A Report of Crop Physiology Laboratory Omission Plot Studies in 2011

Fred E. Below, Adam S. Henninger, and Jason W. Haegele
Crop Physiology Laboratory, Department of Crop Sciences, University of Illinois

Justification and Background

Corn grain yield is the final product of numerous factors that affect crop growth and development during the growing season. Corn is undoubtedly the crop that shows the largest response to technology and management. Growers make critical decisions every year regarding the inputs needed to maximize the profitability of their farm based on the potential yield gain of a given input factor. Data collected over many years and locations by the Crop Physiology Laboratory has led to the identification and ranking of seven categorical management factors that impact yield. These seven factors are weather (planting date, rainfall, temperature), nitrogen (rate, source, and timing), hybrid selection (including biotech traits), previous crop, plant population, tillage (timing and degree), and growth regulators (e.g. 'plant performance' or greening effect of strobilurin fungicides). If the maximum positive yield responses of each of these individual factors are summed together, a yield of approximately 260 bu acre^{-1} can result. Therefore, to surpass this yield level, new management approaches that either increase the potential contributions of individual factors or exploit positive synergistic interactions among multiple factors are needed.

Typically, agronomic studies tend to investigate each factor in separate experiments as an attempt to simplify the experimental design and interpretation of data. This reductionist approach has resulted in an underestimation of the value of modern genetics, crop protection products, and fertilizers that contrasts with the complexity of modern agriculture. Therefore, it is critical to understand the interactions of these factors evaluated as a whole in order to efficiently maximize corn yield and exploit the yield potential of modern corn hybrids grown under advanced levels of management. We believe that this type of research and information will be needed to develop a technology package that can take corn yields to the next level (300 bu acre^{-1}), which is needed to meet an ever increasing food, feed, and fuel demand while sustaining the efficiency and productivity of our agricultural systems.

In order to achieve high corn yield and achieve high input use efficiencies, it is critical to maximize the effect of each management factor and exploit their synergies so that their total effect on corn yield is larger than the sum of each single effect. In previous studies conducted in 2009 and 2010, a five-factor 'high technology' package was compared to a 'standard' package using an omission plot approach. Averaged across two sites and both years, the yield gain from the high technology package was approximately 50 bu acre^{-1}. At the high technology level, all five factors contributed to the overall yield, and it was clear that their individual values under a high tech system were magnified in comparison to the standard system. Based on these earlier successes, the treatment levels for each factor were modified in 2011 to include banded fertility (placement of P fertilizer 4-6" directly under row at planting), and to more thoroughly investigate the role of hybrid selection in the high technology package (Table 1). Hybrids were selected by our seed company collaborators to represent 'workhorse' and

'racehorse' genetics. Our presumption was that workhorse hybrids would be best suited to the low management intensity of the standard package, and that they would not be responsive to the high tech package. We also assumed that a hybrid designated as a racehorse would be responsive to increased inputs, especially increased population and N.

Table 1. Corn omission plot factors and treatment levels for standard and high technology agronomic packages evaluated in 12 separate trials across central and southern Illinois in 2011. All hybrids possessed biotech herbicide tolerance and insect resistance traits. All omission plots had Force 3G insecticide applied in-furrow.

Factor	Standard Technology	High Technology
Fertility	Adequate based on soil test levels of phosphorus and potassium or maintenance levels applied in the fall.	Adequate soil test levels of phosphorus and potassium + 100 lbs acre^{-1} of P_2O_5 banded as MESZ (12-40-0-10S-1Zn) at planting.
Nitrogen	180 lb N acre^{-1} (urea) applied as broadcast at planting.	180 lb N acre^{-1} (SuperU) applied as broadcast at planting and 60 lb N acre^{-1} (Urea + Agrotain) applied as side-dress at V5.
Genetics	'Workhorse' hybrid	'Racehorse' hybrid
Population	32,000 plants acre^{-1} final stand	45,000 plants acre^{-1} final stand
Fungicide	No fungicide	Strobilurin fungicide at VT/R1

Twelve separate omission plot trials were carried out in 2011 at various locations in Illinois (Figure 1), utilizing different hybrids and fungicide products. These sites represented a range of planting dates, planting conditions, and weather conditions throughout the growing season. Generally, all of the sites experienced warmer than average temperatures at flowering and during grain fill with varying degrees of drought stress (Figure 2).

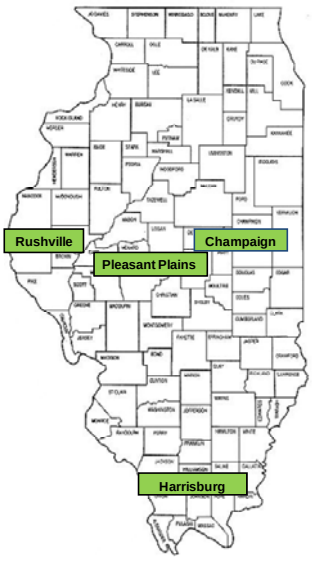

Figure 1. Locations of omission plot trials in 2011. Rushville (1), Pleasant Plains (1), Champaign (8), Harrisburg (2).

Across trials, the average yield gain from the high technology package was 26 bu acre^{-1}, and ranged from a 7 bushel decrease to a 56 bushel increase (Figure 3). Some of this varied response can be attributed to environment, but it is also clear from our data that correct hybrid placement is also crucial to the success of the high technology package. For example, selecting high population intolerant hybrids for the high technology package led to smaller than expected responses in many cases.

Averaged across omission plot trials, placed P fertilizer had the greatest individual positive effect on grain yield in both the standard and high tech packages (Table 2 & Figure 4). On average, increased population had a negative impact on yield in the standard system, and a neutral effect on yield in the high tech package. We attribute these poor plant density responses to the generally stressful environment of 2011, but it is also clear that the impact of population was greatly influenced by hybrid selection. Yield responses to fungicide application were also generally small in 2011, but there was a statistically significant response to fungicide in the high technology package (Table 2).

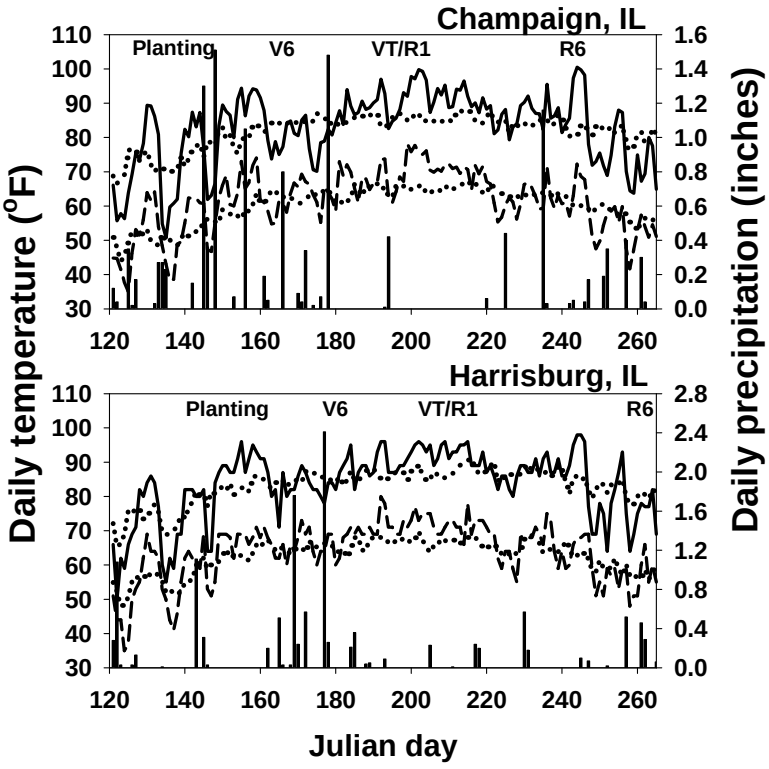

Figure 2. Daily weather observations at Champaign, IL (top) and Harrisburg, IL (bottom). Vertical bars represent daily precipitation (inches). The solid and dashed lines are the observed daily maximum and minimum temperatures, respectively. Dotted lines are the 10-year average maximum and minimum daily temperatures.

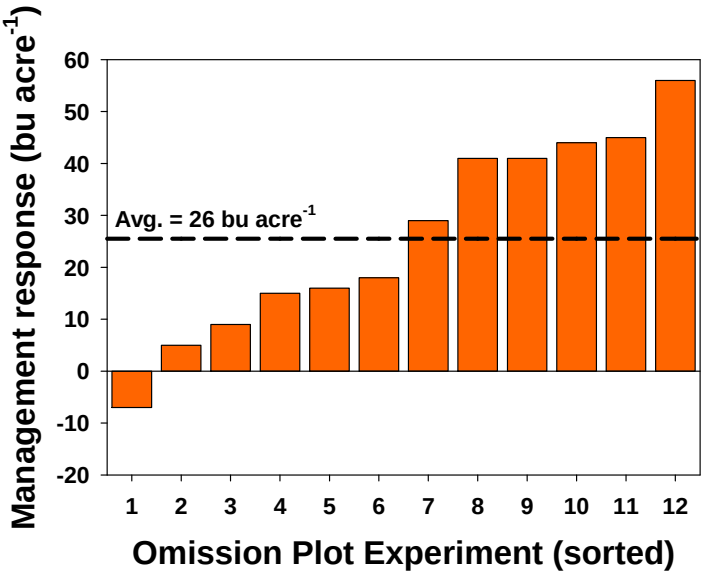

Figure 3. Grain yield response to the high technology package for 12 individual omission plot trials grown across Illinois in 2011. Data summaries for each of these 12 trials are given in Tables 4-15.

Table 2. Combined results and analysis of 12 separate omission plot trials evaluated across central and southern Illinois in 2011. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard		High Tech	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
		bushels acre^{-1}		
None or all	168		195	
Fertility	182	+14	177	-18
Nitrogen	176	+8	185	-10
Genetics	173	+5	186	-9
Population	158	-10	194	-1
Fungicide	172	+3	187	-8

LSD (P ≤ 0.05) = 6

Figure 4. Effect of placed P fertilizer (100 lb P_2O_5 acre^{-1} as MESZ) on the early growth of high tech omission plot treatments in 2011. Row on the left did not receive placed P treatment, while the row on the right received the full treatment.

Results of individual 2011 corn omission plot trials

Although presented here individually in order of magnitude of yield increase resulting from the high tech management system (Tables 3-15), there are multiple comparisons embedded within the twelve trials that can be made. These comparisons include:

- A comparison of twin rows (7.5-inches apart on 30-inch centers) with 30-inch rows at Champaign (Tables 7 and 10) and Harrisburg (Tables 11 and 15).

- The impact of hybrid placement in the standard and high tech systems (Tables 5 and 14). In Table 14, the hybrids were used as originally selected (DKC63-84 VT3 as 'racehorse' and DKC 62-63 VT3P as 'workhorse'). In Table 5, their roles were reversed and DKC62-63 VT3P was instead used in the high tech system.

- A comparison of omission plot treatments under rain-fed (Table 9) and irrigated (Table 13) conditions. These trials were grown side-by-side at Champaign, IL, and the irrigated trial received supplemental water at R1 (1-inch) and R3 (1-inch). These data indicate that small amounts of water at critical times can result in large yield gains, especially for the high tech system. Also, the data shows the importance of water to maximizing responses from fertility placement, nitrogen, and fungicide application.

- In each individual omission plot data table, several comparisons can be made to better understand how hybrids interact with management system. For example, in Figure 5 (data obtained from Table 14), the increase in yield over the standard system was 45 bu acre^{-1} (Comparison A). This represents the difference in yield between a workhorse hybrid (DKC62-63 VT3P) in a minimally managed system (153 bu acre^{-1}), and a racehorse hybrid (DKC63-84 VT3) in a well managed system (198 bu acre^{-1}). If the workhorse hybrid is replaced by the racehorse hybrid in the standard system, a yield increase of 8 bu acre^{-1} results (Comparison B). Similarly, if the racehorse hybrid is replaced by the workhorse hybrid in the high tech system, a yield decrease of -21 bu acre^{-1} results (Comparison C). Together these results show that the best hybrid under the high tech system is also frequently the best hybrid under the standard system, but there is considerably greater risk to choosing the wrong hybrid for the high tech system. If the roles of the two hybrids are switched (Comparison D), the response to the high tech system is only 16 bu acre^{-1}, which is only 36% of the management response realized with proper hybrid selection. The response to increased management for each individual hybrid can be obtained from comparisons E and F. If DKC62-63 VT3P is compared in both management systems, a yield increase of 24 bu acre^{-1} occurs (Comparison E), while a yield increase of 37 bu acre^{-1} occurs for DKC63-84 VT3 (Comparison F). Again, this indicates that DKC63-84 VT3 was the better choice for the high tech management system.

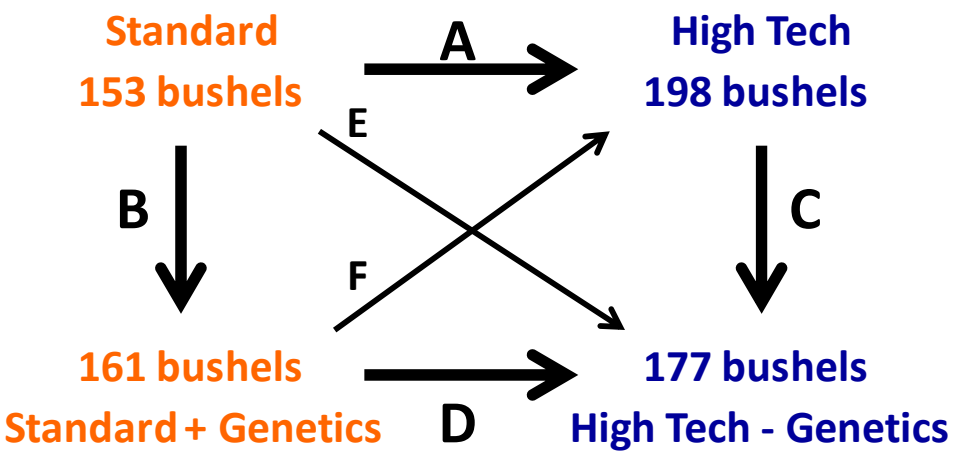

Figure 5. Graphical depiction of data from Table 14 (DEKALB hybrid comparison at Champaign, IL). Arrows show the various comparisons that can be made to understand the importance of hybrid placement in different management systems. Comparison A (+45 bu acre^{-1}) is the response to the high tech system. Comparison B (+8 bu acre^{-1}) results from replacing the workhorse hybrid with the racehorse hybrid in the standard management system. Comparison C (-21 bu acre^{-1}) results from replacing the racehorse hybrid with the workhorse hybrid in the high tech system. Comparison D (+16 bu acre^{-1}) is the response to the high tech system if the roles of the two hybrids are reversed. The responses to high tech management for DKC62-63 VT3P (+24 bu acre^{-1}) and DKC63-84 VT3 (+37 bu acre^{-1}) are obtained from comparisons E and F, respectively.

Table 3. Locations, trial names, planting dates, and P soil test levels for the 12 individual omission plot trials evaluated across Illinois in 2011. The numbers in the first column correspond to the order shown in Figure 3. Individual data tables for each trial are presented in Tables 4-15.

Number	Location	Trial name	Planting date	P soil test levels†
1	Rushville	DEKALB hybrid comparison	5/11/2011	N/A
2	Champaign	DEKALB hybrid comparison	5/19/2011	28, 17
3	Champaign	Pioneer omission plot	5/19/2011	28, 17
4	Champaign	Twin row omission plot	5/19/2011	28, 17
5	Pleasant Plains	DEKALB hybrid comparison	5/12/2011	N/A
6	Champaign	Non-irrigated omission plot	6/4/2011	30, 19
7	Champaign	30-inch omission plot	5/19/2011	28, 17
8	Harrisburg	30-inch omission plot	6/1/2011	N/A
9	Champaign	Syngenta omission plot	5/20/2011	91, 90
10	Champaign	Irrigated omission plot	6/4/2011	30, 19
11	Champaign	DEKALB hybrid comparison	5/19/2011	28, 17
12	Harrisburg	Twin row omission plot	6/1/2011	N/A

†Soil P levels (ppm; parts per million) measured using Mehlich-3 extraction procedure. First value given is the P level at the 0-6 inch depth, and the second value is the P level at the 6-12 inch depth.

Table 4. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide at Rushville, IL in 2011. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC59-35 VT3)		High Tech (DKC65-63 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	174		167	
Fertility	186	+12	175	+8
Nitrogen	186	+12	174	+7
Genetics	180	+6	177	+10
Population	172	-2	178	+11
Fungicide	176	+2	171	+4

LSD (P ≤ 0.1) = 10

Table 5. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide at Champaign, IL in 2011. This trial included DKC62-63 VT3P as the hybrid in the High Tech system. The reverse of this experiment to which comparisons should be made is shown in Table 14. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC63-84 VT3)		High Tech (DKC62-63 VT3P)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	177		182	
Fertility	180	+3	164	-18
Nitrogen	192	+15	168	-14
Genetics	162	-15	188	+6
Population	167	-10	180	-2
Fungicide	168	-9	181	-1

LSD (P ≤ 0.1) = 10

Table 6. Omission plot trial utilizing Pioneer hybrids and Vertisan fungicide at Champaign, IL in 2011. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (P1018HR)		High Tech (P1184XR)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	168		177	
Fertility	190	+22	151	-26
Nitrogen	177	+9	165	-12
Genetics	142	-26	211	+34
Population	155	-13	174	-3
Fungicide	171	+3	168	-9

LSD (P ≤ 0.1) = 11

Table 7. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide evaluated in twin-rows at Champaign, IL in 2011. The comparison of this trial in 30-inch rows is shown in Table 10. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC62-63 VT3P)		High Tech (DKC63-84 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	173		188	
Fertility	174	+1	174	-14
Nitrogen	168	-5	174	-14
Genetics	191	+18	169	-19
Population	153	-20	205	+17
Fungicide	171	-2	177	-11

LSD (P ≤ 0.1) = 17

Table 8. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide at Pleasant Plains, IL in 2011. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC59-35 VT3)		High Tech (DKC65-63 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	145		161	
Fertility	146	+1	139	-22
Nitrogen	135	-10	159	-2
Genetics	151	+6	133	-28
Population	129	-16	166	+5
Fungicide	147	+2	143	-18

LSD (P ≤ 0.1) = 17.5

Table 9. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide under non-irrigated conditions at Champaign, IL in 2011. The irrigated comparison to this trial is shown in Table 13. In this trial, the hybrid comparison represents isolines with and without biotech insect protection (European corn borer + Corn rootworm). Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC61-72 RR2)		High Tech (DKC61-69 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	174		192	
Fertility	182	+8	185	-7
Nitrogen	180	+6	170	-22
Genetics	175	+1	196	+4
Population	174	0	191	-1
Fungicide	170	-4	196	+4

LSD (P ≤ 0.1) = 13

Table 10. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide evaluated in 30-inch rows at Champaign, IL in 2011. The comparison of this trial in twin rows is shown in Table 7. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC62-63 VT3P)		High Tech (DKC63-84 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	165		194	
Fertility	175	+10	181	-13
Nitrogen	176	+11	181	-13
Genetics	170	+5	185	-9
Population	137	-28	203	+9
Fungicide	163	-2	191	-3

LSD (P ≤ 0.1) = 16

Table 11. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide evaluated in 30-inch rows at Harrisburg, IL in 2011. The comparison of this trial in twin rows is shown in Table 15. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC62-63 VT3P)		High Tech (DKC63-84 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	178		219	
Fertility	206	+28	172	-47
Nitrogen	180	+2	210	-9
Genetics	187	+9	216	-3
Population	174	-4	202	-17
Fungicide	191	+13	212	-7

LSD (P ≤ 0.1) = 17

Table 12. Omission plot trial utilizing Syngenta hybrids and Quilt Xcel fungicide at Champaign, IL in 2011. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (N72A-3111)		High Tech (N74R-3000GT)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	193		234	
Fertility	205	+12	229	-5
Nitrogen	188	-5	228	-6
Genetics	215	+22	198	-36
Population	191	-2	226	-8
Fungicide	193	0	225	-9

LSD (P ≤ 0.1) = 14

Table 13. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide under irrigated conditions at Champaign, IL in 2011. The non-irrigated comparison to this trial is shown in Table 9. This trial was irrigated twice; 1-inch applied at VT/R1 and an additional 1-inch applied during the R2-R3 period. In this trial, the hybrid comparison represents isolines with and without biotech insect protection (European corn borer + Corn rootworm). Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC61-72 RR2)		High Tech (DKC61-69 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	170		214	
Fertility	192	+22	189	-25
Nitrogen	197	+27	188	-26
Genetics	178	+8	202	-12
Population	183	+13	212	-2
Fungicide	181	+11	191	-23

LSD (P ≤ 0.1) = 13

Table 14. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide at Champaign, IL in 2011. This trial included DKC63-84 VT3 as the hybrid in the High Tech system. The reverse of this experiment to which comparisons should be made is shown in Table 5. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC62-63 VT3P)		High Tech (DKC63-84 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	153		198	
Fertility	175	+22	180	-18
Nitrogen	176	+23	190	-8
Genetics	161	+8	177	-22
Population	127	-26	200	+2
Fungicide	159	+6	183	-16

LSD (P ≤ 0.1) = 16

Table 15. Omission plot trial utilizing DEKALB hybrids and Headline AMP fungicide evaluated in twin rows at Harrisburg, IL in 2011. The comparison of this trial in 30-inch rows is shown in Table 11. Data are the mean grain yields of standard and high tech agronomic packages, and the yields resulting by adding individual factors to the standard package or by subtracting individual factors from the high tech package.

	Standard (DKC62-63 VT3P)		High Tech (DKC63-84 VT3)	
Factor	**Yield**	**Δ**	**Yield**	**Δ**
	bushels acre^{-1}			
None or all	155		211	
Fertility	180	+25	192	-19
Nitrogen	166	+11	205	-6
Genetics	167	+12	193	-18
Population	149	-6	194	-17
Fungicide	172	+17	211	0

LSD (P ≤ 0.1) = 17

2012 approach

Our work shows that combining the right hybrid with the best crop protection and fertility management practices can combine to achieve a yield that is not achieved by focusing on one strategy alone. We believe that every company has an important role to play in this approach because multiple factors (fertilizers, genetics, traits, fungicides, other crop protection products, and planting/fertilizer application equipment) are all part of the systems approach to achieve 300 bushel corn. The strength of our omission plot approach is that it provides a visual demonstration of the contribution of each factor to the overall yields of the standard and high tech packages. Therefore, we encourage our collaborators to tour our omission plots throughout the season, and to consider the marketing value that these demonstrations have for their products. A basic approach to our 2012 omission plot trials is shown in Table 16. A new factor (foliar insecticide) will be included because we believe that the value of controlling silk clipping insects (e.g. Western corn rootworm beetle and Japanese beetle) as well as Corn Leaf Aphid is magnified in a high tech management system.

Table 16. Basic 2012 corn omission plot design. Two treatments (traditional and high tech) represent the low and high input management systems. Factors are removed from the high tech system, while factors are added to the traditional system to quantify the yield contribution of each factor under both levels of management intensity. Low and high MYP hybrids (MYP; Management Yield Potential) are those that we have separately evaluated in our Management Yield Potential Trial. High MYP hybrids respond to increased plant density and have a larger than average N response. Low MYP hybrids do not tolerate or respond to increased density and some low MYP hybrids achieve their maximum yield at a lower input of N. Additional treatment factors can be added per the request of the omission plot collaborator.

		Factors					
	Treatment	Fertility	Nitrogen	Hybrid	Population	Fungicide	Insecticide
	HIGH TECH	**Placed P & K**	**Base + Slow release**	**High MYP**	**45,000**	**Strobilurin**	**Foliar**
Decrease Technology	-Fertility	No P & K	Base + Slow release	High MYP	45,000	Strobilurin	Foliar
	-Nitrogen	Placed P & K	Base	High MYP	45,000	Strobilurin	Foliar
	-Hybrid	Placed P & K	Base + Slow release	Low MYP	45,000	Strobilurin	Foliar
	-Population	Placed P & K	Base + Slow release	High MYP	32,000	Strobilurin	Foliar
	-Fungicide	Placed P & K	Base + Slow release	High MYP	45,000	None	Foliar
	-Insecticide	Placed P & K	Base + Slow release	High MYP	45,000	Strobilurin	None
	TRADITIONAL	**No P & K**	**Base**	**Low MYP**	**32,000**	**None**	**None**
Add Technology	+Fertility	Placed P & K	Base	Low MYP	32,000	None	None
	+Nitrogen	No P & K	Base + Slow release	Low MYP	32,000	None	None
	+Hybrid	No P & K	Base	High MYP	32,000	None	None
	+Population	No P & K	Base	Low MYP	45,000	None	None
	+Fungicide	No P & K	Base	Low MYP	32,000	Strobilurin	None
	+Insecticide	No P & K	Base	Low MYP	32,000	None	Foliar