Nitrogen Management of Corn in the Chesapeake Bay Region

FINAL REPORT

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Background and Justification

The Chesapeake Bay is the largest estuary in the United States and represents an extremely important ecosystem and food web. The quality of the water in this bay has been in jeopardy for decades, and one of the contributing factors to the reduced water quality is excess nitrogen (N). Nitrogen is a very important element that is required by crops for optimal production and is especially important during corn production. Of all the crops grown in the Chesapeake Bay region, corn requires the largest applications of N fertilizer to optimize production. This N that is applied to fields as fertilizer or manure during corn production can be lost from these fields when excess rainfall occurs. There has been substantial evidence generated to show that excess N does leach from soils and can result in elevated nitrate concentrations of our nation's water supplies.

Elevated nitrate concentrations are present at all depths in the surficial aquifer system of the Delmarva peninsula. Hamilton et al. (1993) reported that nitrate exceeded the USEPA maximum contaminant level (MCL) in about 33% of the samples obtained from the surficial aquifer in agricultural areas. Shedlock et al. (1999) stated that "…High nitrate concentrations are found in the surficial aquifer because nitrate applied in excess of crop uptake is easily leached into ground water through the sandy, permeable soils common to agricultural areas of the Delmarva peninsula". Bohlke and Denver (1995) reported that nitrate concentrations in groundwater have increased in waters recharged since the 1960's at a rate similar to the rate of increase in fertilizer usage and stated "...In general, concentrations of nitrate are highest in water from shallow wells located immediately down-gradient from well-drained agricultural fields" and "…The water recharged in the agricultural areas has nitrate concentrations much higher than those in the overlying water recharged beneath forested lands".

During the production of corn, if too little N is applied, a substantial loss in farm income can occur because of decreased corn yield. However, if too much N is applied, this extra N will most likely leach out of the rooting zone and eventually find its way into ground or surface water supplies, such as the Chesapeake Bay. The challenging part of N management in corn is determining the difference between the optimal rate and any rate above this optimal. From a plant health or yield standpoint, it is impossible to determine the difference between the optimal rate and any rate greater. This means that a grower cannot tell the difference between the economic optimum rate and a rate as much as 100 lb/acre too much or even higher.

With this project, we are proposing using the cornstalk nitrate test in conjunction with remote sensing to demonstrate the value of an end-of-season assessment of N management practices. This cornstalk nitrate test was first developed in the early 1990s by the lead investigator of this project. The test has been widely evaluated and shown to be of value in other research projects throughout the corn growing regions of the United States; however, this test has never been widely adopted as an N management tool in production agriculture. Recent evidence suggests that this cornstalk test has potential to improve grower confidence when managing N during the production of corn. Because of 1) the importance of water quality in the Chesapeake Bay, 2) the amount of corn grown in the region, and 3) the fact that we currently have no way of evaluating current N practices, we feel there is a strong need to develop a performance-based N management system that could be used to evaluate the degree of accuracy of current corn grower N management systems while at the same time give corn producers greater confidence in their abilities to manage N.

Objectives of Project

1) Evaluate the N status of 900 cornfields (300 per year) in the Chesapeake Bay region of Maryland and Delaware using guided stalk nitrate sampling and remote sensing.

2) Evaluate alternative N practices (e.g., rates, timing, forms) on 60 cornfields (20 per year) in the Chesapeake Bay region of Maryland and Delaware.

3) Develop and evaluate a performance-based N recommendation system.

4) Reduce the amount of N applied to corn in the Chesapeake Bay watershed.

5) Create a “paradigm shift” in our current N recommendation system.

Overall Context

Currently, nutrient management programs in Maryland and Delaware are highly dependent on the process of developing a nutrient management plan. The nutrient management plan includes recommendations on how much nutrient should be applied to each field. The plan, however, assumes that this rate will in fact be applied and that this rate is the optimal rate for that field. Recommendations are developed for crops based on research and the research database cannot possibly evaluate all possible soil and environmental conditions. There historically has been no feedback mechanism that allows a grower to determine if the right amount of N was applied. It is assumed that if the corn did not show N deficiency symptoms, that the correct rate of N was supplied to the crop. It is also assumed that if the nutrient management plan was followed then the best rate of N was applied, but without a feedback mechanism it is not possible to know if this applied rate was in fact the most economically optimal rate of N.

A relatively new tool proposed by Binford et al. (1990, 1992a) has become popular in the research community as a method for determining if excess N was available to the crop during the growing season. This test is based on the concentration of nitrate in the lower part of the cornstalk at the end of the season. If concentrations are above 2,000 ppm of nitrate-N, then excess N was available to the crop during the season (Figure 1). Although this test has been popular in the research community, it has been seldom used in production agriculture. Recent projects in Iowa and Pennsylvania suggest that growers are gaining confidence in their N management practices and are reducing rates of N applied by systematically using this test for at least three years.

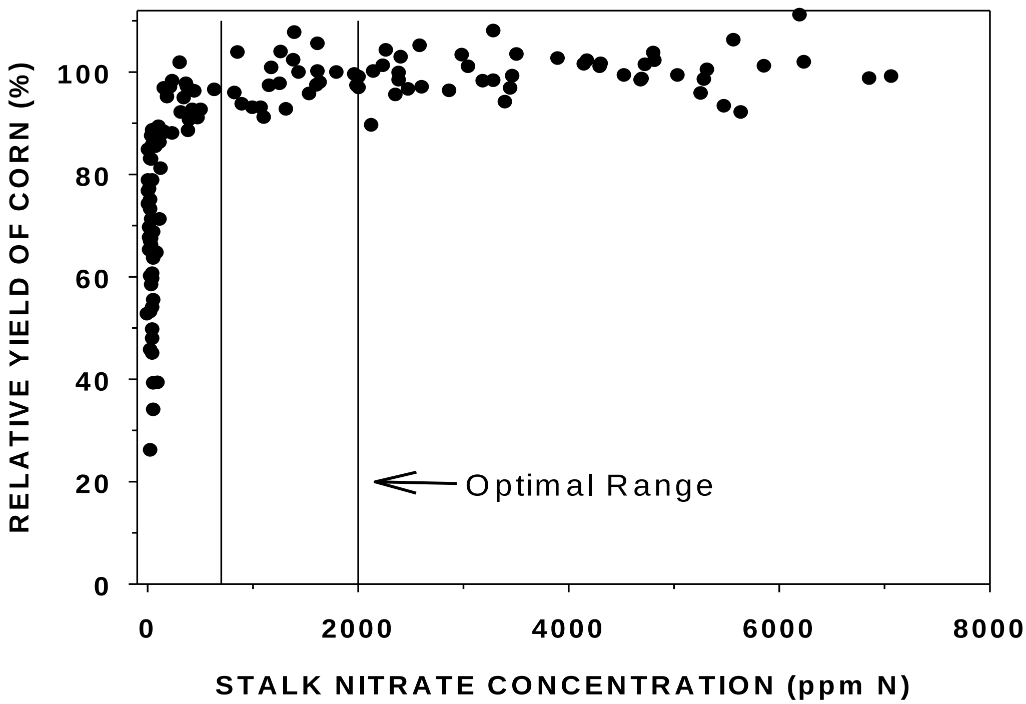

Figure 1. Relationship between corn yield and stalk nitrate concentration {from Binford et al. (1990)}

A project was started as part of National Conservation Innovation Grant in cooperation with the Iowa Soybean Association during the 2007 growing season in Delaware and Maryland. This project involved sampling more than 220 cornfields in these two states. In January of 2008, we had grower meetings and presented the results from 2007. Everyone who participated wants to participate in 2008 and additional growers who did not participate in 2007 have asked if they can participate in 2008. The 2007 stalk nitrate concentrations ranged from 150 to 29,000 with an average of 6,000 ppm N, and it is interesting to note that the average of the irrigated fields was slightly higher than the average of the non-irrigated fields. In fact, the highest concentrations were found on irrigated fields. This finding was surprising because the drought in 2007 was one of the worst droughts that many of the corn growers in Maryland and Delaware have ever experienced and corn yields were greatly reduced.

Funding has already been established for 2008 from a National Conservation Innovation Grant in cooperation with the Iowa Soybean Association. The concern is that after 2008 there is no funding to continue this project. Because this test is an end-of-season assessment, the general recommendation for using this test is to take samples for three years before considering any changes in management practices. If three years of data collection show high nitrate concentrations, then the recommendation is to make adjustments by comparing your normal practice to a new practice and then comparing stalk nitrate concentrations to evaluate the impact of the changes. Therefore, to adequately allow participating growers the opportunity to properly evaluate the idea of a performance-based N test, this project should be conducted for five years. If this project were discontinued after only two years, there's little hope for developing a performance-based N management system with the current project. This NFWF project provided funds for continuation of the project during the 2009, 2010, and 2011 growing seasons.

As mentioned above, current practices allow no way to assess the success of an N management system. Our current N management system is complicated enough to know the correct amount of N to apply when only N fertilizers are used to supply crop needs; however, when animal manures are added to the system, it becomes even more complex. This is because with animal manures only a portion of the N in the manure becomes available to the current year's crop, and this amount of N that becomes available can vary greatly depending on weather conditions and management practices. With our current recommendation system and using nutrient management plans, there is an assumption that a certain percentage of N will become available from manure and that this amount is the same regardless of weather, management, or soil conditions. In reality, the amount of N that becomes available in a given year from organic sources of N varies greatly across different environmental and soil conditions. With the current N management system, however, there is no evaluation or feedback loop that provides information on the success of the system. It's assumed that if the crop produced well, then the right amount of N was applied. A large portion of the corn acres in this region involve the use of animal manures.

With a performance-based N management system, nutrients are supplied to the crop based on normal recommendations but then samples are taken at the end of the season to evaluate the success of the system. In other words, the cornstalk nitrate test provides feedback on the amount of N that was available to the crop during the season. Because the system is a biological system, weather and management will greatly affect the amount of N available to the crop. Therefore, it's important that drastic changes not be made in N management after only one or two years of collecting stalk nitrate results. It also important that good records be maintained on exactly what was done and when it was done (i.e., management practices) and on weather conditions during the season. After about three years, the manager can compare the management practices with the cornstalk nitrate concentrations and begin to look for relationships between management and the end-of-season assessment. If the end-of-season assessment suggests a need for changes, then the manager can begin to slowly make changes and can then evaluate the impact of these changes with an end-of-season assessment (i.e., cornstalk test).

Using the current N recommendation system relies totally on the assumption that the recommended rate is the correct rate. There is ample evidence to suggest that this assumption is not correct because there are numerous published studies that demonstrate corn yield responses to N fertilizers resulted in lower economic optimal rates than were expected based on recommended rates (Binford et al., 1992a,b; Gehl et al., 2005; Lory and Scharf, 2003; Sims et al., 1995). This means that with our current system there are situations where too much N is being applied. Because of the nature of the rainfall patterns and the soil types in Delaware and Maryland, a significant portion of any excess N that is applied to corn will likely be lost from these fields and eventually make its way to our ground and surface water supplies. The development of a performance-based N management system would provide the stimulus needed by corn growers to gain better confidence in how much N they need to supply to their crop and ultimately would reduce the amounts of N that enter into the Chesapeake Bay. This ultimately would accelerate the progress of all programs that are designed to reduce the amount of N that is entering into the Chesapeake Bay.

Methodology

A total of 953 cornfields were sampled over the course of three growing seasons (2009, 2010, and 2011) in the Chesapeake Bay region of Delaware and Maryland. The same growers were used each year of the project because of the main objective of this project, which was an evaluation of performance-based N management, which requires a multi-year approach to complete. The fields to sample were identified in late spring or early summer by the grower and their crop consultant. Aerial images were taken of each field in early August and these aerial images were used as a guide for selecting the locations in each field where stalk nitrate samples were taken. The stalk nitrate samples were taken by the contracted crop consultant or by staff from the University of Delaware. Cornstalk samples were collected from four locations in each field. Sample collection followed the protocol recommended by the University of Delaware Extension Factsheet NM-03 (Hansen et al., 1999). The late-season aerial image combined with soil survey information was used for selecting the cornstalk sample locations using a Geographic Information System (GIS) with referenced field information based on a range of soil types for three of the sampling points. The fourth sampling location was taken from the most stressed portion of the field as determined by the aerial image; this allowed the user to determine if the observed stress was due to lack of N or something else. The samples were collected using a handheld GPS receiver to navigate to the pre-selected sampling points. A state certified soil and plant analysis laboratory analyzed the composite stalk samples. In 2009, we used Agri-Analysis in Intercourse, PA. In 2010, we used Dr. Josh McGrath's laboratory at the University of Maryland. In 2011, we used AgroLab, Inc. out of Milford, DE.

A second part of this project was to fine tune N management practices. This part of the project involved the establishment of about 50 strip trials that were replicated comparisons of two scenarios. One scenario was the grower's normal practice, while the second scenario was a reduced rate of N or some practice that was considered a more efficient method of applying N. Data collected from the strips by University of Delaware personnel included: aerial imagery, stalk nitrate samples, and grain yield. Grain yield was collected by using a yield monitor or weigh wagon.

For all strip trials and all 953 fields, a field history information sheet was filled out by the grower and crop consultant. These field history data were used to evaluate overall trends in the stalk nitrate data, and allowed for comparison of specific management practices.

Results

The greatest challenge for this project during the three growing seasons was abnormal weather conditions. The 2009 growing season was wetter than normal. In fact, rainfall amounts were so great during the early part of the growing season that many fields in the region had areas of corn that drowned out causing large holes in the fields with no plants. The 2010 and 2011 seasons were very similar in terms of rainfall patterns. The early parts of each season were extremely dry. In fact, in many parts of the region it did not rain during June and early July. During a winter meeting following the 2010 growing season that we had to discuss the results of this project, one grower mentioned that he had never seen a year that was so dry and resulted in so much stress on his crops in his 35 years of farming. Grain yields were greatly reduced on many fields in 2010 and in 2011.The weather conditions in 2010 and 2011 were so hot and dry that even irrigated fields were under stress because growers had a difficult time keeping up with crop water demand. Finally, to top off the extreme weather conditions during this three-year project, a severe hurricane hit the region in late August of 2011 causing numerous cornfields in the region to be blown down. In addition to being blown over, the plants were often twisted together. This made it difficult to take the cornstalk samples. A summary of rainfall and temperatures during the three growing seasons is shown in Table 1.

When evaluating stalk nitrate concentrations, it is useful to know what the guidelines are for general interpretations of stalk nitrate concentrations. The guidelines for interpretation, which are based on University research, are the following:

Values below 250 ppm N are considered "**Low**"

Values between 250 and 700 ppm N are considered "**Marginal**"

Values between 700 and 2000 ppm N is considered "**Optimal**"

Values greater than 2000 ppm N are considered "**Excessive**".

During the three years of this project, a total of 953 corn fields were sampled for cornstalk nitrate concentration (CSNT). The CSNT values from these 953 fields ranged from 8 to 14,140 ppm of nitrate-N with a mean of 2735 and a median of 1998 (Figure 1). Of these 953 samples, 542 fields were dryland (not irrigated) and 365 fields were irrigated. The management of some fields is unknown because a field history report was not completed by the cooperating grower. The median CSNT of the dryland fields was 1519 (Figure 2), while the median CSNT of the irrigated fields was 2797 ppm of nitrate-N (Figure 3).

When compared across individual years, the range in observed CSNT values across 319 fields in 2009 was from a low of 84 to a high of 14,140 with a mean of 2598 and a median of 1762 ppm of nitrate-N (Figure 4). The 320 fields sampled in 2010 ranged from 8 to 11,499 with a mean of 2624 and a median of 1989 ppm of nitrate-N (Figure 5). The 314 fields sampled in 2011 ranged from a low of 188 to a high of 13,467 with a mean of 2989 and a median of 2142 ppm of nitrate-N (Figure 6).

Our assumption prior to this project was that CNST values tend to run higher in drought-stressed corn compared to corn grown under good growing conditions. This assumption has been correct in many prior situations where cornstalk samples have been taken from drought-stressed corn by the principal investigator during previous years. The reason for the higher nitrate levels is because corn tends to accumulate nitrate in the lower stalk and then translocates this nitrate-nitrogen from the stalk to the developing ear during grain fill. As a result, if yields were depressed due to drought then the nitrate stays in the stalk resulting in higher nitrate values. Interestingly, in 2010 we noticed many fields that were extremely drought stressed during the growing season, but the CSNT values were quite low often in the range of 100 to 300 ppm of nitrate-N. This trend became rather obvious during the winter meetings with the cooperating farmers following the 2010 growing season. We reran numerous samples in the laboratory to be sure there were no analytical issues. During one of the grower meetings, we found a trend that early planted corn in 2010 tended to have lower CSNT values than neighboring fields that were planted later. We also noticed that sidedressed corn tended to have lower CSNT values than corn that had a significant portion of the nitrogen applied preplant.

With all these observations and trends it has become apparent that drought-stressed corn will not always have high CSNT values. In hindsight this makes sense. If a drought occurs early in the growing season and most of the nitrogen is applied as a sideressing during early summer, this nitrogen will not have an opportunity to get into the plant because it is positionally unavailable to the corn plant if there is no rain following sideressing. In addition, the uptake of nitrate from the soil will be much less if the plants are stressed during the time of rapid vegetative growth (about 12” to tasseling; V5 to VT). This finding of low stalk nitrates was repeated in the 2011 results because the early growing season of 2011 was nearly identical to the 2010 season.

An interesting trend that was observed nearly every year was that irrigated fields tended to have higher stalk nitrate values than dryland fields. Part of this was explained by the discussion above regarding early-season drought, but there is another trend that was observed that tended to result in higher stalk nitrate concentrations. Of the 365 irrigated fields, 223 of these fields were not fertigated, while 142 were fertigated. Fertigation is the application of nitrogen through the irrigation system. Fertigation is a more efficient method of application because only small doses of nitrogen are applied at a time so there is less potential for loss of the nitrogen to the environment. The median CSNT value from the 223 non-fertigated, irrigated fields was 2279 (Figure 7), while the median CSNT value from the 142 fertigated fields was 3703 ppm of nitrate-N (Figure 8).

One reason for higher stalk nitrate concentrations could be that the fertilizer that is applied via fertigation should be more efficient. In other words, more of the nitrogen should get into the plant with less potential for loss to the environment as compared to applying most of the nitrogen in one or two applications. Most recommendations on how much nitrogen to apply for a given corn crop are based on the expected yield of the crop, but there is no adjustment made for the time of application. Because fertigation is more efficient with less potential for loss, it would be expected that fertigated fields should have higher CSNT values if the same nitrogen recommendation system is used for determining rates of nitrogen to apply. It is also possible that fertigated cornfields could have a higher optimal CSNT value than non-fertigated fields, although we can think of no good reason this might happen. In fact, we conducted a study at one location in 2010 and another location in 2011 where the nitrogen fertilizer was applied by hand and we compared application timings that ranged from a single application at sidedress to eight spoon-fed applications all the way up until silking. The total rate of nitrogen was the same for each treatment. We found no significant differences in CSNT values among the different application timings, in fact, there was not even a trend for higher stalk nitrate concentrations with increasing number of applications. This should not be considered definitive because more thorough testing and more locations should be evaluated and the nitrogen should be applied exactly how it is with fertigation (i.e., UAN injected into the water stream) in grower fields instead of hand applied like we did with our project. Nonetheless, the results suggest that the higher CSNT values on fertigated fields may likely be from more efficient use of the applied nitrogen.

Another factor that would be expected to influence CSNT values is manure history including not only the year of application but also previous applications in prior years. A high percentage of the fields had received manure prior to the corn crop the year the CSNT samples were taken. In fact, 611 fields received manure in either the spring or fall prior to the corn crop being grown and the median CSNT value on these manured fields was 2233 (Figure 9), while the median CSNT value for the 296 fields that did not receive manure was 1658 ppm of nitrate-N (Figure 10). There were 501 fields that the growers reported had received manure in 2 of the past 4 years and these fields had a median CSNT of 2289 (Figure 11), while the 394 fields that did not receive manure in 2 or the past 4 years had a median CSNT value of 1627 ppm of nitrate-N (Figure 12). One other question asked on the field history reports was the following: “Did the field receive manure in 8 of the past 10 years?” There were 194 fields that had received manure in 8 of the past 10 years and their median CSNT value was 2271 (Figure 13), while there were 706 fields that had not received manure in 8 of the past 10 years and their median CSNT value was 1827 ppm of nitrate-N (Figure 14). As expected, manuring tended to result in higher CSNT values. This is most likely due to the fact that it is difficult to know the exact amount of nitrogen that will become available from an application of manure. All we can do is make an educated estimate and this estimate should be conservative to prevent nitrogen stress to the crop. A goal of using the CSNT is to help growers fine-tune their nitrogen programs and this approach is especially helpful on fields with manure histories. By taking CSNT samples each year from multiple fields, these CSNT results can help fine-tune and gain greater confidence in their nitrogen management program.

Evaluating the CSNT values from the 953 fields relative to the CSNT interpretations indicates that 7% of the fields were rated as “Low”, 16% were rated as “Marginal”, 27% were rated as “Optimal”, and 50% were rated as “Excessive”. Further evaluation of the “Excessive” indicates that about half the fields in this category (25% of the total 953 fields) were greater than 4000 ppm of nitrate-N. Considering that half of all fields sampled were in the “Excessive” category, it would suggest that there are a significant number of growers who have room to fine tune their nitrogen management system in this region.

A goal of this project was to begin the process of fine-tuning the growers’ nitrogen management systems if justified by the results of the CSNT samples. We never reached this point of truly fine tuning individual grower management programs during the timeframe of this project. The primary reason for this was weather. Over the course of this 5-year project (two years from a previous project and three years from this NFWF project), we had three years with serious-to-severe drought in a large portion of this region. As a result, we were hesitant to ask growers to make changes in their nitrogen management program when so much of the data was impacted by drought conditions. Nonetheless, it was apparent during the grower meetings that this project was having an impact on grower thought processes towards their nitrogen management systems. This occurred because quite often there was a common trend among the same growers in that their fields often were in the same categories year after year on a majority of their fields. In other words, it was common to see the same growers have high CSNT concentrations on numerous fields over several years. Some of these growers began to ask questions regarding a need to change their practices.

One important part of this project was the grower meetings in the winter. Getting 100% of the cooperating growers to attend the winter meetings did not happen with this project, but once a grower attended a winter meeting, they nearly always came back for future meetings. In fact, in the latter years of the project, we started getting phone calls after the growing season ended with questions about when the meetings were going to occur because the cooperating farmers wanted to get the dates on their calendars so they’d be sure they could attend. The format of the meetings involved providing the cooperators with their data that included their CSNT values overlaid onto the aerial images of their fields. The CSNT values along with the aerial images provided a great picture of what was happening on that field. As part of the meeting, we discussed any image and results that the growers wanted to discuss. Other participants would get involved in the discussion, which led to great discussion, learning opportunities, and new ideas for all present at the meeting.

During the winter meetings, we recruited growers interested in doing strip trials. At the time of the winter meetings, we had over 75 agreed upon strip trials during the three-year project. Of this total, 57 trials actually were established in the field. Of these 57, we were able to collect data from 40 trials. Normally, each strip trial was setup to compare the farmer's normal practice (FP) with some other management practice that should provide improved efficiency of nitrogen within the cropping system. The various treatments that were evaluated in the strip trials included: (1) rate of nitrogen, (2) Greenseeker technology, (3) method of application, and (4) nitrogen stabilizer technology.

The results of the strip trials are shown in Tables 2 through 7. In general, the limiting factor controlling yields at many of the sites was water, which makes the comparisons of other treatments difficult to interpret when water is the limiting factor. There was no clear cut benefit at most locations for reducing the farmer's normal rate of N. In fact, yields were reduced at some sites when the N rate was reduced. The nitrogen stabilizer, Instinct, provided little advantage, however, it should not be expected to provide a benefit at most of the locations because it was too dry for nitrogen to be lost from the soil. The Greenseeker trials were mostly drought limited. There was a clear reduction in stalk nitrate concentration at two locations where Greenseeker was used with no reduction in yield. In fact, at one location yields were increased with Greenseeker compared to normal practice. This technology certainly shows promise and should be further evaluated.

Project Summary

This projected utilized aerial imagery as a guide for taking end-of-season cornstalk nitrate samples from 953 fields in the Chesapeake Bay Region. The stalk nitrate samples ranged from a low of 8 ppm of N to a high of 14,140 ppm of N; the mean of all fields was 2735 and the median was 1998 ppm of nitrate-N. Fertigated fields tended to have significantly higher nitrate concentrations than non-fertigated, irrigated fields. Manured fields tended to have higher stalk nitrate concentrations than did non-manured fields. Droughty fields often had lower stalk nitrate concentrations than expected.

Grower interest and participation in this project was strong. The interest among the growers was for several reasons: 1) they appreciated the aerial images of their fields, 2) the stalk nitrate concentrations tended to make more sense when overlaid on top of the aerial imagery, and 3) the discussion among participants was thought provoking and a good learning opportunity. There was a clear disappointment among many growers when they learned the project would not be continued in 2012.

This goal of this project was to develop a better nitrogen management system than we currently use during the production of corn in the Chesapeake Bay Region. Overall, we were not able to get to the point of developing a new system because we had too many abnormally dry years during the years of the project. However, there was great interest among the farmers and consultants who participated in this project. It was clear that the project did raise awareness among some participants in the potential need for changing their nitrogen management practices.

Table 1. Weather summary data from Delaware for the three years of this project.

	Rainfall			Growing Degree Units		
Month	**2009**	**2010**	**2011**	**2009**	**2010**	**2011**
	---------- inches ----------			---------- 50°F base ----------		
April	6.3	1.3	3.2	173	251	240
May	3.7	0.4	1.9	459	513	534
June	4.6	2.9	3.5	644	832	754
July	1.2	4.1	1.8	791	911	957
August	5.7	2.2	10.5	861	851	798
Sept	6.4	4.5	6.5	513	648	636
Total	**27.8**	**15.4**	**27.4**	**3440**	**4005**	**3918**

Table 2. Nitrogen management trials at 10 sites in 2009.

Site	Trmt	FP[†]	CSNT	Yield
			- ppm N -	- bu/ac -
1	Normal	x	190	185
	100+		311	212
2	75	x	3136	190
	100		3055	194
3	32	x	7270	169
	0		420	159
4	0 gal		290	111
	15 gal		768	138
	22 gal		183	148
	32 gal	x	157	142
5	Dribble		376	156
	Knife	x	176	157
6	35		205	127
	25	x	368	128
	15		213	130
7	Dribble		281	145
	Knife	x	452	147
8	AS		2537	189
	Urea		2473	99
9	150		88	107
	150 PL		85	92
	180		118	141
	180 PL		94	128
	210		143	154
	210 PL		111	154
10	Reduced		3447	121
	Normal	x	278	125

[†]FP = Farmer normal practice

Table 3. Turbo-till strip trials in 2009.

Site	Trmt	FP†	CSNT	Yield
			- ppm N -	- bu/ac -
1	No Till		185	Lost
	Turbo Till	X	248	Lost
2	No Till		288	Lost
	Turbo Till	X	218	Lost
3	No Till		150	Lost
	Turbo Till	X	591	Lost

†FP = Farmer normal practice

Table 4. Nitrogen management trials at 11 sites in 2010.

Site	Trmt	FP[†]	CSNT	Yield
			- ppm N -	- bu/ac -
1	Reduced		1099	174
	Normal	x	1819	171
2	0		4818	54
	20		3817	58
	35		4996	55
	40	x	4590	61
	85		4674	59
3	Normal	x	3784	127
	Reduced		3255	137
4	Normal	x	5329	222
	Reduced		5067	212
5	Dribble		4852	48
	Knife	x	4439	38
6	Dribble		1769	107
	Knife	x	2154	108
7	Dribble		1923	56
	Knife	x	998	59
8	Normal	x	3950	87
	Reduced		2587	77
9	Normal	x	3266	204
	Reduced		3012	188
10	N Rich		6853	289
	Normal	x	7166	277
11	N Rich		6680	293
	Normal	x	7151	306

[†]FP = Farmer normal practice

Table 5. Instinct strip trials in 2010.

Site	Trmt	FP[†]	CSNT	Yield
			- ppm N -	- bu/ac -
1	Normal	X	4053	188
	Instinct		4575	190
2	Normal	X	4506	225
	Instinct		4396	226
3	Instinct		4126	203
	Normal	X	3209	217

[†]FP = Farmer normal practice

Table 6. Greenseeker trials at 9 sites in 2011.

Site	Trmt	FP[†]	CSNT	Yield
			- ppm N -	- bu/ac -
1	Normal	X	222	106
	GreenSeeker		391	112
2	Normal	X	2432	184
	GreenSeeker		483	183
3	Normal	X	4811	74
	GreenSeeker		4544	78
4	Normal	X	642	94
	GreenSeeker		972	90
5	Normal	X	454	68
	GreenSeeker		1844	56
6	Normal	X	2221	188
	GreenSeeker		2528	188
7	Normal	X	13911	222
	GreenSeeker		4327	247
8	Normal	X	677	96
	GreenSeeker		824	110
9	Normal	X	4750	218
	GreenSeeker		3526	222

[†]FP = Farmer normal practice

Table 7. Nitrogen management trials at 4 sites in 2011.

Site	Trmt	FP[†]	CSNT	Yield
			- ppm N -	- bu/ac -
1	Instinct		396	Lost
	Normal	X	372	Lost
2	Instinct		4215	39
	Normal	X	3943	56
3	Preplant	X	7305	6
	Sidedress		6383	7
4	40		1436	214
	50	X	2332	213
	60		2990	216
	0		277	200
	Broadcast		302	203

[†]**FP = Farmer normal practice**