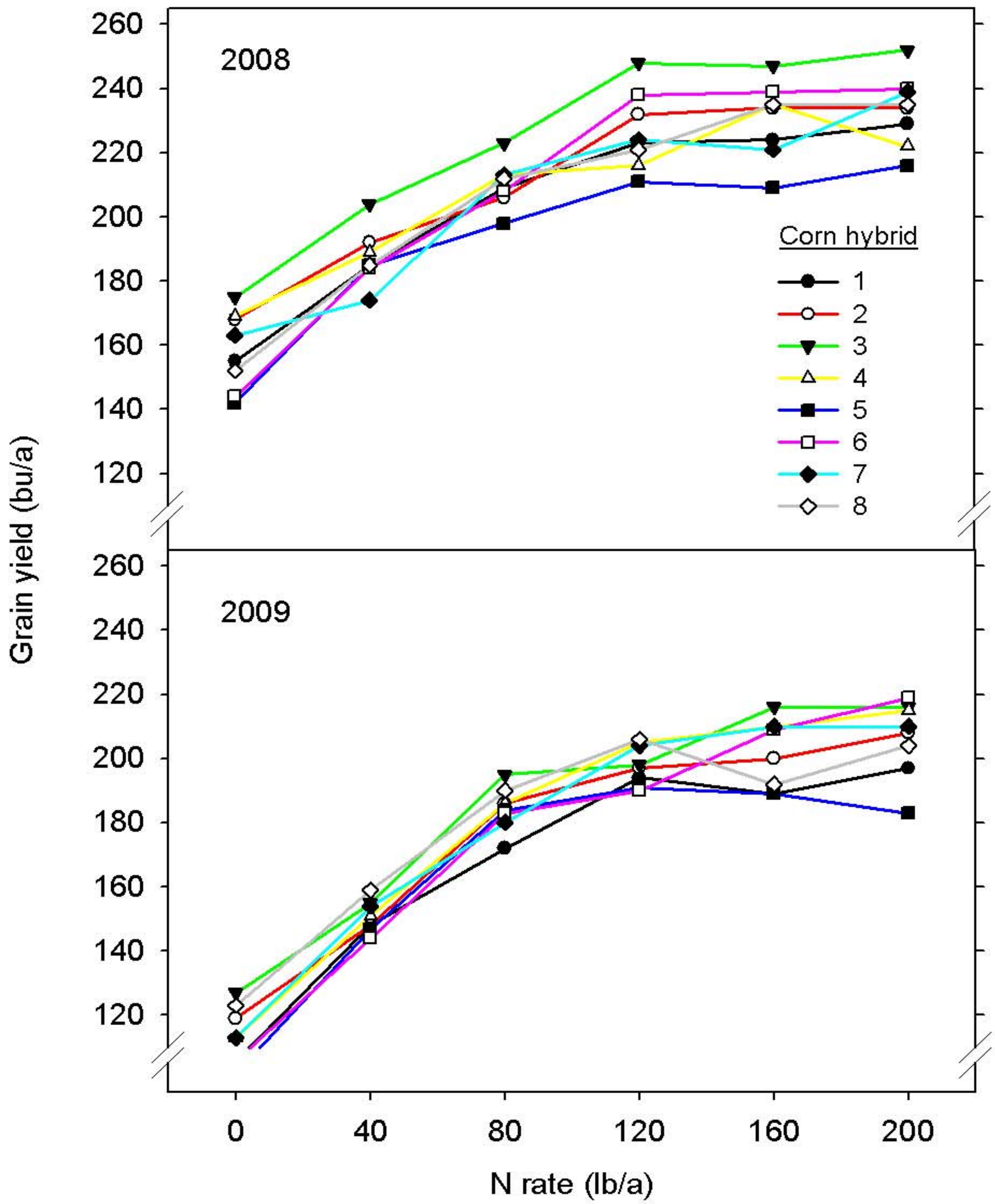


Fig. 2. Relationship between N rate and corn grain yield for eight corn hybrids at Arlington, WI, 2008 and 2009.