

# ***Mid-Atlantic Grain and Forage Journal***

***A Compilation of  
Research and Extension Projects on Corn, Soybean,  
Small Grain and Forage Production***



***Supported by:***

***Rutgers Cooperative Extension  
New Jersey Agricultural Experiment Station  
Rutgers – The State University of New Jersey***

***2006***

***Volume 10***

# **Mid-Atlantic Grain and Forage Journal-2006**

## **Volume 10**

### **PREFACE**

This is the tenth edition of the *Mid-Atlantic Grain and Forage Journal*, formerly named the *New Jersey Grain and Forage Journal*.

The purpose of this publication is to provide summaries of research, demonstration and outreach activities to farmers and producers, industry personnel, researchers and educators. Other goals are to assist in information sharing across state borders and to increase collaborative efforts in research and extension activities.

I would like to acknowledge and thank Rutgers Cooperative Extension/New Jersey Agricultural Experiment Station (NJAES) for their on-going support of this project, as well as the following people who served as reviewers for this edition: Dr. Robert Kratochvil, University of Maryland; Mr. William Bamka, Rutgers University; and Dr. Wade Thomason, Virginia Polytechnic Institute and State University. Lastly, thanks to the NJAES Office of Communications for their assistance in publishing this journal.

I hope that these results will be of interest and use to you. Your suggestions are always welcome, as it is our desire to meet your most important needs.

Sincerely,



Daniel Kluchinski, Editor  
Mid-Atlantic Grain and Forage Journal

County Agent I (Professor),  
Chair, Department of Agricultural and Resource Management Agents  
and Assistant Director of Extension  
Rutgers Cooperative Extension  
New Jersey Agricultural Experiment Station  
88 Lipman Drive, New Brunswick, NJ 08901-8525 USA  
E-mail: [kluchinski@rce.rutgers.edu](mailto:kluchinski@rce.rutgers.edu)

# TABLE OF CONTENTS

## MULTI-YEAR RESEARCH PROJECT RESULTS

**Performance of YieldGard® Rootworm Corn and Insecticides in Corn Following Corn** ..... p. 1-5

G. W. Roth, R. J. Hoover, D. D. Calvin, C. E. Altemose, A. Frankenfield, K. Fry, D. H. Johnson, M. Madden, T. B. Murphy, and J. E. Rowehl  
Pennsylvania State University

Summary p. 1  
Research Paper p. 2-5

## SINGLE-YEAR RESEARCH AND DEMONSTRATIONS

**Center-Pivot Irrigation System Evaluations in Delaware: Preliminary Results** ..... p. 6-8

I. McCann and J. Adkins  
University of Delaware

**Irrigation Management of Corn on the Delmarva Peninsula: A 2005 Case Study from New Castle County, Delaware** ..... p. 9-15

I. McCann<sup>1</sup>, R. W. Taylor<sup>1</sup>, C. P. Davis<sup>1</sup>, and J. Lakatos<sup>2</sup>  
University of Delaware<sup>1</sup> and Natural Resources Conservation Service<sup>2</sup>

# Performance of YieldGard® Rootworm Corn and Insecticides in Corn Following Corn

## Summary

Greg W. Roth<sup>1</sup>, Ronald J. Hoover<sup>1</sup>, Dennis D. Calvin<sup>2</sup>, Craig E. Altemose<sup>3</sup>, Andrew Frankenfield<sup>3</sup>, Kevin Fry<sup>3</sup>, David H. Johnson<sup>4</sup>, Mark Madden<sup>3</sup>, Thomas B. Murphy<sup>3</sup>, and John E. Rowehl<sup>3</sup>

<sup>1</sup>Department of Crop and Soil Sciences

<sup>2</sup>Department of Entomology

<sup>3</sup>Cooperative Extension

<sup>4</sup>Southeast Research and Extension Center

Pennsylvania State University, University Park, PA 16802

Corresponding Author E-mail: [gwr@psu.edu](mailto:gwr@psu.edu)

- Research Question** Transgenic Bt corn (*Zea mays L.*) for control of corn rootworm marketed as YieldGard® Rootworm (YGRW) was introduced in 2003 but its performance has not been well documented in the mid-Atlantic region compared to competitive products. This study was initiated to evaluate root injury, agronomic differences, and the yield potential of YGRW hybrids compared to their isolines managed with other pest control approaches.
- Literature Summary** Evaluations of YGRW hybrids conducted in Iowa and Illinois have show that responses to insecticides and YGRW hybrids are highest where heavy rootworm pressure is combined with drought stress. Iowa researchers found that a YGRW hybrid yielded 21 bushels/acre higher than isolate treated with Force (tefluthrin) across seven locations.
- Study Description** Studies were conducted at twelve locations in 2003 and 2004 in fields cropped to corn in the previous year. Treatments consisted of a YGRW corn hybrid and its near-isogenic isolate with the following treatments: untreated check, a row insecticide (Force 3G), and at three locations in 2004, a rootworm seed applied insecticide [Poncho 1250 (clothianidin)]. Treatments were planted in strip plots, four to six rows wide and replicated at least four times. Roots were evaluated for corn rootworm (*Diabrotica virgifera*) damage using the Iowa State 0-3 scale. Grain yields were determined at harvest.
- Applied Question** *How well did the YGRW hybrids control the injury from the corn rootworm?*
- The YGRW hybrids provided similar or superior control as the Force or Poncho 1250 treatments. At one location, some feeding was observed on the YGRW hybrids (rating =0.42), but this did not appear to affect the yield performance.
- What were the yields of the YGRW hybrids compared to the other treatments?*
- Averaged over all environments in the study during both years, the YGRW had yields that were 4.8 bushels/acre higher than the Force treatment and 13.7 bushels/acre higher than the control, which averaged a root rating of 1.0. In two of the three environments where Poncho 1250 was included, YGRW hybrids resulted in significantly higher yields than the Poncho 1250.
- Recommendations** YGRW hybrids appear to be an effective tool for corn rootworm management in our region. Not all fields following corn show significant responses to corn rootworm management controls, so some opportunity exists for scouting to identify these fields and avoiding the expense of corn rootworm management.

# Performance of YieldGard® Rootworm Corn and Insecticides in Corn Following Corn

## Research Article

Greg W. Roth<sup>1</sup>, Ronald J. Hoover<sup>1</sup>, Dennis D. Calvin<sup>2</sup>, Craig E. Altemose<sup>3</sup>, Andrew Frankenfield<sup>3</sup>, Kevin Fry<sup>3</sup>, David H. Johnson<sup>4</sup>, Mark Madden<sup>3</sup>, Thomas B. Murphy<sup>3</sup>, and John E. Rowehl<sup>3</sup>

<sup>1</sup>Department of Crop and Soil Sciences

<sup>2</sup>Department of Entomology

<sup>3</sup>Cooperative Extension

<sup>4</sup>Southeast Research and Extension Center

Pennsylvania State University, University Park, PA 16802

Corresponding Author E-mail: [gwr@psu.edu](mailto:gwr@psu.edu)

### Introduction

Recently transgenic Bt corn, resistant to larval damage from the corn rootworm (*Diabrotica virgifera*), became available to Pennsylvania corn producers. This product is derived from the MON 863 Bt event and is commercially marketed as YieldGard® Rootworm (YGRW) Corn. With the commercial registration of YGRW, a new technology for managing corn rootworm became available. Since the 1960s, carbamates, synthetic pyrethroids and other soil insecticides have been used as corn rootworm control tactics where this pest is anticipated. More recently seed applied insecticides such as Poncho (clothianidin) or Cruiser (thiamethoxam) have become available that can provide some control of corn rootworm damage. Root injury ratings of some of these products were tested initially in Iowa (Rice and Oleson, 2005) and Illinois (Estes, 2004), however limited performance and yield data were available from the eastern U.S. where corn after corn rotations are common and many fields are treated for this pest.

The objective of this research was to assess root injury rating, agronomic performance and grain yield of a YGRW corn hybrid compared to its non transgenic isolate planted with and without a soil applied rootworm insecticide or a seed applied insecticide in on-farm trials.

### Materials and Methods

Twelve replicated field strip trials were conducted at six locations in Pennsylvania during both 2003 and 2004 to evaluate the YGRW and other methods of corn rootworm management. All fields were in corn during the previous year with several having a history of more than one year of corn. All locations except the SEREC (Southeast PA Research and Extension Center) and the Rock Springs site were located on private farms. At each location, cooperators were responsible for crop management, herbicide, and fertilizer applications. The experimental design at each location was a randomized complete block with four to five replications. Individual plots were four or six rows (30 inch rows) and 500 to 800 feet long.

Two different transgenic hybrids were used in this study. In 2003, 110-day relative maturity (RM) Asgrow Bt rootworm transgenic hybrid, RX 708 YGRW, was used while in 2004 the hybrid DKC 60-05 YGRW was evaluated. The YGRW hybrid seed was treated with Poncho 250 insecticide. These hybrids were compared to two treatments with their non-transgenic isolines, RX 708 and DKC 59-08 during 2003 and 2004, respectively. A control treatment consisted of these hybrids with no insecticide treatment. The second isolate treatment received the soil-applied insecticide, tefluthrin (Force 3G), band-applied at 5 oz/1000 feet of row with the corn planter. In 2004 at three locations, an additional treatment consisted of the isolate treated with the Poncho 1250 seed treatment insecticide.

Fifteen corn roots were randomly selected and dug from the center two rows of each plot. Roots were transported to a washing facility where all soil was removed and root-feeding injury was quantified. Root injury ratings are presented on the Iowa State 0-3 scale.

In 2004, plant heights were measured during late vegetative growth at four of the six locations. Grain was harvested using a combine at each location and weighed with platform scales or a weigh wagon. Grain moisture of several subsamples was measured with an electronic grain moisture meter. Grain yields were adjusted to 15.5% moisture.

## Results and Discussion

Corn growth across the six locations during 2003 ranged from good to excellent with the exception of the SEREC site, where yields were fair to low. Damage from the corn rootworm larva varied across locations and was most severe at the Centre and SEREC sites (Table 1). At the SEREC site, some furrow sidewall compaction due to planting in wet conditions was observed and this may have led to the slower corn root growth and increased the severity of rootworm injury. The Lycoming trial had very low injury levels in the control treatment, and damage in the York trial was also below the suggested root rating threshold level of 0.25. These observations confirm that not all fields following corn in this region need protection from corn rootworm feeding, as some have low populations of the pest. Some damage from the corn rootworm to the YGRW treatments were observed in the Centre and SEREC trials. At the Centre trial, the rootworm injury rating of the YGRW treatment was higher than that of the Force treatment. This has been observed by other researchers at Illinois (Estes, 2004).

Table 1. Root injury ratings and grain yields from YieldGard Rootworm (YGRW) hybrid and its non transgenic isoline without (control) and with a soil insecticide (Force 3G) in Pennsylvania in 2003.

Treatment	Location						Mean
	Lancaster 1	Lancaster 2	York	Lycoming	Centre	SEREC	
	Root injury rating (0-3)						
YGRW	0.02	0.08	0.01	0.02	0.42	0.30	0.14
Force	0.38	0.19	0.06	0.02	0.24	0.20	0.18
Control	0.90	0.66	0.17	0.05	1.89	2.39	1.01
LSD(0.05)	0.22	0.21	NS	NS	0.54	0.22	
	Yield (bushels/acre)						
YGRW	191.8	156.4	131.4	136.4	112.7	79.8	134.7
Force	194.1	158.4	131.1	142.4	110.3	55.5	132.0
Control	185.4	152.5	128.9	129.3	107.5	42.7	124.4
LSD(0.05)	NS	NS	NS	NS	NS	12.3	4.5

Grain yield differences among treatments were significant only at SEREC where the YGRW hybrid yielded more than the Force treatment, which had higher yields than the control. Corn at this location encountered significant stress due to soil compaction in the furrow resulting from planting in wet soil conditions. The yield response to rootworm control at other locations was likely limited by the wet season, since the conditions were favorable for corn roots to recover from rootworm injury.

Even though yield differences among treatments were significant at only one location, yields of the untreated control were numerically lower at every location compared to both of the rootworm control tactics. Averaged over locations, yields of the untreated plots were 7.6 bushels/acre lower than those in the insecticide treated or the YGRW plots, but much of this difference was due to the large response at the SEREC location.

In 2004, corn growth across the six locations ranged from very good to excellent due to lack of moisture stress at most locations (Table 2). All locations were planted by 18 May. Corn rootworm pressure was more consistent across locations in 2004 but none of the locations had the severe pressure documented at the SEREC location in 2003. Control from both the Force and YGRW treatments were excellent in all locations, except at the Rock Springs location, where the Force treatment had significantly higher root damage ratings than the YGRW. At the three locations where the Poncho 1250 seed treatment was included, it provided excellent control, similar to the YGRW treatment. In other trials where higher corn rootworm pressure has been encountered, the seed treatment has shown less consistent performance than YGRW.

Mid season plant heights were measured in 2004, since occasionally field reports have suggested the YGRW hybrids are taller than their conventional counterparts. This effect was observed at one of the four locations, the SEREC site, where the YGRW hybrid was 5 cm taller than its isoline treated with Force. This occurred even though the root ratings of these two treatments were similar. Factors that influence the height response to the YGRW hybrids are not well understood, but may be related to soil characteristics or root feeding outside of the zone that is traditionally evaluated by the root damage ratings.

Table 2. Root injury ratings, grain yields and plant heights from YieldGard Rootworm hybrid and its non transgenic isoline without (control) and with a soil insecticide (Force 3G) or seed treatment (Poncho 1250) in Pennsylvania in 2004.

Treatment	Location						Mean
	Lancaster 1	Lancaster 2	York	Lycoming	Rock Springs	SEREC	
	Root injury rating (0-3)						
YGRW	0.08	0.05	0.01	0.01	0.02	0.06	0.04
Force	0.09	0.02	0.08	0.02	0.35	0.02	0.14
Poncho			0.02	0.01	0.15		
Control	0.98	0.86	1.0	0.60	0.47	0.88	0.80
LSD(0.05)	0.47	0.34	0.28	0.26	0.26	0.48	
	Yield (bushels/acre)						
YGRW	165.3	207.8	167.7	189.1	181.7	161.4	178.8
Force	163.0	210.7	154.9	187.4	171.2	144.4	171.9
Poncho			146.5	187.1	172.5		
Control	170.4	197.6	132.8	173.2	158.6	138.7	161.8
LSD(0.05)	NS	8.9	8.7	NS	5.7	12.7	4.5
	Plant height (inches)						
YGRW		56	65		48	60	
Force		54	64		48	55	
Poncho			64		43		
Control		53	59		44	55	
LSD(0.05)		NS	0.7		4.1	2.7	

Grain yield differences were significant at four of the six locations where the YGRW plots yielded more than the control and had higher yields than the Force (and Poncho 1250, if present) in three of the four trials. Grain yields from the Poncho 1250 and Force treatments were not significantly different at any of the three locations where they were tested together. Yields were not significantly different at the high yielding Lancaster 1 farm, the location with one of the most severe rootworm feeding injury observed in

the mid-season, possibly due to recovery from the corn rootworm injury. Grain yield differences between the YGRW and Force treatments occurred despite minimal differences in root ratings at the York and SEREC locations. As in 2003 yield responses to the YGRW were largest at the lower yielding locations where there was evidently more crop stress. When averaged across all six locations, the YGRW and Force treatments yielded 12.3 and 7.6 bushels/acre more than the control, respectively.

Averaged over all environments during both years of the study, the YGRW hybrids produced 4.8 bushels/acre more than the Force treatment and 13.7 bushels/acre more than the control, which averaged a root rating of 1.0. In Iowa (Rice and Oleson, 2005), in a similar study across 7 locations, researchers reported a 21 bushel/acre differential between YGRW hybrids and Force under heavy corn rootworm pressure, where root ratings of untreated controls averaged 2.0 on the 1-3 scale. These researchers also indicated that yield responses to the corn rootworm control were greatest in environments with significant drought stress. They also found no yield differences between the Force and Poncho 1250 treatments, but noted that there was more inconsistency in control with the Poncho 1250 treatments.

## **Conclusions**

This study has demonstrated that the YGRW hybrids can be an effective corn rootworm management tool in the mid-Atlantic region. Corn rootworm ratings with the YGRW are similar or below those achieved with conventional insecticides. In some environments YGRW hybrids may be taller and/or higher yielding than their isolines treated with insecticides. Also, this study has shown that yield responses are often not closely related to differences in mid-season root injury ratings, suggesting that insect management treatments may have other effects than those observed with the root ratings. Response to the corn rootworm treatments appeared to be greatest in environments with some crop stress. This study has also demonstrated that where corn follows corn, variability can be observed for economic injury from the corn rootworm, affirming that scouting tactics can be an effective part of an Integrated Pest Management approach for managing the western corn rootworm in these rotations.

## **References**

- Rice, M.E. and J.D. Oleson. 2005. Three year summary of rootworm control products. Integrated Crop Management Newsletter, IC494 (26), Dec. 12, 2005, Iowa State University, Ames, IA.  
<http://www.ipm.iastate.edu/ipm/icm/issue/6051>
- Estes, R. 2004. 2004 Evaluations of Rootworm Control Products. The Bulletin: Pest management and crop development information for Illinois, No. 22, September 2, 2004. University of Illinois, Urbana, IL.  
<http://www.ipm.uiuc.edu/bulletin/article.php?id=182>

# Center-Pivot Irrigation System Evaluations in Delaware: Preliminary Results

Ian McCann and James Adkins

Dept. of Bioresource Engineering, University of Delaware REC, 16483 County Seat Highway,  
Georgetown, DE 19947

Corresponding Author E-mail: [mccann@udel.edu](mailto:mccann@udel.edu)

**Research Question** Most of the irrigated area on the Delmarva Peninsula is under center-pivot irrigation. Such systems are widely used on grain, forage and vegetable crops. With either new or well maintained equipment, and with good management, center-pivots can efficiently apply uniform amounts of water to a crop. However, non-uniform water application leads to either over or under irrigation in parts of the field. Either of those outcomes will directly affect soil water content, and indirectly have consequences such as nitrogen (N) leaching and poor N distribution when that nutrient is applied through the irrigation system. The rising cost of energy is impacting two energy dependent crop inputs by increasing the costs for irrigation water pumping and nitrogen, ultimately affecting profitability for intensive crop production. Both corn and alfalfa have high water requirements, while corn also has high N requirements. Both crops may therefore be especially affected. To help keep a center pivot irrigation system at peak efficiency, on-farm evaluations can be used to measure a system's average irrigation amount and identify uniformity problems that cannot be seen visually.

**Literature Summary** The American Society of Agricultural and Biological Engineers (ASABE) has published a standard method to evaluate center-pivot performance. The method uses two radial lines of catch-cans five degrees apart extending from the first tower to the end of the system. The cans are evenly spaced 10 ft apart within each line. The amount of water in each can is measured after the irrigation system has completely passed over both lines. A coefficient of uniformity (CU) can be calculated from the data to quantify how close the system is to a theoretical ideal in which all cans would contain exactly the same amount of water. The CU is a measure of the average absolute deviation from the average irrigation amount, relative to the average irrigation amount.

As a hypothetical example of CU in its simplest form, if 100 cans were measured and 50 had irrigation depths of 0.8 inches and the other 50 had irrigation depths of 1.2 inches, the average irrigation depth would be 1.0 inches. The average absolute deviation of this sample would be 0.2 inches, which is 20% of the average depth, and would result in a CU of 80% (100%-20%). The situation for a center-pivot is however more complex than this simple example because the area covered by the irrigation system increases with distance from the pivot point. Non-uniformity at the far end of the system therefore has a greater impact than the same non-uniformity would have close to the pivot point. To account for this, all the measurements are weighted according to the distance from the pivot point. The distance weighted CU of a well performing center pivot ranges from 85% to 95%.

**Study Description** The Natural Resources Conservation Service (NRCS) and the University of Delaware (UD) initiated a 3 year cooperative project in 2004 to evaluate the on-farm performance of center-pivot irrigation systems within Delaware. Over 300 catch cans (rain gauges) were constructed to enable us to evaluate almost all sizes of center-pivots in Delmarva. The cans were constructed from standard plastic pipe materials. The diameter of the can opening is 5 inches, with the edge beveled similar to a rain gauge to reduce splash. The water is funneled into a

smaller diameter clear plastic tube to which is affixed a clear label that is calibrated directly in units of 1/100 inch. A metal spike at the bottom secures the can upright in the soil.

Placement location for each can along the line was identified using a 10 ft perimeter measuring wheel equipped with a cam-operated inverted paint marker that was triggered each full revolution of the wheel, providing visible spray marks every 10 ft. The cans were placed at each sprayed mark using an all-terrain vehicle (ATV) to transport them.

After asking the farmer for the percentage timer setting required to apply at least 0.6 inches of irrigation, the irrigation system was then operated until it had passed completely over both lines of cans. The depth of water in each can was recorded and later entered into a spreadsheet that calculated average irrigation amount and the area weighted CU. Graphs were created that show the measured irrigation depth along each of the two lines. In addition, an application rate chart was also created from the data and compared with the chart originally provided by the dealer for the system (if available).

Other data collected included:

- The GPS coordinates of the pivot point and the last tower
- The distance of each tower from the pivot point
- The operating pressure if available
- The type of sprinkler (overhead impact, drop sprays, etc.)
- Weather conditions (temperature, wind speed)
- The travel speed of the outermost tower at the designated timer setting

## Applied Questions

*How well was a particular irrigation system performing?*

If the CU was above 85%, the system was performing well. It may, however, still have had some problems but they were likely to have been localized and not severe or extensive enough to significantly impact CU. Examples were occasional leaking, incorrectly sized, missing, or blocked sprinkler heads which alone did not substantially reduce CU. More extensive problems, such as irrigation that was consistently lower or higher over a part of the system than the system average, were apparent from the graph that showed catch can depth vs. distance along the system.

*How do the measured average irrigation amounts compare to the original application chart?*

While there was often reasonable agreement between the average measured irrigation and the supplier's chart at the same timer setting, there were discrepancies. It was also not uncommon for there to be a difference between the irrigation amount the producer believed was being applied, and the amount we measured. This tended to occur in systems for which there was no manufacturer's chart available. In these cases, the amount we measured was often less than the farmer thought was being applied. Correction of these misconceptions can significantly impact the profitability of an irrigation system.

*How well are the systems evaluated to date performing?*

Figure 1 shows the percentage of the 69 center-pivots evaluated in 2004 and 2005 within selected CU ranges. The majority of systems had acceptable CU. Although newer systems tended to have a good CU, we found some old systems that were among the best performers. Age appears to be less a factor than is the level of management and maintenance.

*What can be done when the CU value is low?*

A low CU can be caused by factors such as incorrect, worn or malfunctioning sprinklers, or incorrect operating pressure. Other factors that may be readily visible from the graph of catch can results but are not reflected in the CU include inadequate flow and incorrect end-gun operation. For example, the end gun may be swinging back too far allowing additional water to be applied under the last span. There were also a number of systems with no pressure gauge. In these cases, the addition of a pressure gauge is a simple and inexpensive way to at least ensure that system pressure is within an acceptable range.

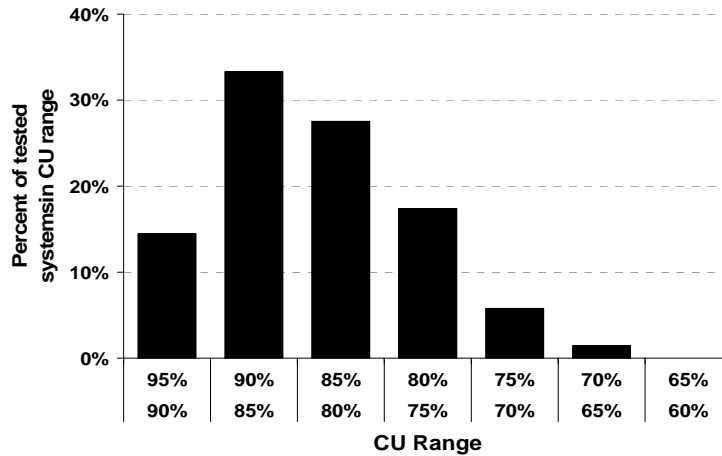


Figure 1. Distribution of CU in center-pivot systems evaluated from 2004 to 2005.

*Why is irrigation system performance important?*

The increasing cost of energy and energy intensive products such as N fertilizer will impact profitability. An irrigation system that is operating efficiently can optimize yield and reduce yield variability within a field. It can also reduce N leaching caused by excessive irrigation over the entire field or excessive irrigation in parts of the field resulting from non-uniformity of water application. Also, if N is applied with the irrigation water, it will only be applied as uniformly as the water.

**Recommendations**

A periodic (every three to five years) evaluation of an irrigation system is recommended to detect problems that may not be readily visible, and to confirm that the system is applying the amount of water it was designed to apply. The problems resulting from poorly performing irrigation systems are exacerbated for crops that have high water or N use, such as corn, alfalfa and vegetables. These problems are particularly apparent during dry years when more irrigation is required.

**Acknowledgement**

The able assistance of Jeremy Ernest and Sammy Tyndall in conducting the evaluations is appreciated.

# Irrigation Management of Corn on the Delmarva Peninsula: A 2005 Case Study from New Castle County, Delaware

Ian McCann<sup>1</sup>, Richard W. Taylor<sup>2</sup>, Carl P. Davis<sup>3</sup>, and Jack Lakatos<sup>4</sup>

<sup>1</sup>Bioresources Engineering, University of Delaware, Research and Education Center, 16483 County Seat Highway, Georgetown, DE 19947

<sup>2</sup>Department of Plant and Soil Sciences, University of Delaware, Newark, DE 19716

<sup>3</sup>University of Delaware Cooperative Extension, Newark, DE 19716

<sup>4</sup>Natural Resource Conservation Service, New Castle County, Newark, DE 19702

Corresponding Author E-mail: [mccann@udel.edu](mailto:mccann@udel.edu)

**Research Question** Rainfall during the crop season in the mid-Atlantic region of the United States is usually sufficient to produce a corn crop, but obtaining maximum yield often requires supplemental irrigation. Even when total rainfall during the season is sufficient to meet crop water requirements, it may be poorly distributed in amount and timing. Periods of drought during which rainfall is not sufficient to maintain soil water content within the desired range are common. These periods of drought are exacerbated by the low water holding capacity of the sandy soils that predominate in the coastal portions of the region. Irrigation management is a challenge under such conditions.

Center-pivot is the predominant irrigation method in the region. The irrigation amount is a function of travel speed (which is controlled by the “percentage timer”) and the flow rate, which in turn is determined by the sprinkler package. When a system is purchased, the dealer will provide a chart with irrigation amounts at various timer settings. Over time, this chart may no longer be available, or may not reflect changes to the system such as sprinkler wear or replacement. Good irrigation management with a center-pivot requires knowledge of:

- The performance of the center-pivot in terms the depth of irrigation water applied over the range of travel speeds, and the uniformity of water application.
- The depth of irrigation water necessary to prevent crop moisture stress from occurring before the next irrigation without exceeding soil water holding capacity in the root zone.

The question posed in this study was whether the combination of an irrigation system evaluation and the use of a simple spreadsheet to estimate soil water content using daily weather information are tools that growers would use to improve their irrigation management.

**Literature Summary** The American Society of Agricultural and Biological Engineers (ASABE) has published a standard for evaluating center-pivots, based on using catch cans to measure area weighted irrigation amount and uniformity.

One approach to irrigation management is to estimate water content in the root zone using the “check book” method, which accounts for additions (primarily rain and irrigation) and withdrawals (crop water use, evaporation, and drainage). Reference evapotranspiration ( $ET_0$ ) is the water use of a standard vegetated surface such as clipped grass. It can be estimated using weather measurements. Crop water use and evaporation (or evapotranspiration,  $ET$ ) can be estimated by multiplying  $ET_0$  by coefficients specific to a particular crop ( $k_c$ ), wetness of the soil surface and degree of crop cover ( $k_e$ ) and degree of crop water stress ( $k_s$ ). The

international standard reference for estimating  $ET_0$  is FAO Publication 56 (Allen, et al. 1998), which includes a simple spreadsheet model to implement the checkbook method for irrigation scheduling.

### **Study Description**

To help provide the information needed for good irrigation management, the Natural Resources Conservation Service (NRCS) and the University of Delaware (UD) have initiated a cooperative program for producers that includes an irrigation system evaluation and a checkbook spreadsheet based on FAO Publication 56 modified for easier use and interpretation.

The user enters initial information such as water holding capacity, planting date, and crop into the spreadsheet for a particular field. Daily values of  $ET_0$  are entered (obtained from the UD website [www.rec.udel.edu/irrig/MONTHirt.HTM](http://www.rec.udel.edu/irrig/MONTHirt.HTM)) for the closest automatic weather station. Daily rainfall amounts, ideally from an on-site rain gauge, are also entered. Daily crop water use is calculated using  $ET_0$  and a crop coefficient that is automatically estimated by the program. If measured, or known values, of soil water content are available for any given date during the growing season, they can be entered to correct the estimated soil water content. For example, after a sufficiently large rainfall, soil water content on the following day will likely be at field capacity. For days when irrigation occurs, the irrigation amount and the percentage timer setting are also entered.

The spreadsheet graphically displays soil water content for the current day and previous two weeks, and allows users to see the effect of irrigation or rainfall on soil water content during the following week (Figure 1). From this graphic display a grower can evaluate the past impact of weather and irrigation patterns on available soil moisture and view the projected trend for the coming week. The critical period for corn begins as early as the V-5 or fifth true leaf stage (5 leaf collars visible) but stress is especially damaging just prior to tassel emergence through the soft dough stage. Any water stress during this period can reduce grain yield significantly. To minimize yield losses due to moisture stress, irrigation should occur before available soil moisture falls below the predetermined amount (50% in this case) by the time it will take the irrigation system to complete the irrigation on the entire field.

Irrigation system evaluations were conducted using catch cans following the method recommended by the ASABE. In this standard, two radial lines of cans are used to measure the irrigation amount after the center-pivot has completely passed over them. We used fabricated catch cans and installed them at a 10 ft spacing. The lines extended the length of the center-pivot (except the first span) and, where possible, beyond to the area covered by the end gun. Relevant parameters were recorded for each evaluation; including the GPS coordinates, the percentage timer setting, wind speed and temperature, and the operating pressure and the supplier's chart of timer setting vs. irrigation amount where available.

Seven producers recorded their irrigation management on corn fields using the spreadsheet. One producer did not irrigate at all. The irrigation systems on four of the fields were evaluated prior to the season. The results were used to determine the irrigation amount applied at the recorded percentage timer settings.

### **Applied Questions**

*How successful was the method when used by farmers?*

Figure 2 (a, b and c) show  $ET_0$  and rainfall for the 70 day period from 01 June to 08 August 2005, after which there were a number of days that weather data

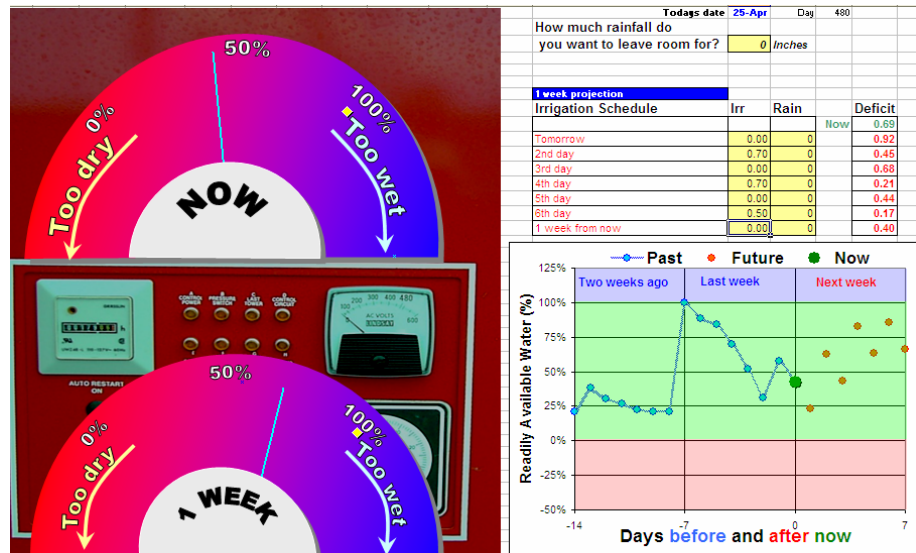


Figure 1. Example page from the irrigation scheduling spreadsheet. The left top shows a gauge indicating current estimated soil water content, relative to the readily available water content for the particular soil. 100% is field capacity, and 0% is the lower limit of readily available water. The gauge at bottom left shows the same information projected forwards one week based on ET assumptions and rain and irrigation entered in the irrigation schedule table (top right). Also at the top right is projected soil water deficit (irrigation required to increase soil moisture to field capacity). The graph (bottom right) gives the two week history of estimated soil water content, and the projections for the coming week. The green shaded area represents the desired range of soil water content.

were not available. However, most of the season is included in the available data. Figure 2a shows daily rainfall, figure 2b shows daily  $ET_0$ , and figure 2c cumulative rainfall and  $ET_0$  during this period. It was relatively dry during the first half of this period (high  $ET_0$  and low rainfall), and relatively wet during the second half (low  $ET_0$  and high rainfall).

Figure 3 shows the percentage timer settings, from 01 June until 31 August used by each of the 6 farmers who irrigated. The number of irrigations ranged from 2 to 9. The top four graphs also show the cumulative irrigation amount estimated from the irrigation system evaluations completed on these fields. Three of these four fields each received 9 irrigations, with total irrigation amounts between 2.5 and 3 inches. Each irrigation was in the range 0.25 to 0.38 inches. Yields on these three fields, as reported by the producers, ranged from 220 to 240 bushels/acre. The remaining field on which the irrigation system was evaluated received 1.2 inches in two irrigations of 0.6 inches each. However, this field was not typical in that it was planted late (at the end of May) with a short season variety that yielded less than 150 bushels/acre.

This sample of producers operated their irrigation systems at only one or two timer settings and varied the frequency of irrigation. The irrigation amounts were relatively small. If all the irrigation water recharged the root zone, it would typically be sufficient to meet  $ET$  for about 2 days, less if the weather was hot, dry and windy. However, not all the irrigation will effectively recharge the root zone because some of it will be intercepted by the plant canopy and subsequently evaporate. The relative importance of this interception increases as the irrigation amount decreases.

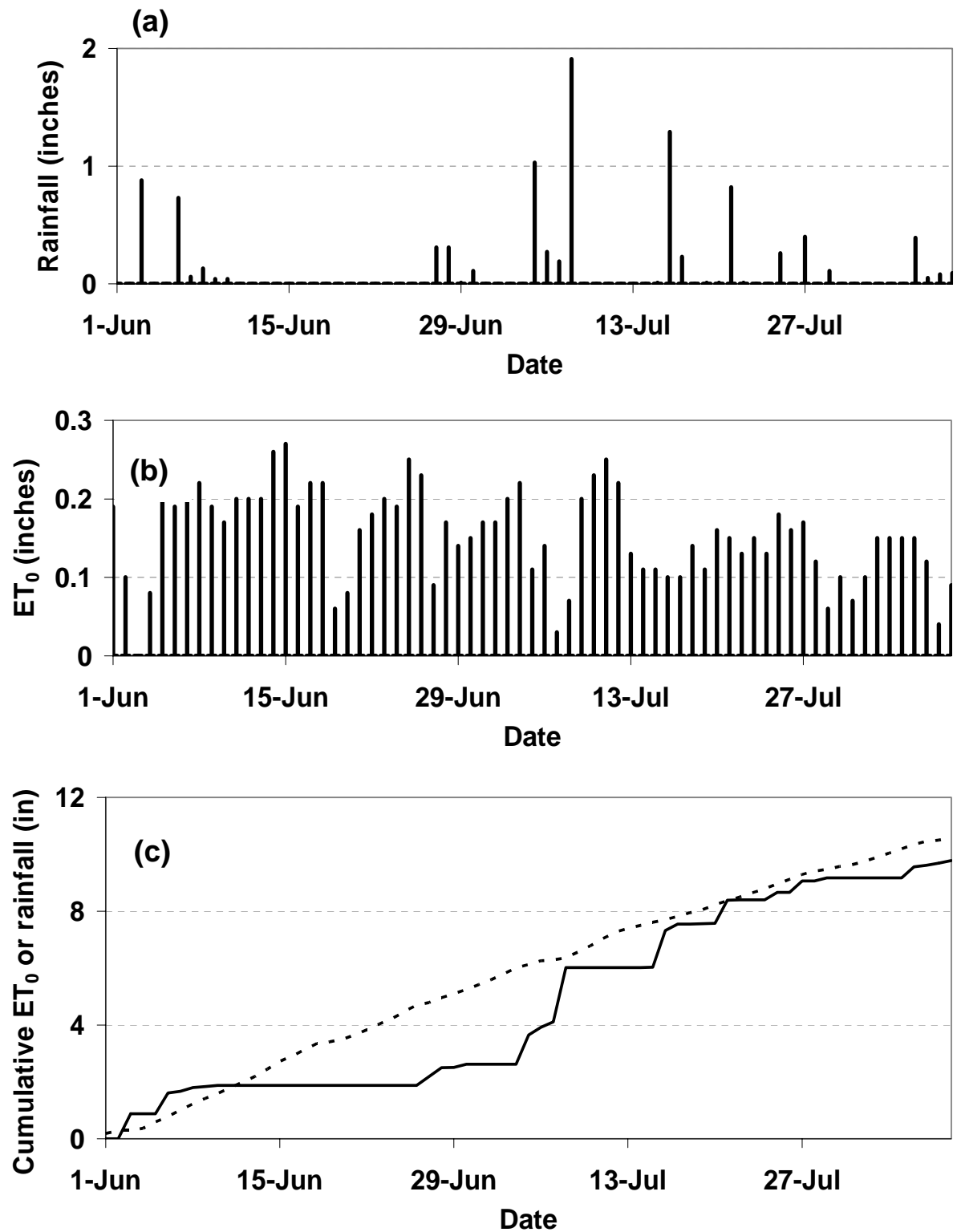


Figure 2. Daily rainfall (a),  $ET_0$  (b), and cumulative rainfall and  $ET_0$  (c) for the 70 day period beginning 01 June 2005, from the University of Delaware weather station at Townsend, New Castle County, DE.

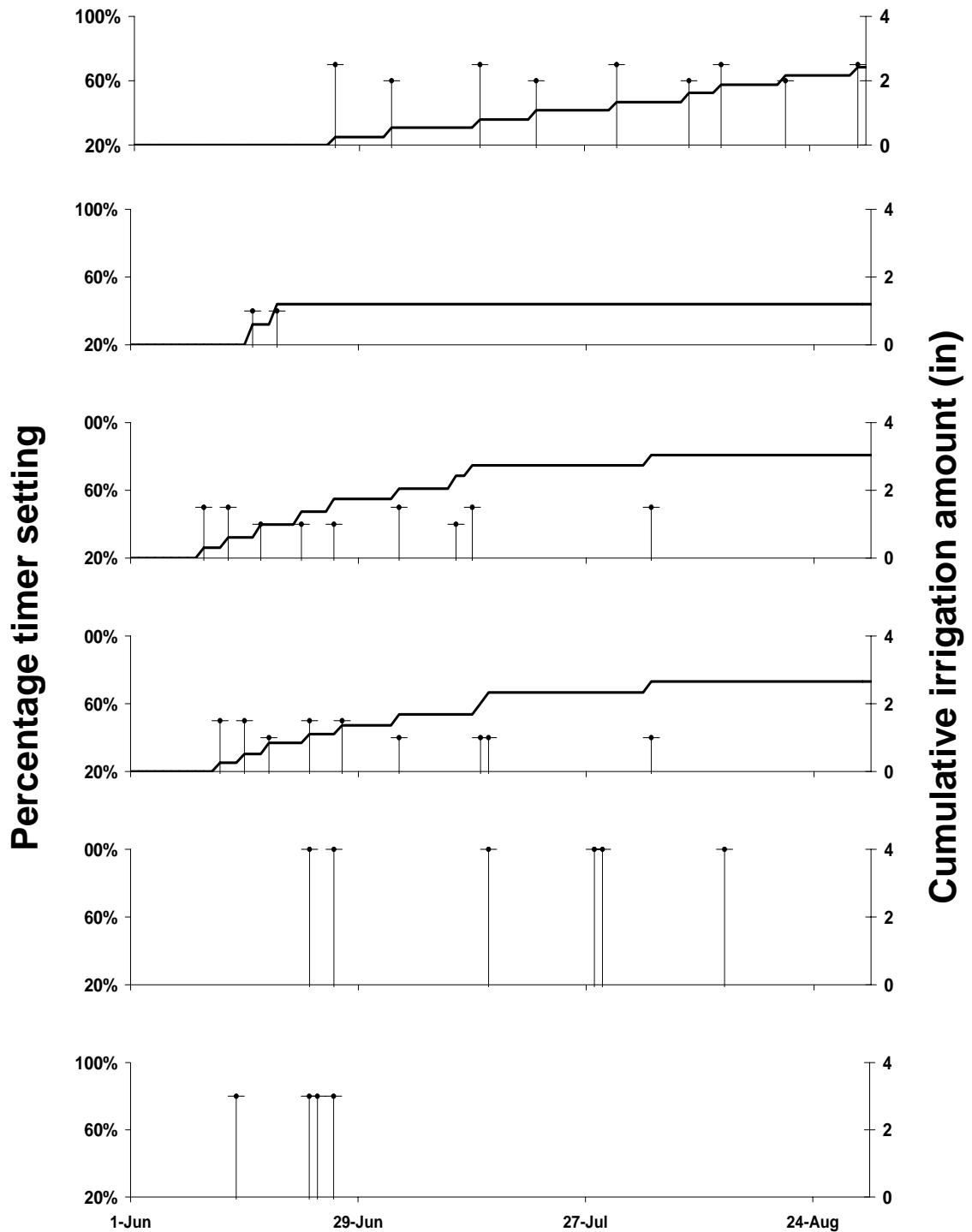


Figure 3. Irrigation management reported by six producers. The vertical lines indicate the center-pivot percentage timer settings (left axis) The right axis shows the cumulative irrigation amount using data from system evaluations where available (top 4 graphs).

The water inputs (rainfall plus irrigation) from the first irrigation until 08 August are in the same range as the total  $ET_0$  during the same period for the four producers whose irrigation systems were evaluated. This approximate balance, however, does not consider non-effective irrigation or rainfall and the fact that actual water use by the corn crop will likely be higher than  $ET_0$ .

Compared with many of the sandy soils in coastal areas of the Mid-Atlantic region, the water holding capacity of the soil in New Castle County is relatively high, allowing larger irrigations without deep percolation. However, the maximum irrigation amount as compared with sandier soils may be limited by the infiltration rate of the soil. Further investigation would be needed to determine if runoff under higher irrigation amounts would occur. Larger irrigations may be more effective in that proportionately more water would enter the soil, but at the same time higher soil water content before a rainfall event would mean less effective "space" within the root zone to store and fully utilize rainfall.

A benefit of irrigation scheduling such as required by this program is that soil water measurements must be made periodically. While it is unlikely that growers will purchase expensive instruments to make the measurements, it should encourage them to make more measurements than they might have otherwise, even if the measurements are only made by visual inspection and feel. Some consultants have shown interest in this program, and they may have the resources to use it effectively.

*Is good irrigation management important in areas with significant rainfall during the season?*

In years with adequate and well distributed rainfall, total irrigation amounts are relatively low, as in 2005. However in a dry year, such as last occurred in 2002, optimal crop water use is high and rainfall is low. This requires substantial irrigation, considerably more than was applied in 2005. An irrigation scheduling tool such as the spreadsheet used in this study would enable growers to develop better irrigation strategies by showing estimated soil water trends over time. Some growers may be unable to keep up with crop water requirements because of inadequate system capacity, while others may have the capacity to irrigate at the best time and so may be able to eliminate or reduce a number of applications. Irrigation costs money in terms of pumping costs and increased wear and tear on equipment, and poor irrigation management can have an impact on associated costs such as nitrogen. As energy and related costs rise it will become even more important to manage irrigation well.

*Will growers use a spreadsheet to aid in irrigation scheduling?*

Growers in New Castle County, Delaware, successfully used the supplied spreadsheet and the web-generated data to assist in their irrigation management. Because of the amount of rainfall received during the growing season, not all producers reached critical soil water content values at which irrigation was required.

## **Recommendations**

The producers in this relatively small sample seemed to manage irrigation reasonably well. However, 2005 was not a challenging year for irrigation management. A dry year with high irrigation requirements and some additional irrigation system evaluations would enable a more complete assessment. As the costs of energy and energy based inputs such as fertilizer continue to increase, the value of good irrigation management will increase. The ability to use nearby automated weather station data and a spreadsheet that can graphically represent the potential crop need for irrigation will be beneficial for irrigation managers.

## References

Allen, R. G., et al. 1998. Crop evapotranspiration - guidelines for computing crop water requirements, FAO Irrigation and drainage paper 56. Food and Agriculture Organization of the United Nations, Rome, Italy.

Mention or display of a trademark, proprietary product, or firm in text or figures does not constitute an endorsement by Rutgers Cooperative Extension and does not imply approval to the exclusion of other suitable products or firms.



Distributed in cooperation with U. S. Department of Agriculture in furtherance of the Acts of Congress of May 8 and June 30, 1914. Cooperative Extension work in agriculture, family and community health sciences, and 4-H. Karyn Malinowski, director of Extension. The U. S. Department of Agriculture (USDA) prohibits discrimination in all programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, or marital and family status. (Not all prohibited bases apply to all programs.)  
Rutgers Cooperative Extension is an Equal Opportunity Employer.

