# IMPACT OF NITROGEN APPLICATION TIMING ON CORN PRODUCTION

**John E. Sawyer, Daniel W. Barker, and John P. Lundvall**
Iowa State University, Ames, IA
jsawyer@iastate.edu

## INTRODUCTION

Water quality issues have renewed interest in timing of nitrogen (N) application as a means to improve use efficiency in corn and reduce losses. Improved economic return is also desired as N fertilization is one of the most costly inputs to corn production. Time of fertilizer application is a component of the site-specific 4R nutrient management stewardship programs. In Iowa, the Nutrient Reduction Strategy has a 7% (37% std. dev.) nitrate-N reduction with a 0% (3% std. dev.) corn yield change for sidedress compared to pre-plant N application (SP 0435A).

A main area of emphasis for sidedressing is the potential to apply N during the time of rapid plant N uptake, reducing the time applied N is subject to potential losses with wet conditions. Sidedress and in-season N application may also allow for adjustment of application rate. However, producers can be reluctant to apply N in-season as they are busy with other operations, concerned about yield loss due to early N stress, or concerned that wet weather will prevent application. Delay in sidedress applications can reduce yield, but the potential can be mitigated with use of split application where part of the N is applied at or before planting. However, as corn accumulates approximately 70% of total N uptake by R1 (Woli et al., 2016), N limitation during vegetative growth can affect yield potential. Sidedress (split) application has historically shown consistent benefit on coarse textured soils. On medium- to fine-textured soils, the yield, water quality, and economic return have not been consistent. This report will summarize studies conducted in the past twelve years on the effect of N application timing on corn production.

## METHODS

Information from several projects will be used to highlight corn production response and economic optimum N rate (EONR) with various sidedress and in-season (mid- to late-vegetative stages) N applications. Traditional sidedress/split N is the application of partial N before or at planting, with the remainder applied as a sidedress before corn becomes too tall for sidedress equipment; with either a planned sidedressing or rate based on soil nitrate testing. Examples of such research include Woli et al. (2014) with anhydrous ammonia, and other projects currently underway. Enhanced in-season sidedress/split N is typically the application of the majority of N based on plant N sensing and application at mid- to late-vegetative growth stages; application possible with high-clearance equipment. Examples of such research include Ruiz Diaz et al. (2008), Barker et al. (2012), and Barker and Sawyer (2016).

## RESULTS AND DISCUSSION

### Traditional Split/Sidedress N Application Timing

Anhydrous ammonia is a common N source used for corn production in Iowa, being about half of the fertilizer N consumed. Fall application historically is less efficient than spring application. A study conduct in central Iowa for three years found exactly that, with late fall application 6% lower yield and 54 lb N/acre higher EONR (Fig. 1). This potential for lower yield and higher N rate need is why farmers are encouraged to apply anhydrous ammonia in late fall (cold soil temperatures) and to consider a nitrification inhibitor. An all spring preplant and a split/sidedress (20 lb/acre ammonium nitrate at planting and the remaining N as anhydrous ammonia sidedress) had the same yield and EONR (144 lb N/acre preplant and 147 lb N/acre split/sidedress).

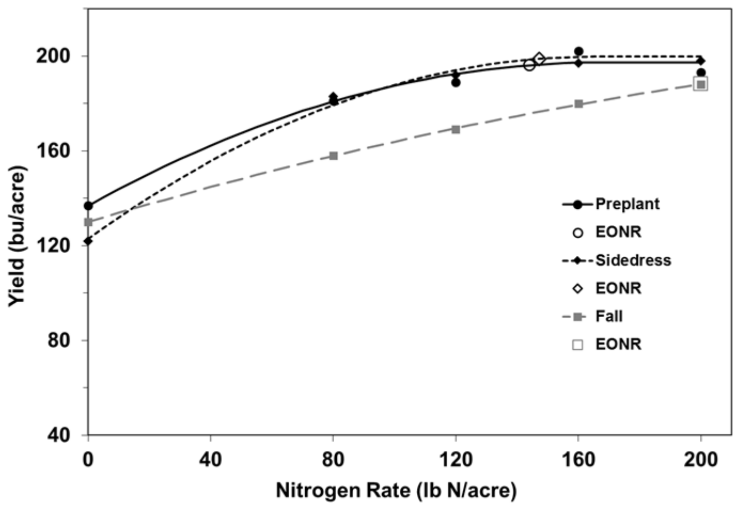


Fig. 1. Corn yield response and economic optimum N rate (EONR, 0.10 $/lb N:$/bu corn price ratio) with fall, spring preplant, and spring split/sidedress (V2-V4 growth stage) anhydrous ammonia with a site each year in central Iowa (2007-2009). Clarion-Nicollet-Webster soils with corn following soybean (Woli et al., 2014).

At four site-years in 2015 with sidedress N applied at the V5-V8 stages (Table 1, Nashua, Kanawha, Lewis, Crawfordsville), the mean yield at the economic optimum N rate (YEONR) was 210 bu/acre with all N applied preplant and 213 bu/acre with split/sidedress application. The economic optimum N rate (EONR) was 126 lb N/acre with preplant N and 130 lb N/acre with split/sidedress N. For the other sites in 2015 and in 2014 (Table 1), the initial N was applied at-planting and the sidedress N at V9. The mean YEONR was 206 bu/acre with at-planting N and 205 bu/acre with the split/sidedress. The mean EONR was 137 lb N/acre with at-planting N and 134 lb N/acre with the split/sidedress.

Across all 2014 and 2015 sites, the mean YEONR was 208 bu/acre with pre- or at-planting application and 209 bu/acre split/sidedress. The EONR was the same at 132 lb N/acre. Interestingly, with both sidedress timings (approximately V4 or V9 growth stages), the EONR was not lower with the split/sidedress application compared to preplant or at-planting application of the entire rate. Specific weather conditions can influence optimal N rate and corn response to applied N. Of interest, sites in Table 1 do not consistently have preplant or at-planting N with either lower yield or higher EONR compared to split/sidedress. Only at one site did split/sidedress application have either more than 5 bu/acre higher yield or 10 lb N/acre lower EONR compared to preplant or at-planting N. On the other hand, one site had yield higher with preplant or at-planting N and three sites the EONR was at least 10 lb N/acre higher with split/sidedress compared to preplant or at-planting N. Most frequently, the EONR and YEONR were the same. The mean EONR for both N application timings is nearly the same as the suggested MRTN rate for corn following soybean in Iowa at the 0.10 price ratio (CNRC, 2016).

However, some individual sites have an EONR outside the most profitable range. One 2015 site at Chariton not included in Table 1 had a yield response still increasing at 250 lb N/acre, the highest N rate applied – with both preplant and split/sidedress timing. Soils at this site have poor internal drainage, no drainage tile, and there was high rainfall in 2015. The similar N response to rate with both preplant and sidedress highlights that wet conditions can cause N loss with any N application timing, and that sidedressing will not always avoid N loss conditions.

Table 1. Economic optimum N rate (EONR, 0.10 N:corn price ratio) and corn yield at the EONR (YEONR) for several sites in Iowa with all N preplant or at-planting and split/sidedress with 40-50 lb N/acre preplant or at-planting and the remainder sidedress (approximately V4 or V9 growth stages depending on the study) (projects in progress, J. Sawyer, D. Barker, J. Hall, and J. Lundvall, 2015).

| Year | Site | Timing | No-N | YEONR | EONR | N Source | Place | Date |
|---|---|---|---|---|---|---|---|---|
| | | | - - bu/acre - - | | lb N/acre | | | |
| 2015 | Nashua | Preplant | 123 | 184 | 89 | Urea | Inc. | 14-Apr |
| | | Split | 121 | 189 | 105 | Urea | Inc. | 10-Jun |
| | Kanawha | Preplant | 179 | 221 | 88 | UAN | Bdc-Inc. | 23-Apr |
| | | Split | 177 | 225 | 105 | UAN | Inj. | 8-Jun |
| | Lewis | Preplant | 158 | 208 | 114 | UAN | Inj. | 30-Apr |
| | | Split | 155 | 204 | 106 | UAN | Inj. | 18-Jun |
| | Crawfordsville | Preplant | 109 | 225 | 213 | UAN | Inj. | 24-Apr |
| | | Split | 96 | 235 | 205 | UAN | Inj. | 4-Jun |
| | Boone | Plant | 80 | 203 | 147 | AN | Surf. | 19-May |
| | | Split | 83 | 206 | 167 | AN | Surf. | 9-Jul |
| | Lewis | Plant | 99 | 187 | 116 | AN | Surf. | 1-May |
| | | Split | 97 | 184 | 95 | AN | Surf. | 23-Jun |
| 2014 | Ames | Plant | 134 | 229 | 143 | AN | Surf. | 9-May |
| | | Split | 132 | 233 | 138 | AN | Surf. | 26-Jun |
| | Mason City | Plant | 82 | 205 | 143 | AN | Surf. | 15-May |
| | | Split | 82 | 197 | 137 | AN | Surf. | 3-Jul |
| | **Mean Response** | **Preplant** | **120** | **208** | **132** | | | |
| | | **Split** | **118** | **209** | **132** | | | |

### Mid- to Late-Vegetative (In-Season) N Application Timing

With high-clearance application equipment now commonly available, N application is now readily possible later into the corn vegetative growth period (in this report called “in-season”). Table 1 has several examples that could be considered “mid” vegetative timing. A summary of those sites was presented in the previous section; with no difference in yield or EONR between at-planting and mid-vegetative N application. The EONR does vary by site-year conditions, which is highlighted by the EONR at individual sites. Therefore, sidedressing provides an opportunity to adjust rate or apply additional N based on input information such as springtime precipitation, models, canopy sensors, or soil tests.

In 2004-2006, N was applied preplant/early sidedress (pre-sensing N) or split-applied (post-sensing N) in-season at corn V10-VT stages (SPAD meter based) across 30 fields with corn following soybean (Ruiz Diaz et al., 2008) (Table 2). Across the 30 sites, and with a pre-sensing N application of 60 lb N/acre plus a mean 55 lb N/acre post-sensing N (total 115 lb N/acre), there was a yield increase from 141 bu/acre (no N) to 185 bu/acre. However, the yield with 120 lb N/acre all applied early was 7 bu/acre higher than the post-sensing N (192 bu/acre vs. 185 bu/acre). In some fields, response to the post-sensing N was not enough to achieve full yield potential. In other fields, yield with the post-sensing N was equivalent to that with the pre-sensing N only; especially when rain was received shortly after N application. Overall the sensor-based split N system would not be fully justified compared to applying all N early because the in-season application did not reduce the total-N applied, nor did it improve yield relative to early applied N. Additionally, the in-season application would incur sensing and higher application costs.

Table 2. Total fertilizer N applied and corn grain yield response to pre- and post-sensing N application in 30 fields with corn following soybean, 2004-2006 (Ruiz Diaz et al., 2008).

| N Application Treatment† | Mean Total N Applied† | Number of Sites with Post-Sensing N Applied | Mean Yield‡ |
|---|---|---|---|
| | lb N/acre | n | bu/acre |
| 0 | 0 | - | 141d |
| 60 | 60 | - | 177c |
| 60+ | 115 | 28 | 185b |
| 120 | 120 | - | 192a |
| 120+ | 131 | 9 | 193a |
| 240 | 240 | - | 197a |

† Treatment is the pre-sensing N rate, with the "+" symbol indicating post-sensing based N. Mean total N applied is the sum of pre-sensing and post-sensing N rate across the 30 corn-soybean sites.
‡ Mean yields are not significantly different when followed by the same letter ($P \leq 0.10$).
Mean EONR (0.10 N:corn price ratio) for pre-N rates was 132 lb N/acre.

In a study conducted in 2009-2010 (Barker and Sawyer, 2012), total N applied preplant (PP-N) or a combination of preplant plus sensor-based (PP+S-N) resulted in the same corn yield level at equivalent total N rates (Fig. 2). Nitrogen response and EONR was quite different between years, with 2010 having large rainfall events and high EONR. While the yield response was the same to both timings in each year, there was potential to adjust in-season rate for the different seasons and N fertilization needs. Best in-season rate determination each year was with no N applied preplant.

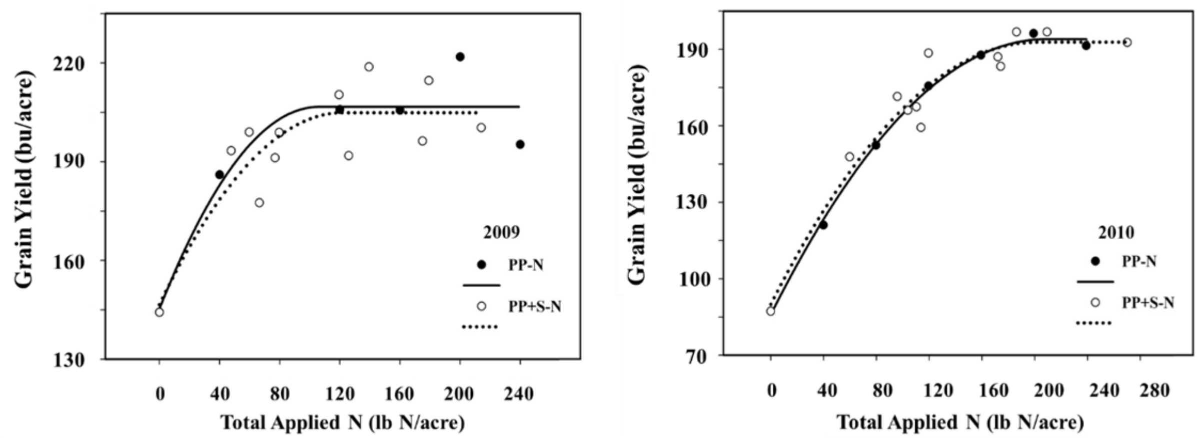


Fig. 2. Corn yield with UAN solution or urea applied preplant (PP-N) and preplant plus V10 stage sensor-based (PP+S-N) UAN, 2009 and 2010 (Barker and Sawyer, 2012). Economic optimum N rate (0.10 N:corn price ratio) in 2009 was 98 lb N/acre and in 2010 was 190 lb N/acre.

In two years with dry conditions (2012-2013) (Barker and Sawyer, 2016), sensor based in-season N application increased yield when preplant (PP-N) rates were deficient (Fig. 3). However, the yield increase from in-season N (PP+S-N) was limited when applied in addition to PP-N rates below the EONR. Also, the total amount of N applied (PP+S-N) at all preplant (PP-N) rates was greater than the EONR, with the sensor-based rate (total N) quite high when 150 lb N/acre or more had been applied preplant.

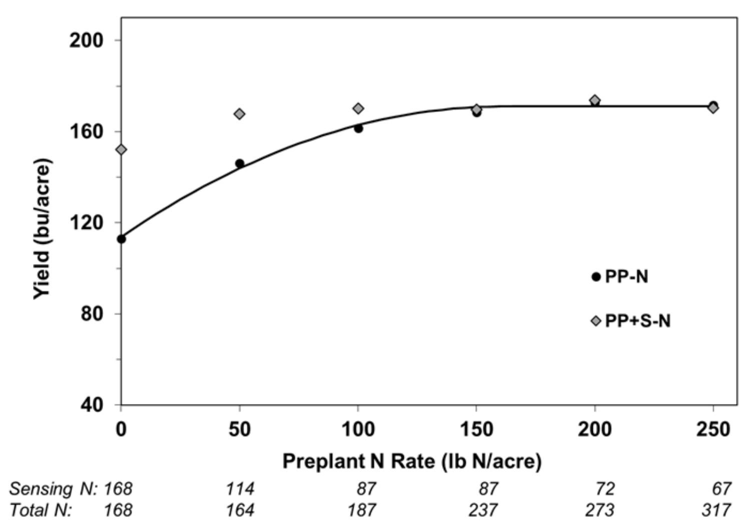


Fig. 3. Corn yield with urea applied preplant (PP-N) and preplant plus V10 stage sensor-based (PP+S-N) urea, 2012 and 2013 with corn following soybean at eight sites (Barker and Sawyer, 2016). Economic optimum N rate (0.10 N:corn price ratio) across site-years for the PP-N application was 138 lb N/acre.

**SUMMARY**

While sidedress/split N application has appeal for yield and economic return improvement, recent research has shown it is difficult to achieve a frequent and consistent positive response in corn production. While the sidedress practice may be of frequent benefit in coarse-textured soils, with irrigation, or in geographic areas with high rainfall and poorly drained soils (ex. eastern U.S. Corn Belt), that has not been the general case with Iowa soils and conditions. Certainly soils that are poorly drained and with high springtime rainfall periods can have positive return to sidedress or in-season N application; however, that should not be an expected occurrence on all soils or in all years. In addition, in years with dry conditions, especially after sidedress application, dry soils and lack of rainfall can result in poor crop fertilizer N uptake and reduced yield compared to preplant or early season application. In-season N application, by itself, will not improve yield unless there is deficient N in the soil system and the crop can respond. More N does not mean more yield even if late applied. There are many opportunities for N applications to be accomplished during the spring season, with options for successful preplant through mid-season timing, along with tools to adjust rates. The potential frequency of soil and weather conditions that may impact optimal N timing, along with time and equipment to accomplish applications, should be considered when implementing sidedress/split N application systems.

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PROGRAM CHAIR:

**Dorivar Ruiz Diaz**
Kansas State University
Manhattan, KS 66506
(785) 532-7213
ruizdiaz@ksu.edu



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**International Plant Nutrition Institute**
2301 Research Park Way, Suite 126
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