A COMPREHENSIVE CORN NITROGEN RESEARCH PROGRAM FOR ILLINOIS

2016 Annual Report to the Nutrient Research & Education Council

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This project includes as a primary objective gathering data on the response of corn grain yield to N fertilizer rates with replicated, field-scale N rate trials at numerous on-farm locations throughout Illinois, representing the large diversity of soils and weather in the State. In some cases these trials include comparing fall-applied and spring-applied or early spring and sidedressed fertilizer N rates. The second primary objective is to evaluate combinations of fertilizer N rate, form, inhibitor treatments, and application timing on corn yield and economic return using smaller-plot trials on UI research centers.

On-Farm Trials: EONR versus MRTN

In 2016, 46 trials were completed under this project, including 7 strip trials at UI Crop Sciences Research & Education Centers, done using the same design as in producer fields. This exceeded the goal of completing 30 to 35 trials in 2016.

Figure 1 shows the N response data from 33 sites with corn following soybean in 2016. Each response was fitted with an appropriate function and the point at which return to N was maximized (the economically optimum N rate, or EONR) was calculated using a price of $0.375 per lb. of N and a corn price of $3.75 per bushel. In addition, we used the MRTN N rate from the N rate calculator, run for the appropriate Illinois region and previous crop for each trial, and for each curve we show that rate and the yield at that N rate. Averaged across all 33 sites, the average EONR value (157 lb. N/acre) was 17 lb. less than the MRTN (174 lb. N/acre) and the average yield at the EONR (225 bushels per acre) was one bushel more than the average using the MRTN at each site (224 bushels per acre). At 17 lb. less N and a bushel higher yield, using the EONR (if we somehow knew it beforehand for each field) would have returned on average about $10 per acre more than using the MRTN in 2016. In contrast, averaged over 36 corn following soybean trials in 2015, the average EONR was 25 lb. N per acre higher than the MRTN rate (191 v 166 lb. N) and yields at the EONR averaged 9 bushels per acre more than yields calculated at the MRTN rate (220 v 211 bu./acre). The net effect was a return to N about $24 per acre higher using the EONR rates in 2015 rather than the MRTN. We think this is because the wet weather both damaged the crop and perhaps led to some loss of plant-available N in 2015. There was little of this in 2016.

Figure 2 shows the N response from 11 on-farm sites with corn following corn in 2016. Averaged across sites, the EONR was 18 lb. N/acre less than the MRTN N rate (172 v 200 lb. N/acre), and average yield at the EONR was the same (224 bu/acre) as at the MRTN rate. The net return to N averaged about $10 more at the EONR than at the MRTN. In contrast, in 2015 the corn following corn trials produced an average EONR value that was 16 lb. more than at the MRTN and produced 6 more bushels, for a net advantage of $15 per acre for the EONR.

The MRTN values, which are calculated based on many previous trials, cannot anticipate field conditions before the season for a given field, so are almost never exactly the amount of N needed in a field. In 2016, in contrast to 2105, most of the actual EONR values in the 2016 trials were less than the MRTN; the yellow triangles in Figures 1 and 2 are to the left of the green circles. In part this happened because the 2015 data, which were put into the N rate calculator in early spring 2016, moved the MRTN values up, especially for corn following soybean in central Illinois. We have already submitted the 2016 data to be used to update the calculator before the spring of 2017. The results of having most of the trials show the need for less N in 2016 than the MRTN means that adding in these data will lower the MRTN back down by a few pounds of N. While the fact that the MRTN "moves around" is seen as a negative by some, the advantage to continuing to add to the data is that the average over different years actually does change, and an approach in which a year like 2016 helps offset the higher N need we saw in 2015 is a good thing.

Trials in which N application was split to compare fall versus spring or early spring versus sidedress N rates showed inconsistent responses to N timing. In one on-farm trial in 2016, spring-applied N produced about the same yield while using about 17 lb. less N than fall-applied N, resulting in a modestly higher return for spring-applied N (Figure 3.) We saw a larger advantage for spring-applied N in 2015, as expected given the wet spring weather. Averaged over six on-farm comparisons, yield was one bushel less and the N rate required to optimize yield was 18 lb. N more for fall-applied versus spring-applied N (data not shown.) This is an advantage of about $10 per acre in favor of spring N, not counting any risk associated with waiting until spring to apply N, or of more N loss with fall application.

At another on-farm site in 2016, applying N in the fall compared to applying all but 50 lb. in the fall then coming back with 50 lb. at sidedress produced virtually identical yields, with slightly more N needed if applied in the fall only (Figure 4.)

Late-split N

In 2016 we added to this project a new trial designed to see if keeping back 50 lb. of N to apply at tasseling time will increase yields. The late N was dribbled using a hand-boom into the row near the base of the plants as a way to duplicate the "Y-Drop" tubes being marketed to apply N into standing corn, including into tall corn. Trials were conducted in corn following soybean at DeKalb, Monmouth, Urbana, and Perry, and in corn following corn at all of these locations except DeKalb. A trial conducted at Ewing field was damaged by heavy rainfall and results won't be included.

Applying N rates at planting or keeping 50 lb. N to apply at tasseling produced virtually identical N responses for corn following soybean (Figure 5) and for corn following corn (Figure 6). Responses at Urbana were virtually identical to those at the other sites, so responses from the other won't be included here. The only site at which late-split N increased the return to N (at the optimum N rate and yield) was Monmouth, where the two trials (C-C and S-C) averaged $7.12 per acre higher net to late N (not including the cost of the application); on average, late-split N over the other five trials resulted in a loss of $8.23 per acre compared to planting-time application. Rainfall was somewhat higher at Monmouth (totaling about 13 inches in June and July) than at other sites, which might have provided a small advantage to late N. In a year with a good supply of soil N and corn that was well-supplied by N through pollination, however, there may be no yield advantage to keeping back some N to apply late. With no yield advantage and no reduction in the amount of N needed, the cost of late application would have meant lower profits in 2016.

N Rate, Timing, and Form

Small-plot trials were conducted according to the project plan at DeKalb, Monmouth, Urbana and Perry (Orr Center – a new site) in 2016. All were planted on time and managed well, with treatments applied as planned. We added two treatments in 2016: 150 lb. N as UAN injected at planting plus 50 lb. N as UAN dribbled in the row at tasseling; and 150 lb. N injected at planting with Nutrisphere® added. Corn followed soybean at all locations. The base N response (against which other treatments were compared) was generated with UAN applied by injection at planting at rates ranging from 0 to 250 lb. N per acre in 50-lb. increments. The response to sidedressing N was tested using 50 lb. N at planting plus 50, 100, or 150 lb. N at stage V5-V6, with corn 12 to 16" tall. An additional 19 treatments were applied at the rate of 150 lb. N/acre using a range of timings, forms, and inhibitors. Table 1 lists the treatments.

Figures 7 to 10 show N responses at DeKalb, Monmouth, Urbana, and Perry. As we saw with most other N trials in 2016, optimum N rates were relatively low and yields relatively high. Yields without N fertilizer were high at Monmouth (196 bu/acre) and Perry (184 bu/acre) and optimum N rates low (121 and 104 lb. N/acre); both reflect the large amount of mineralized N available under June conditions in 2016. At DeKalb and Urbana, yields without N were lower (153 and 142 bu/acre) and EONR values higher (165 and 167 lb. N/acre), respectively. Applying N as 50 lb. at planting and the rest as sidedressed UAN showed a yield benefit at Monmouth but not at the other sites. This comparison, including data from previous years, will be discussed in more detail near the end of the report.

The different timings and forms of N compared at 150 lb. N per produced different yields, without great consistency in treatments among sites (Table 1.) The yield range among these treatments was 36, 27, 12, and 18 bushels per acre at DeKalb, Monmouth, Urbana, Perry, respectively. These ranges were generally smaller than we saw in 2015, probably due to less N loss or better root function under drier conditions in 2016. When the range of treatments was very small, as it was at Urbana, statistical differences are rare, and value of ranking yields by treatment is lower. As an example, broadcast ESN at planting ranked eighteenth (of 20) in yield at Urbana but third across all four sites (Table 1); the yield difference between ESN and the top yield at Urban was only 11 bushels per acre, not enough to offset the high yields from this treatment at other sites. Still, inconsistency of performance among sites means less ability to declare differences to be statistically significant, so when averaged across sites there are few “significant” differences among treatments. Only the three highest-yielding treatments are statistically different from the two lowest-yielding treatments when averaged across sites in 2016; the other15 treatments are not statistically different from the highest-yielding treatment, or in many cases from the lowest-yielding treatment (Table 1).

Over sites in 2016, the highest yields were from dry fertilizer broadcast at planting – urea with Agrotain, SuperU, and ESN ranked 1, 2, and 3, and all yielded 230 bushels per acre (Table 1). The next 15 treatments were not significantly lower-yielding than the top three (all have the letter “a” behind them), but ones that yielded within 5 bushels of the highest-yielding included mostly spilt-N treatments, mostly those with 100 lb. N as UAN injected at planting followed by 50 lb. UAN dribbled in-row or (at VT) mid-row. The base treatment of 150 lb. UAN injected at planting was the only other treatment with all of the N applied at planting to yield among the top third of treatments. Lower-yielding treatments included those in which UAN was applied to the soil surface, either broadcast or dribbled, including the treatments that included Agrotain and Instinct II. Treatments with ammonia at planting, with or without N-Serve, did not produce high yields, and waiting until sidedress time (V5 or V9) to apply all of the N resulted in considerable yield loss (Table 1). So even in a year with a considerable amount of mineralized N available, plants seemed to benefit from having at least some of the N applied early, and in a form that quickly becomes available to the young plants as they emerge.

Because spring conditions, especially June rainfall, contrasted so much between 2015 and 2016, rankings of N form and timing treatments are shown by year and across the two years in Table 2. Those that ranked at least 5 places higher in 2015 than in 2016 included split-N treatments, with 100 lb. of N as UAN injected at planting followed by 50 lb. N, either injected at V5, broadcast as urea with Agrotain at V5, or as UAN dribbled between the rows at VT (Table 2). Treatments in which all N was delayed until V5 (injected) or V9 (dribbled) also did considerably better in 2015 than in 2016. Those treatments that did better in 2016 than in 2015 included three with all of the N applied at planting – UAN dribbled (still not a very good treatment), urea with Agrotain broadcast, and ESN broadcast. The only other treatment to do much better in 2016 than in 2015 was 100 lb. N as UAN injected at planting followed by 50 lb. UAN dribbled between the rows at VT. Across all seven site-years, though, the top 7 treatments (those followed by “a” or “ab” in Table 2) included dry fertilizer broadcast at planting, UAN injected at planting (the base treatment), and 100 lb. N as UAN injected at planting followed by 50 lb. UAN dribbled between the rows at V9, or dribbled in the row at V5 or at VT. Most of the rest of the treatments with all of the N applied at planting or with UAN applied to the soil surface did not yield statistically higher (the letter “f” follows each yield) than the lowest-yielding treatment, which was broadcast UAN with Agrotain at planting. We don’t have a good way to know if UAN applied to the soil surface is lost to urease activity (even when a urease inhibitor is used) or does not become available to the plant in time to prevent yield loss. We do know, however, that this is that it is not a very good way to apply N to the crop.

Of the current treatments we have used to compare 150 lb. N using different forms and time, 15 were used the first year (2014) and are still in the trials. Spring conditions in 2014 season fell between those of the wet 2015 and the drier 2016. Table 3 has yields from these treatments averaged over the ten site-years – DeKalb, Monmouth, and Urbana 2014-2016 and Perry in 2016. The base treatment – UAN injected at planting – ranked fourth in yield, 3 bushels (but not significantly) less than the highest-yielding treatments of urea + Agrotain and SuperU broadcast at planting (Table 3). Other treatment whose relative ranks changed somewhat comparing the last two years with the last three years include the treatment with 50 lb. N broadcast at planting followed by injection of 100 lb. at V5, and injection of 100 lb. N at planting followed by 50 lb. injected as UAN at V5 – both were better treatments in 2014 than in 2015-16. Waiting until V5 to apply all of the N also worked better in 2014 than in 2015 or 2016.

Planting-time versus split N

The N form and timing studies discussed above include a number of treatments that compare one-time and split N applications, all at the same N rate (150 lb. N/acre). Our small-plot studies under this project also include a comparison of N at three rates – 100, 150, and 200 lb. N/acre – applied either as injected UAN at planting or with 50 lb. N injected at planting and the remaining N sidedressed at V5-V6. It is noted above that of the four sites in 2016, we found higher yield with split N than with N applied at planting time at only one site (Monmouth.)

Data from ten site-years comparing N responses between these two methods of application show that yield at the 100-lb. rate was higher (by 12 bushels) with all-early application than with split application (Figure 11). The two methods produced similar yields at the two higher rates, and the optimum N rates and yields at those rates were similar; the optimum N rate and yield at that rate were, averaged over sites, about 9 lb. N and 1.6 bushels per acre higher for split compared to all-early N. Such differences are too small to be considered as “real” differences, but it is clear that expecting split N with a sidedress application to require less N, and perhaps to yield more, may not be realistic. Finding a lower yield with split application at the low rate (100 lb. of N) might support the idea, mentioned above, that not having all of the N in the soil early might sometimes result in N deficiency that can’t be overcome by later application of N.

DAP as an N source

This study is a new one added for 2016, and consists of applying N rates of 100 (base rate using UAN only), 120, 140, 160, and 180 lb. N/acre by three N source/timing combinations: 1) DAP broadcast in the fall after soybean harvest 2) DAP broadcast in the spring before secondary tillage; and 3) UAN injected in the spring before secondary tillage. TSP (0-45-0) was used to bring the P rate to the same for each treatment. Rates were assigned to main plots, and source to subplots, with 6 reps to better detect small differences.

These trials were done exactly according to plan, at Monmouth and Urbana. Results for this first year were, however, somewhat unusual, especially at Urbana, and we will wait until we have results from 2017 before we try to reach any conclusions. At Monmouth, N responses to spring DAP and (spring) UAN were similar, and fall DAP needed about 16 lb. more N per acre to maximize yield than spring DAP. The N response at Urbana was very unusual: all the three sources of N showed an accelerating curve, with the highest yield at the highest N rate and no differences among sources. We do not have a good explanation for such a response from any source, let alone more than one source.

Outreach

Results of this work were made known through the Extension presentations, including the IFCA Conference in January 2017, and webinars in March 2016 and scheduled for February 2017. A (UI) Bulletin article on December 5, 2016 provided a first look at N responses in 2016. Several other presentations, both inside Illinois and in Ontario, Ohio, and Indiana, included data generated under this project, with credit given to NREC for funding. Audience totals for in-person presentations over the past year is estimated at 1,000.

Budget

The budgeted amounts were spent as planned in FY 2016; following is the record of expenditure (from the beginning of the project on January 1, 2014 through February 14, 2017). Unspent funds (originally for payment to producers for on-farm trials, now being covered by IFCA) will be used for soil analyses and other expenditures ("participant support costs" are part of the "services" category used to pay for analyses, plot fees, etc.) This was a 3-year project scheduled to end on February 28, 2017; it has been extended (request for two more years) for 2017.

C3787	**A Comprehensive Corn Nitrogen Research Program for Illinois**			
Line Description	**Budget**	**Expenditures**	**Encumbrances**	**Balance**
Total Salaries and Wages	77,875	78,930	1,776	-2,832
Total Fringe Benefits	31,364	30,194	757	413
Total Travel	9,000	4,672	0	4,328
Total Participant Support Costs	70,000	0	0	70,000
Materials and Supplies	2,507	4,982	0	-2,475
Services	4,500	36,900	0	-32,400
Total Other Direct Costs	7,202	41,881	0	-34,679
Total Indirect Costs	21,677	16,656	281	4,740
Total Budget, Expenditures, Encumbrances, and Balance:	**217,118**	**172,334**	**2,815**	**41,969**

Plans for 2017

We plan to use the same set of treatments used in 2016, and to again run the same types of trials. The closing of the DeKalb REC means we have to travel to do all of the work there, but we were been able to arrange to fields on that farm in 2016, and plan to do so again in 2017. The smaller trials being conducted in southern Illinois (these started as part of Dr. Rachel Cook's project and I didn't report on them here) will continue at one site.

Table 1. Effect of N form and timing on yield at four Illinois sites in 2016, and averaged across sites. All plots received 150 lb. of N per acre. Treatments are ranked (1=highest yield to 20) and across-site means are separated with letters at p=0.1.

Treatment	DeKalb		Monmouth		Urbana		Perry		4-site average		
	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield		Rank
All N applied at planting:	bu/ac	1 to 20	bu/ac	1 to 20	bu/ac	1 to 20	bu/ac	1 to 20	bu/ac		1 to 20
UAN injected mid-row	234	8	248	9	219	11	205	8	226	ab	7
UAN dribbled mid-row	235	6	248	10	216	16	197	18	224	abc	13
Urea/Agrotain broadcast	235	4	263	1	221	9	201	15	230	a	1
SuperU broadcast	234	7	256	3	223	3	206	6	230	a	2
ESN broadcast	245	1	250	8	214	18	210	2	230	a	3
UAN/Agrotain broadcast	214	19	251	4	219	13	191	20	219	bc	19
NH3 injected mid-row	221	18	251	5	222	7	210	1	225	ab	11
NH3/N-Serve injected mid-row	---		247	12	219	12	199	17	223	abc	16
UAN/Instinct II broadcast	227	15	246	13	214	19	203	10	222	abc	17
UAN/Nutrisphere injected	231	13	239	19	217	15	205	7	223	abc	15
Split N application (1st at planting):											
UAN 50 broadcast+UAN 100 inj V5	223	16	258	2	213	20	208	4	226	ab	9
UAN 100 inj+UAN 50 injected V5	233	12	240	18	220	10	201	14	223	abc	14
UAN 100 inj+Urea/AT 50 brdcst V5	236	3	244	15	223	4	201	16	226	ab	10
UAN 100 inj+UAN 50 drbl in-row V9	240	2	247	11	222	6	202	12	228	ab	5
UAN 100 inj+Urea/AT 50 bdcst V9	235	5	243	16	223	5	205	9	226	ab	8
UAN 100 inj+UAN 50 drbl in-row V5	233	10	250	7	222	8	203	11	227	ab	6
UAN 100 inj+UAN 50 drbl mid-row VT	233	9	251	6	225	1	206	5	229	ab	4
UAN 100 inj+UAN 50 drbl in-row VT	229	14	240	17	224	2	209	3	225	ab	12
All N sidedressed:											
V5 UAN injected mid-row V5	223	17	245	14	218	14	202	13	222	abc	18
UAN dribbled mid-row V9	209	20	236	20	216	17	194	19	214	cd	20

Table 2. Effect of N form and timing on yield over three Illinois sites in 2015 and four sites in 2016. All treatments included N at a total rate of 150 lb. N/acre. Rank (1=highest to 19) is given, and across-site means were separated at p = 0.10.

Treatment	**Rank (1 to 19)**			**Yield**	**p=0.1**
	2015	**2016**	**2-yr**	bu/acre	
All N applied at planting:					
UAN injected mid-row	7	7	7	221	ab
UAN dribbled mid-row	19	13	17	214	ef
Urea/Agrotain broadcast	9	1	2	223	ab
SuperU broadcast	1	2	1	225	a
ESN broadcast	12	3	5	222	ab
UAN/Agrotain broadcast	17	18	19	213	f
NH3 injected mid-row	18	11	15	215	cdef
NH3/N-Serve injected mid-row	16	15	16	215	def
UAN/Instinct II broadcast	13	16	14	217	bcdef
Split N application (1st at planting):					
UAN 50 broadcast+UAN 100 inj V5	15	9	13	218	bcdef
UAN 100 inj+UAN 50 injected V5	4	14	10	220	abcde
UAN 100 inj+Urea/AT 50 bdcst V5	5	10	8	221	abc
UAN 100 inj+UAN 50 drbl in-row V9	8	5	4	222	ab
UAN 100 inj+Urea/AT 50 bdcst V9	11	8	11	220	abcde
UAN 100 inj+UAN 50 drbl in-row V5	2	6	3	223	ab
UAN 100 inj+UAN 50 drbl mid-row VT	14	4	9	221	abcd
UAN 100 inj+UAN 50 drbl in-row VT	3	12	6	222	ab
All N sidedressed:					
UAN injected mid-row V5	6	17	12	218	bcdef
UAN dribbled mid-row V9	10	19	18	213	f

Table 3. N form and timing effects averaged across ten Illinois site-years, 2014-2016.

Treatment	Rank	avg 10 sites	
	1 to 15	bu/acre	
<u>All N applied at planting:</u>			
UAN injected mid-row	4	220	abc
UAN dribbled mid-row	13	215	def
Urea/Agrotain broadcast	1	223	a
SuperU broadcast	2	223	ab
ESN broadcast	8	219	abcde
UAN/Agrotain broadcast	15	213	f
NH_3 injected mid-row	12	216	cdef
NH_3/N-Serve injected mid-row	11	216	cdef
<u>Split N application (1st at planting):</u>			
UAN 50 broadcast+UAN 100 inj V5	9	218	bcde
UAN 100 inj+UAN 50 injected V5	5	220	abc
UAN 100 inj+Urea/AT 50 bdcst V5	7	219	abcd
UAN 100 inj+UAN 50 drbl in-row V9	3	221	abc
UAN 100 inj+Urea/AT 50 bdcst V9	10	218	cde
<u>All N sidedressed:</u>			
UAN injected mid-row at V5	6	220	abc
UAN dribbled mid-row at V9	14	214	ef

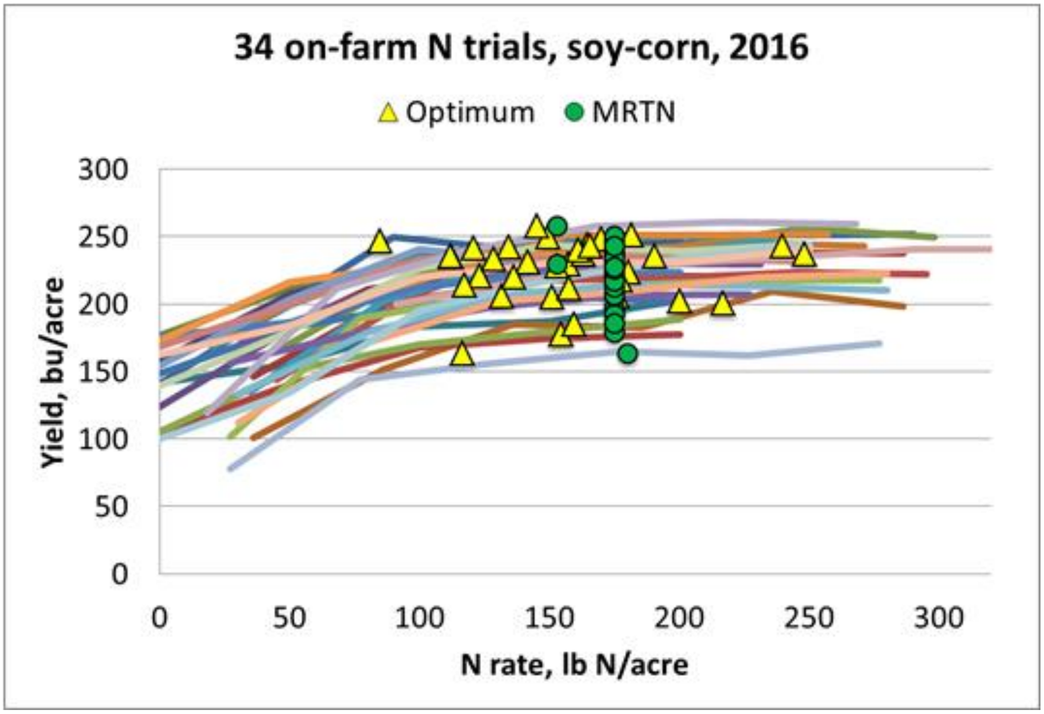

Figure 1. N responses in 34 on-farm N rate trials in Illinois in 2016. Yellow triangles indicate the optimum N rate for each trial, and green circles show yield at the MRTN N rate.

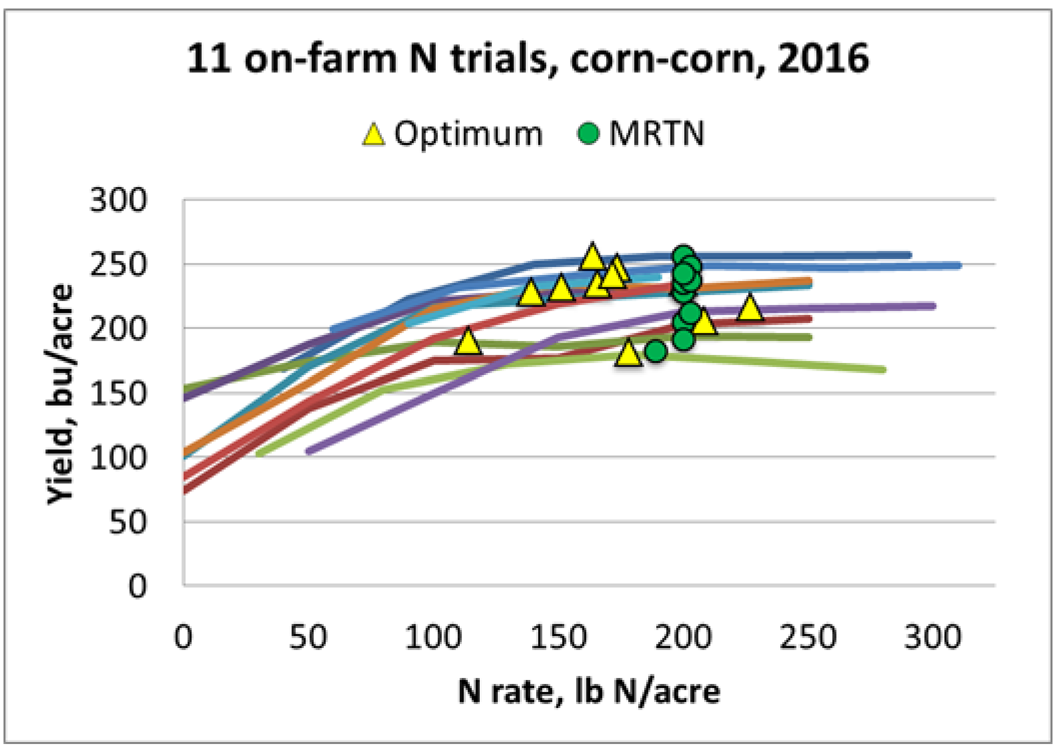

Figure 2. N responses from 11 on-farm N rate trials in Illinois in 2016. Yellow triangles indicate the optimum N rate for each curve, and green circles show yield at the MRTN N rate.

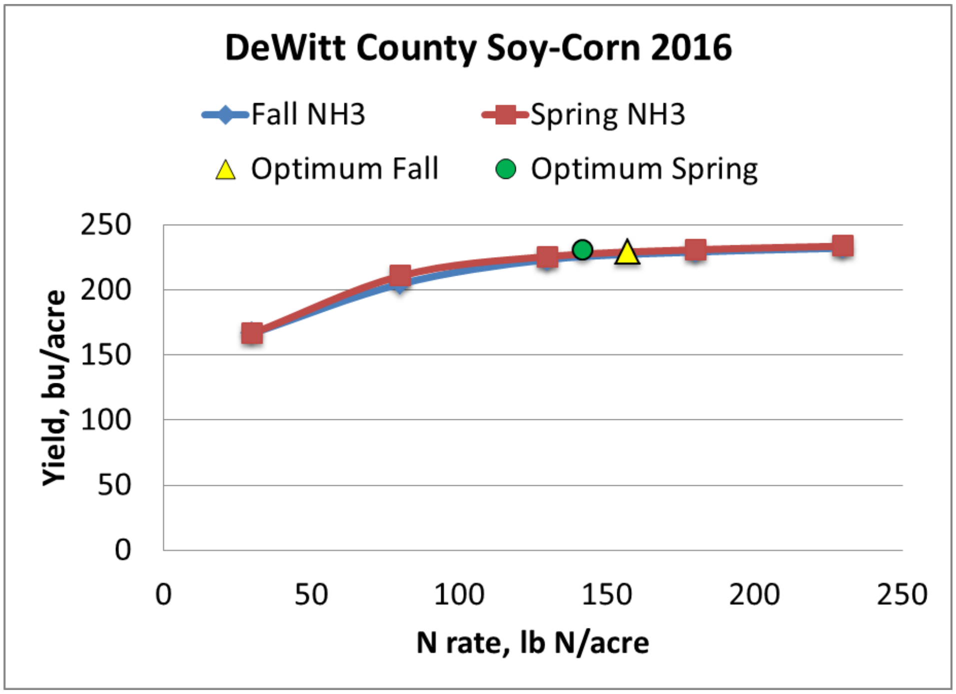

Figure 3. A comparison of fall versus spring N application at an on-farm site in central Illinois in 2016. The yellow triangle marks the N rate and yield at the point of maximum return to N for fall-applied NH_3, and the green circle does the same for spring-applied NH_3.

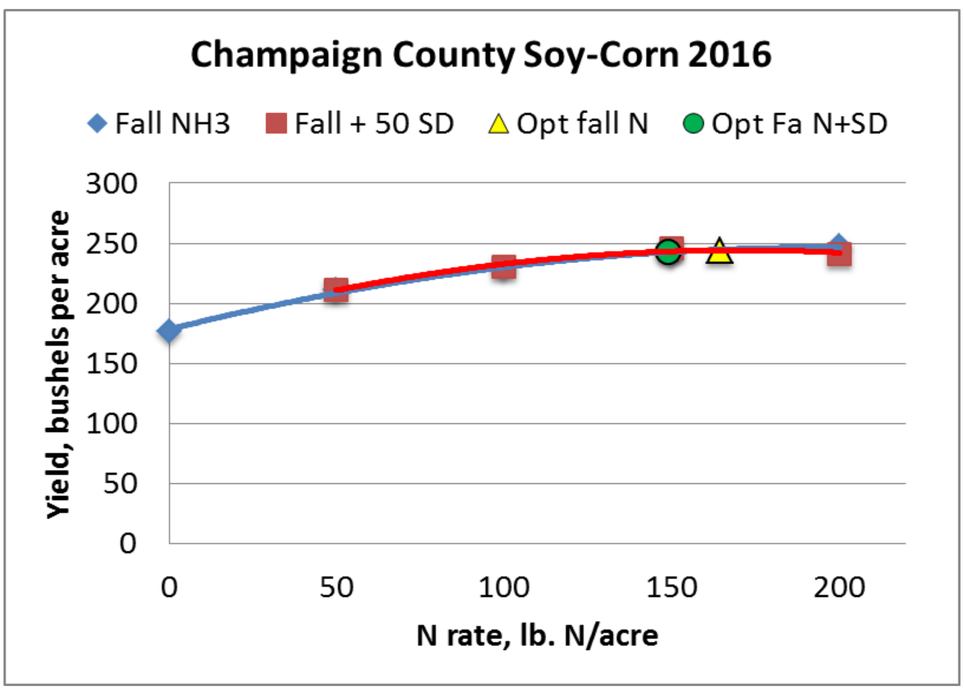

Figure 4. Response to N applied as NH_3 in the fall compared to applying the same rate split, with all but 50 lb. applied in the fall and 50 lb. applied as UAN sidedressed in early June, in an on-farm trial in 2016. The yellow triangle marks the N rate and yield at the point of maximum return to N for fall-applied NH_3, and the green circle does the same for fall-applied NH_3 plus 50 lb. N sidedressed in the spring.

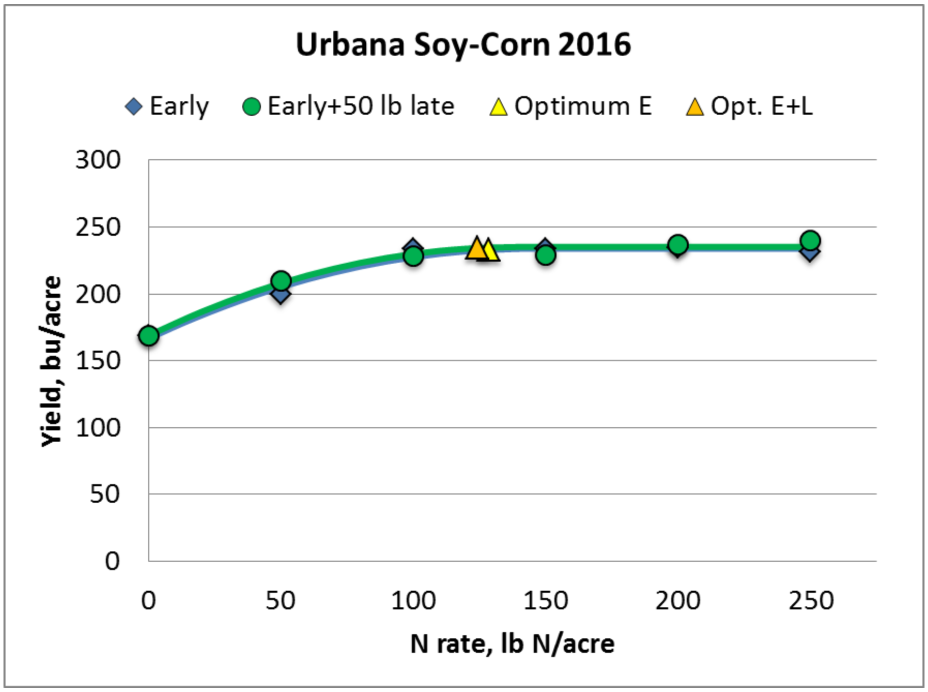

Figure 5. Response from N applied at planting time (Early) compared to N split into planting-time and 50 lb. N (Early + late) as UAN dribbled into the row at tasseling. Data are from a corn following soybean trial at Urbana, Illinois in 2016.

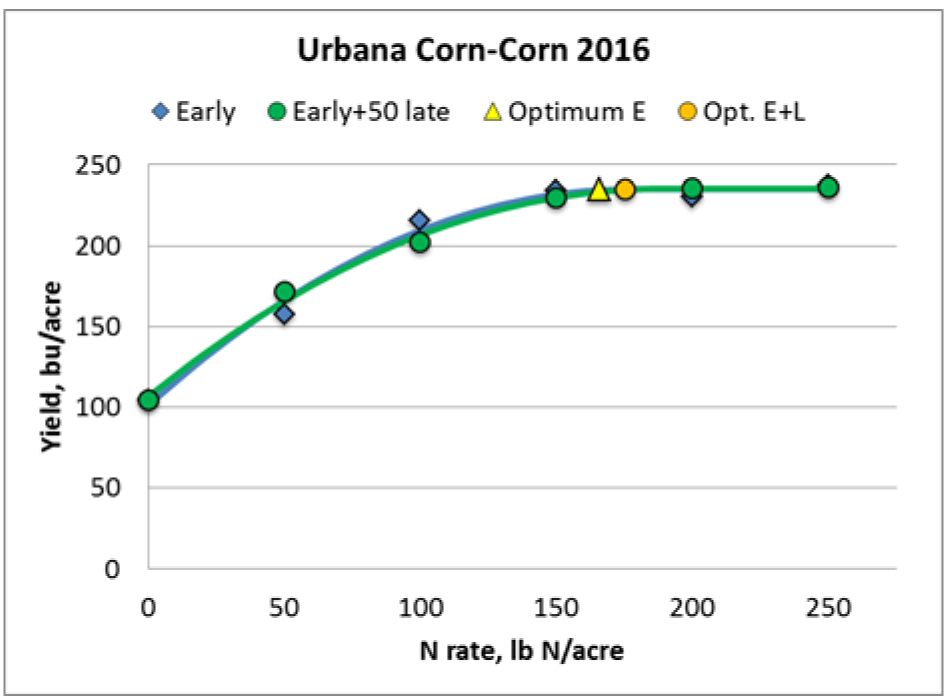

Figure 6. Response from N applied at planting time compared to N split into planting-time and 50 lb. N as UAN dribbled into the row at tasseling. Data are from a corn following corn trial at Urbana, Illinois in 2016.

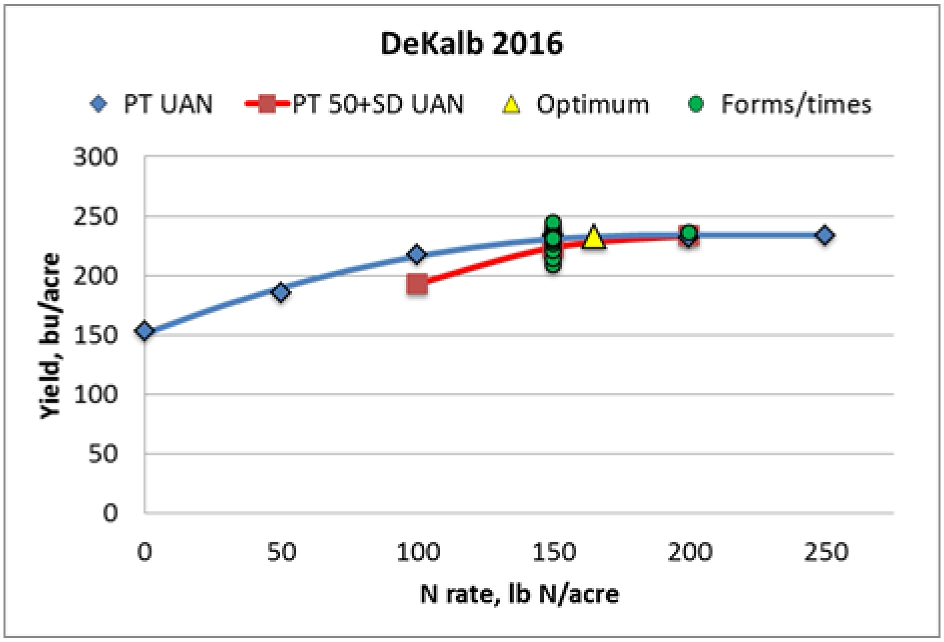

Figure 7. Responses to N rate, form, and timing at DeKalb, Illinois in 2016. Base rates were applied as UAN at planting time, and sidedress (SD) as 50 lb. N at planting plus UAN at V5-V6. Form and timing treatments and yields are given in Table 1.

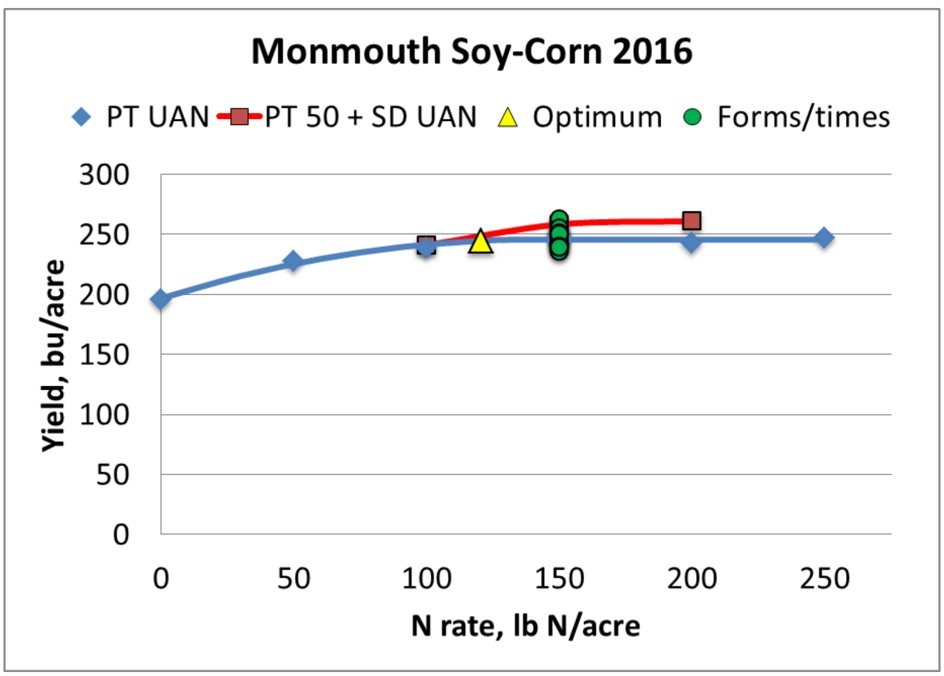

Figure 8. Responses to N rate, form, and timing at Monmouth, Illinois in 2016. Base rates were applied as UAN at planting time, and sidedress as 50 lb. N at planting plus UAN at V5-V6. Form and timing treatments and yields are given in Table 1.

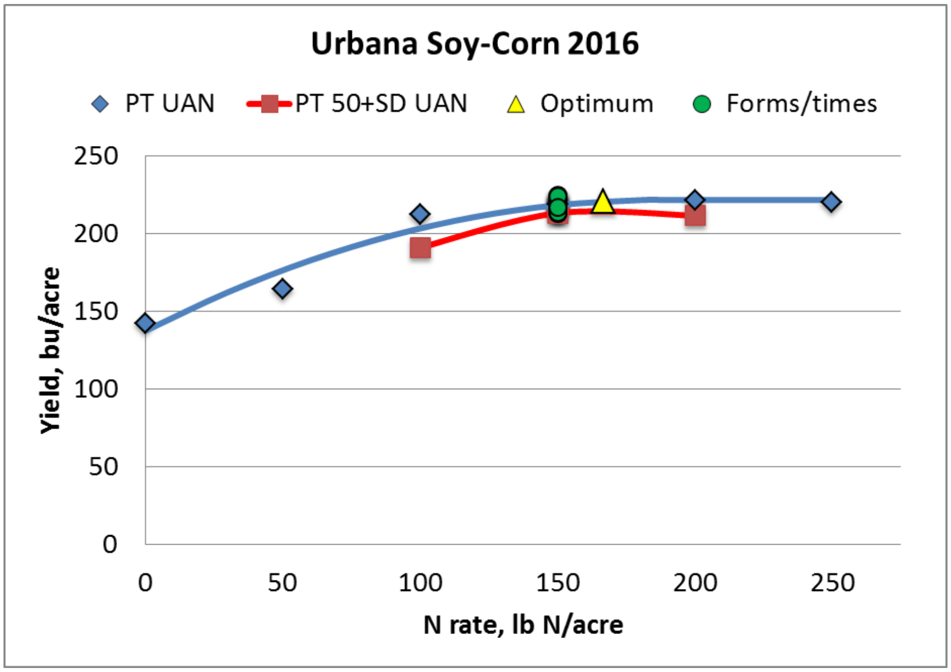

Figure 9. Responses to N rate, form, and timing at Urbana, Illinois in 2016. Base rates were applied as UAN at planting time, and sidedress as 50 lb. N at planting plus UAN at V5-V6. Form and timing treatments and yields are given in Table 1.

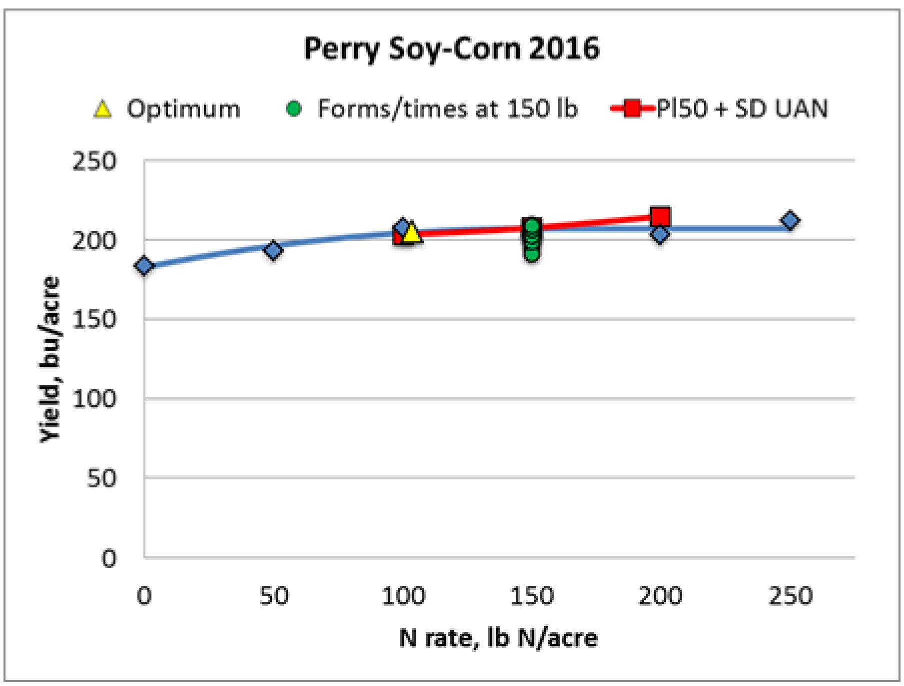

Figure 10. Responses to N rate, form, and timing at Perry, Illinois in 2016. Base rates were applied as UAN at planting time, and sidedress as 50 lb. N at planting plus UAN at V5-V6. Form and timing treatments and yields are given in Table 1.

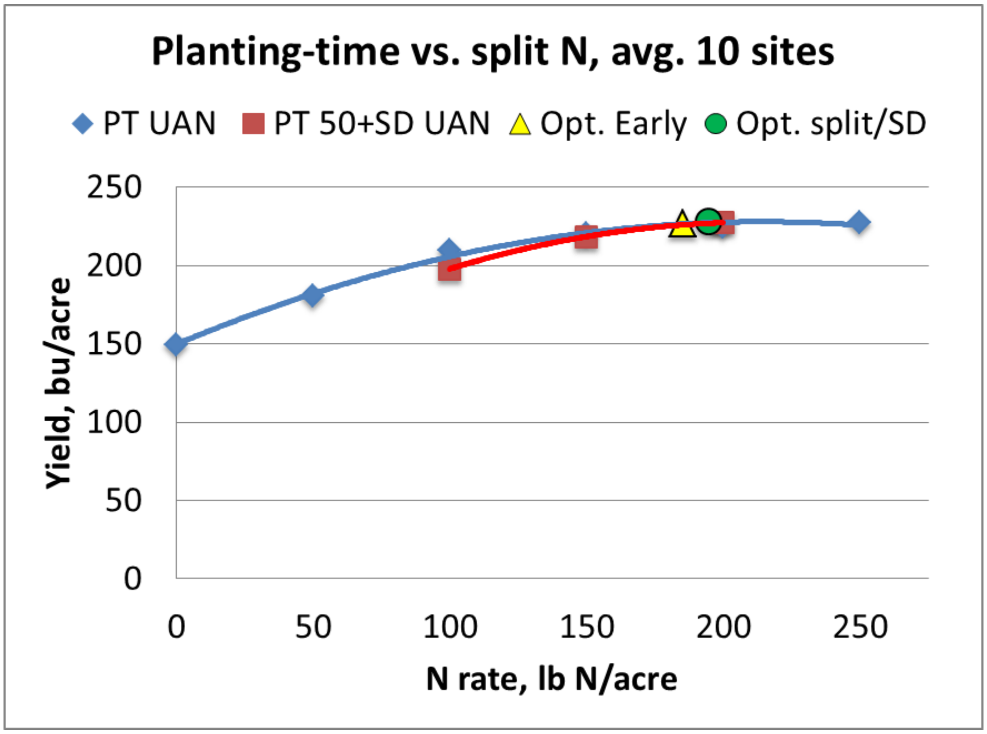

Figure 11. Responses to N rate for N applied as injected UAN at planting compared to 50 lb. N injected at planting and the remaining N sidedressed at V5-V6. Data are averages over Illinois ten site-years, 2014-16.