Corn Marketing Program of Michgian
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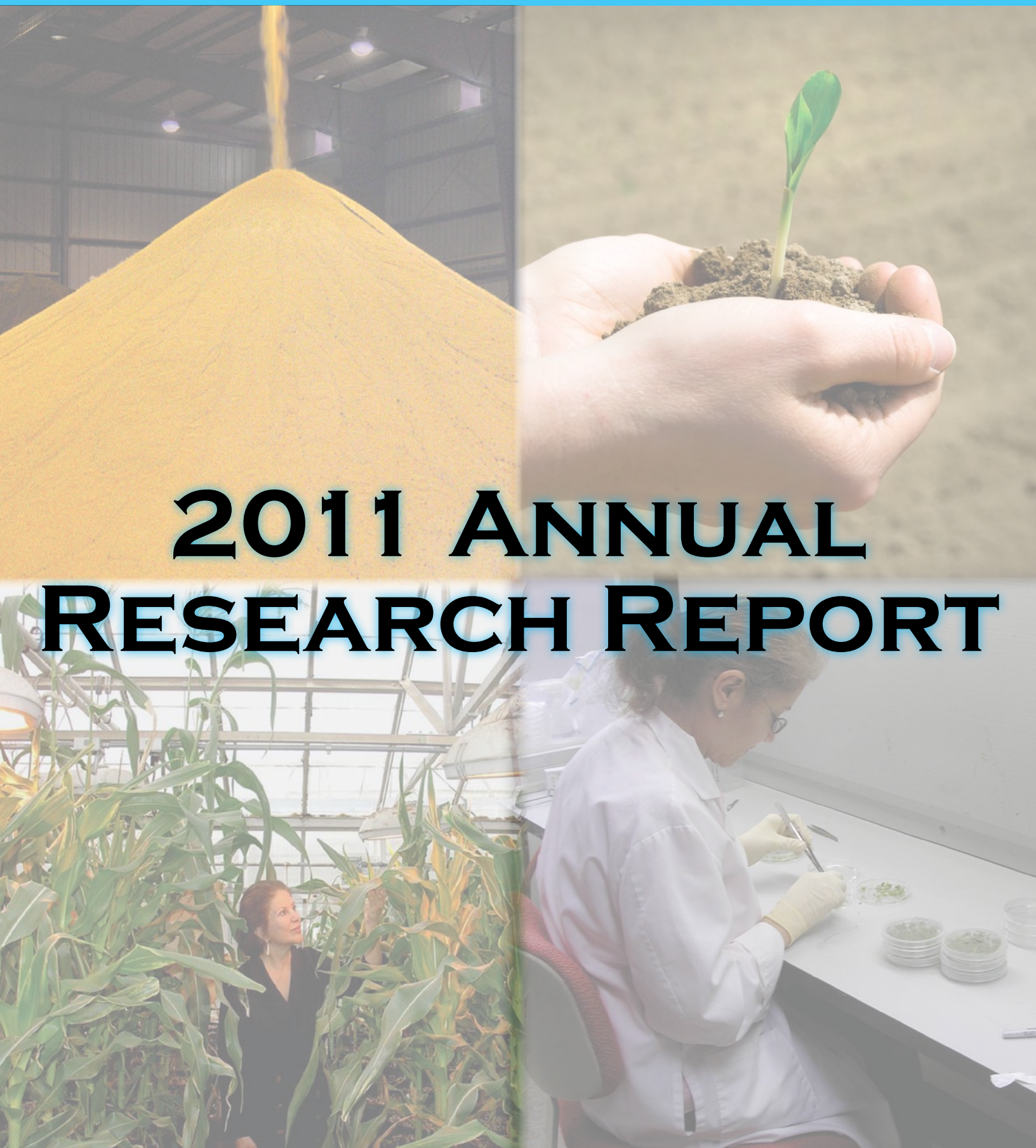

2011 Annual Research Report

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Corn Marketing Program of Michigan Board of Directors

Front row, left to right: Brian Kreps, Secretary; Pat Feldpausch, President; Carl Barth, Treasurer; and Mark Kies, Vice President. Back row, left to right: Tom Durand; Jeff Sandborn, MCGA President; Richard Dobbins; Clark Gerstacker; Ed Breitmeyer; Gary Kaufman; and Randy Poll. Not pictured: Dr. Doug Buhler.

Welcome From the President

Dear Michigan Corn Farmer:

As you know, the Corn Marketing Program of Michigan (CMPM) was established in 1992 by you, Michigan's corn farmers, to enhance the economic viability of corn production in our state. As part of that mission, the penny per bushel check-off is spent on research, education, market development and new uses. This publication will highlight the research expenditures approved by the nine-member farmer board of directors.

As you can see from this report, much care is taken to select projects that fit in with the long-term goals and markets for Michigan corn farmers. Research dollars are focused on traditional corn markets, such as livestock; improving production efficiencies, such as nutrient management and conservation tillage; as well as new markets and new uses.

As the board of directors looks to the future, we see an ever-increasing annual crop that will need a market and a use. As we look at the past and the effects weather has had on the corn crop, it becomes evident that we have varieties that are increasingly more hardy and robust. As our crop continues to evolve, we are working very hard to ensure that future market opportunities for corn evolve as well.

It is exciting to be part of such a forward-looking group and to know the research we fund today will be the new markets of tomorrow. Research requires patience and commitment to projects to see them through, especially when commercialization is involved. Through the CMPM, grower check-off funds have led to the development of many new uses, including a sodium-free salt substitute, pharmaceuticals, chemical compounds, plastics, clothing and much more.

To utilize more time and funds for the research projects themselves, the CMPM board and its research proposal review process has gone paperless. All proposal submissions, correspondence and presentations are now done electronically. The CMPM is dedicated to wisely investing funds contributed by the state's corn farmers into not only improving production practices and strengthening traditional markets, but also toward developing new markets for Michigan's growing corn crop.

The following pages in our Annual Research Report showcase how the CMPM has invested check-off funds. All of the research is designed to help keep the Michigan corn industry on the cutting edge of production, technology and new uses. If you have any questions or suggestions about the research funded through the grower check-off funds, please contact the CMPM office at 1-888-323-6601.

Sincerely,

Pat Feldpausch, President
Corn Marketing Program of Michigan

About the CMPM

Established under Public Act 232 of 1965 and approved by our state's corn farmers in 1992, the **Corn Marketing Program of Michigan** receives one penny per bushel for all Michigan corn sold. The "check-off" funding is invested in research, education, market development and new uses. The continuation of the program is voted on every five years by Michigan farmers. For the program to be approved for continuation, the referendum vote must be approved by both the majority of voting farmers and corn production voted. The nine-member Board of Directors, appointed by the Governor, sets the yearly direction of the program. As a way to dispense research results to the state's corn farmers, the CMPM annually holds the Corn & Soybean Winter Research Meetings and publishes an Annual Research Report, highlighting current and past check-off funded research projects.

Production Research

The Corn Marketing Program of Michigan (CMPM) board of directors understands the importance of agronomic research and the role it plays within the agricultural industry. The technology and innovations that are tested will play a role in continuing to help farmers grow more corn per acre to meet the needs for food, fuel and fiber. Over the past two decades, Michigan's farmers have increased corn yields from 110 bushels per acre in 1991 to 150 bushels per acre in 2010. The CMPM believes that the production research presented on the next few pages will help Michigan's corn farmers continue to produce more corn on less land and with less inputs.

Corn Nematodes Effect Michigan Farms

With symptoms that are commonly mistaken as nutrient deficiency, disease or other problems, corn nematodes are corn-damaging pests that Michigan farmers frequently overlook. By damaging the plant's root system, nematodes can stunt growth and affect yields. As many nematologists around the Corn Belt believe populations of nematodes are on the rise, the minuscule pests present a growing threat to Michigan's nearly 12,000 corn farmers.

To help Michigan's farmers understand the impact of corn nematode damage and implement effective management practices, the CMPM has partnered with B&M Crop Consulting, Inc. to conduct corn nematode research. The main objective of this year's study was to determine baseline nematode levels across Michigan and evaluate their potential threat.

Missy Bauer taking root samples for her corn nematode survey.

To accomplish these tasks, Missy Bauer, principal researcher, implemented a nematode sampling system throughout Michigan. The system used a sampling procedure that included 10 to 12 soil cores from the corn's root zone and five root balls for each sample. The samples were shipped to Michigan State University's Plant and Pest Diagnostic Lab for nematode analysis. In total, 366 samples were collected from twenty different counties and were processed and analyzed for dagger, lance, lesion, needle, pin, spiral, stubby root and stunt nematodes.

Since each nematode has its own threshold and multiple nematodes are often present in one sample, a risk index is used to label the sample results. The risk index levels are as follows: 0 – non-detected; 1 – low; 2 – moderate-2; 3 – moderate-3; 4 – high; and 5 – severe. Of the 366 corn nematode samples, 7.1 percent of the samples had a high to severe risk index level and are therefore subject to yield loss due to corn nematodes. Those results with a risk index of moderate-3 would also have a potential for yield loss, and nearly 15 percent of samples fell into this category. In total, the survey indicated that yield loss may be occurring from nematodes in 22 percent of corn fields. Michigan corn growers should monitor their fields for the pest.

The roots of nematode damaged corn, which show fewer root hairs and stunted growth.

Although only 22 percent of the samples had moderate to high risk levels, 97.5 percent of the samples contained nematodes at some level. The most common nematode detected was the lesion nematode as illustrated in Figure 1, which also shows the other varieties of corn nematodes and the frequency in which they were detected. Lesion and dagger nematodes, both of which are considered moderate risk as they can cause yield reduction, were found in 83 percent and 39 percent of samples, respectively. Spiral and stunt nematodes (lower risk) were in 59 percent and 46 percent of the samples, respectively. The lance and stubby root nematodes present only moderate risk, however, these were found in 6 percent or less of the samples. The pin nematode, considered to be low risk, was detected in 5 percent of the samples. Fortunately, the needle nematode (very high risk) was found in only 1 percent of the samples.

This survey indicates that corn nematodes are common in Michigan and that there is a potential yield threat for farmers. Corn growers in Michigan should be sampling their own fields to determine how common nematodes are and their potential risk index. There are currently seed treatment products on the market which offer protection from yield loss as the result of corn nematodes. These products should be utilized in fields that have a moderate-3 or above risk index to determine if higher yields can be achieved.

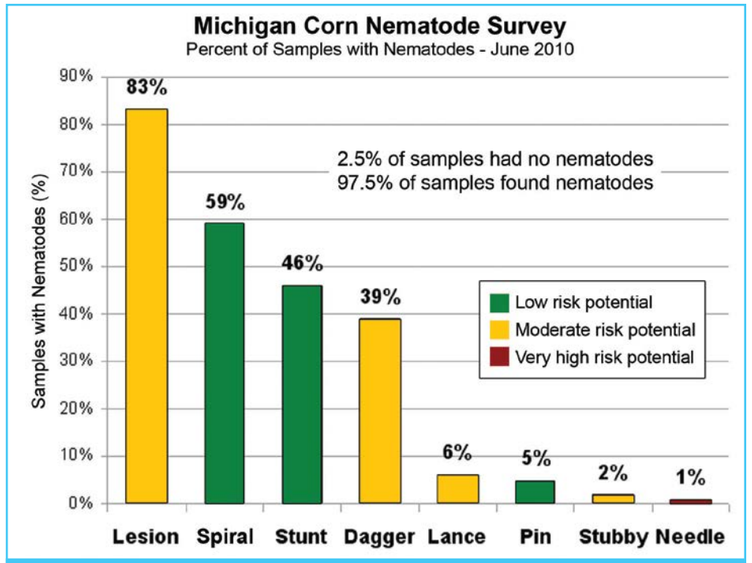

Figure 1: Various types of corn nematodes and the frequency in which they were detected in 366 samples pulled in 20 counties throughout Michigan in early June of 2010.

"Farmers should be aware of all potential threats to their crops," said Richard Dobbins, CMPM board member and corn grower from Concord. "Nematode damage usually goes undiagnosed, which means farmers are suffering yield losses. This baseline research is very valuable for growers across Michigan as it will help to bring awareness to the issue and aid farmers in correctly identifying nematode problems."

Western Bean Cutworm Biology and Life History in the Great Lakes

Western bean cutworm (WBC) is a corn-damaging pest that is native to the western United States. Larvae feed on ears late in the season, causing loss in yield as well as reduction in grain quality by increasing the potential for mycotoxins. WBC also attacks sweet corn, dry beans, tomatoes, and potentially other minor crops, thus is a major concern for many growers in Michigan. WBC infestations have resulted in economic damage in certain locations and fields in Michigan since 2007.

In order to help Michigan's corn farmers understand the impact of WBC caterpillar damage and implement effective management practices, the CMPM has partnered with Michigan State University (MSU) since 2009 to conduct WBC research. The main objective of this year's study was to determine the unique aspects of WBC biology and life history specific to the Great Lakes region.

A young western bean cutworm larva feeding on an ear of corn.

To accomplish these objectives, Dr. Chris DiFonzo, principal researcher and professor of entomology at MSU, set up a WBC sampling system throughout Michigan. The system used pheromone lures to trap WBC moths at 346 unique locations in Michigan. An online database was set up so that counts could be entered by researchers and volunteers from across the state, the results of which can be viewed online at www.msuent.com.

WBC moth counts were performed weekly from June to September using milk jug pheromone traps. At 12 different locations, two types of traps, milk jugs and

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dry buckets, were compared. Both performed well and were sufficient for trapping, however, dry buckets require some monetary investment as they are $10 per unit whereas milk jugs are free. The moth counts were entered onto the online trapping system and totaled 78,367 moths at the conclusion of the study. While the traps caught WBC moths as early as late-June and as late as mid-August, the overall trap catch peaked during the third week of July. Compared to trap catch in 2009, peak flight was two weeks earlier in 2010. Since scouting should start as moth flights increase, this demonstrated the importance of monitoring flight each season to determine optimal scouting time. Direct observations of the pheromone study also noted that moths fly between peak hours of 1:00 and 3:00 a.m. The results of the 2009 (gray bars) and 2010 (green bars) WBC moth counts can be seen in Figure 2.

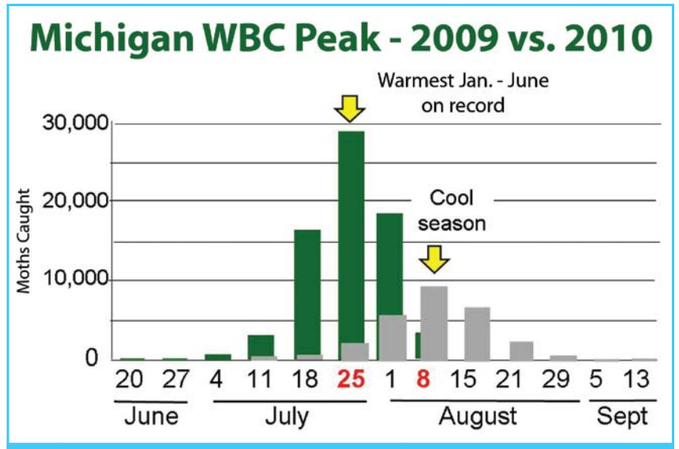

Figure 2: Peak season for WBC moth trapping. Gray bars show 2009 and the green bars show 2010.

The WBC study also looked at plant maturity to see which stages were more susceptible to WBC infestation. Whorl stage corn appears to be a poor host for WBC. When plants in pre-tassel and whorl stage were compared after being infested with individual masses, the larvae survived only on the pre-tassel corn. Researchers suspect it is unlikely that larvae could survive well on leaf tissue alone without pollen or silk. As a result of this finding, growers should continue to concentrate on pre-tassel corn for scouting, as this stage is most at risk.

The 2010 WBC research also looked at genetically modified (Bt) hybrids to detect their effectiveness against WBC. These Bt efficacy trials were performed with industry partners. Ear damage and mold were significantly less and produced a greater yield with Cry1F Bt (Herculex and SmartStax) corn as compared to Yieldgard-type or non-Bt hybrids. However, growers need to be aware of both the advantages and limitations of the seed they purchase. On one hand, not all seed is created equal in terms of WBC control, but on the other, no Bt corn is totally resistant to WBC damage and fungal infection. The efficacy studies also sampled WBC egg masses weekly and found that egg laying occurred over a three week period (15 percent, 53 percent and 27 percent of the egg masses were found on July 7, 14 and 20, respectively). These findings suggest that spray timing should be based on scouting multiple times and considering cumulative egg mass numbers, not based on a single scouting date going over the current 5 percent threshold.

In addition to corn, WBC has several potential crop and weed hosts. During 2010, entomologists from MSU and the University of Guelph compiled a list of potential WBC hosts and tested WBC's survival on each plant species. WBC survival on corn, peas and dry beans was high, as well as on squash and several weed species. Survival on soybeans was moderate, although larvae did not grow well. Survival on peppers, tomatoes and potatoes was generally poor. By identifying alternative hosts that may create WBC refuge populations, the results may lead to modification of management recommendations so that corn crops are better protected.

A group of newly hatched western bean cutworm larvae.

"As a result of this study, Michigan's farmers are better informed about the biology and practices of WBC, both of which will help farmers combat WBC damage through more effective scouting, better refuge choices and more knowledgeable seed selection," said Ed Breitmeyer, CMPM board member and a corn grower from Buckley. "We are grateful for the work Dr. DiFonzo has done regarding WBC. The results from her project will allow farmers across the state to increase their productivity and decrease their losses from the increasing threat of WBC."

In 2011, DiFonzo did a second year of research on the flight and host range work, as well as the night observations of insects. She also conducted an open 'public' test (not tied to industry) of Bt hybrids in relation to WBC survival and damage. By collecting WBC biology information for a third year in Michigan, DiFonzo hopes to be able to modify current recommendations for WBC management to account for Great Lakes conditions.

Center for Excellence Showcases New Agronomic Practices

The Corn Marketing Program of Michigan (CMPM) partnered with the Lenawee Conservation District, the Natural Resources Conservation Service and the Michigan Soybean Promotion Committee to conduct an extensive research and demonstration project known as the Lenawee County Center for Excellence. Through the Center for Excellence, new practices are tried in test plots for growers to learn and evaluate data without it affecting their farming operation's bottom line.

The Center for Excellence, which began in 1998, is a research and testing program consisting of plots on two farms in Lenawee County — Bakerlads Farm and Raymond & Stutzman Farms. The plots test various production practices including conservation tillage, soil fertility levels and testing new seed genetics to determine how producers can increase productivity while conserving Michigan's natural resources. The research projects and plots at the Center for Excellence are done over a period of time to ensure the most accurate data is obtained.

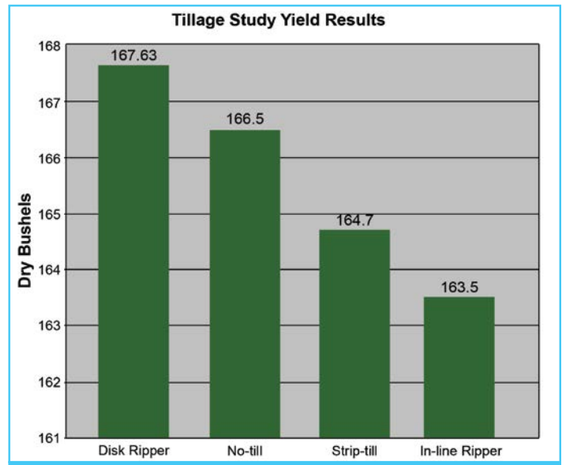

Figure 3: Yield results from the tillage study.

"Corn and soybean farmers from across Michigan have benefited from check-off and privately funded research at the Lenawee County Center for Excellence for thirteen years," said Mark Kies, CMPM vice president and a corn grower from Allen. "The Center for Excellence allows corn farmers to see the effects of the new agricultural innovations and techniques without having to assume the risk."

Each year, the Center for Excellence hosts a Field Day where farmers can learn more about the research being done at both locations and see the plots first-hand before harvest. The 2010 Field Day focused on developing and refining viable conservation tillage systems that can be adopted on farms at a local level. The five different tillage practices that were researched at the 2010 corn and soybean plots grown at Bakerlads Farm included:

1. Deep Tillage (In-line Ripper)
2. Orthman Strip-Tillage
3. No-Till
4. Disk-Ripper

Treatment	2010 Yield (bu/ac)	2009 Yield (bu/ac)
Untreated A	156.7	121.6
Untreated B	167.99	124.6
Untreated C	156.99	118.25
Average	160.56	121.48
Quilt A	173.98	No Data
Quilt B	174.34	No Data
Quilt C	170.65	No Data
Average	172.99	
Headline A	166.52	186.96
Headline B	169.8	191.65
Headline C	169.12	182.70
Average	168.48	187.1
Headline	+7.92 bu	+65.62 bu
Quilt	+12.43 bu	

Figure 4: Yield results from the fungicide trials.

The results of these tillage trials are shown in Figure 3. Although the greatest yield advantage can be seen when the trials used a disk ripper, it should be noted that there have been yield differences from year to year and there has never been a single tillage operation that has developed a trend of significantly higher yields.

Another trial done by the Center for Excellence in 2010 was the continuation of a two-year replicated fungicide study. The two fungicides used in the study were Headline and Quilt. While the yield increases seen in 2010 were not as substantial as those seen in 2009, the study still consistently shows a large yield increase when using a fungicide on corn in late growth stages. Results from both year 1 and year 2 of the study can be found in Figure 4.

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EXCELLENCE... FROM PAGE 7

"The data compiled at the Center for Excellence this year will prove to be very valuable to Michigan's nearly 12,000 corn farmers," Kies said. "By providing science-based information on the tillage methods and fungicides researched in the 2010 trials, the Center for Excellence will allow farmers to make educated choices about tillage practices and fungicides they incorporate for use on their own operations. Research, like that done at the Center for Excellence, encourages corn growers to make positive changes on their own farms and it is through these types of advancements that farmers are able to achieve positive yield trends year after year, something that is very important as we strive to feed and fuel the world with our corn crop."

THUMB AG RESEARCH AND EDUCATION

The CMPM understands the importance of agronomic research and the role it plays within the agricultural industry. It is through this research that advancements in technology and production practices are made, which ultimately improves the bottom line for the state's corn farmers. One way the CMPM works on behalf of corn growers in Michigan is to fund agronomic research on various corn variety trials to help farmers find the best available seed for their operation.

To do this, the CMPM has partnered with the agricultural Extension Educators of Huron, Sanilac and Tuscola counties for six years. This study, known as the Thumb Ag Research and Education (TARE) project, collaborates with thumb-area growers to conduct extensive corn and soybean variety field trials. "On-farm research and demonstration plots are critical to evaluate the value of emerging technologies, varieties and products to ensure the profitable production of corn," said Tom Durand, CMPM board member and a corn farmer from Croswell. "As a result of on-farm plots, corn farmers across the state are able to make more informed decisions that will ultimately affect their individual farming operations."

Hybrid	RM†	Traits	Seed Trt‡	Average of 5 Locations			
				Lodging§	Moisture	Test Wt.	Yield¶
	days				%	——— bu / ac ———	
NK Syngenta N29T-GT/CB/LL #	92	GT/CB/LL	C250	0.50	17.25	60.23	***190.25***
NuTech 5B-290 GT/CB/LL	90	GT/CB/LL	C250	0.83	17.21	60.29	182.48
Masters Choice MCT-493	93	RR/CB/RW	P250	0.17	17.30	60.25	177.00
NK Syngenta N33R-GT/CB/LL	94	GT/CB/LL	C250	0.83	16.92	60.47	175.51
G2 5H-696 RR/HX	94	RR/HX1/LL	C250	0.33	18.42	59.76	175.49
Croplan 3424	94	VT3	C	0.83	17.68	60.02	172.27
Great Lakes 4041G3	90	VT3	P250	0.67	17.40	60.15	170.76
Hyland HL CVR54	92	VT3	P250	0.50	16.78	60.46	170.00
Dekalb DKC42-72	92	VT3	AC	0.17	16.82	60.63	168.96
Heritage 4250VT3	94	VT3	AC	0.33	17.57	60.07	168.40
Hyland HL B32R	90	HX/RR	P250	0.33	17.13	60.23	168.34
Mycogen 2J337	92	VT3/RR	CLR	1.00	17.29	60.28	167.00
NuTech 5N-695 GT/CB/LL/RW	94	GT/CB/LL/RW	C250	1.00	17.43	60.11	166.08
Croplan 3114	91	VT3	C	0.50	17.31	60.31	165.70
NK Syngenta N27B-3000GT	91	GT/CB/RW/LL	C250	0.50	16.85	60.48	164.98
Mycogen 2C302	90	HXI,RR	CLR	1.00	17.44	60.16	164.40
Rupp xr 8002	94	VT3	MXL, C250	0.67	16.94	60.41	164.26
NK Syngenta N23K-3000GT	88	GT/CB/RW/LL	C250	0.33	17.06	60.39	163.61
Dyna-Gro D27GC19	87	GT/CB/LL	P250	0.17	16.85	60.63	157.60
Pioneer 38M58	94	HX1/LL/RR	C250	0.67	17.25	60.34	156.63
Garst 89K65-3000GT	89	GT/CB/RW/LL	C250	0.00	17.14	60.38	154.13
Pioneer 38N88	92	HX1/LL/RR	C250	0.83	17.22	60.18	149.14
Average				0.55	17.24	60.28	167.86
LSD @ 0.05							6.74
C.V. %							6.45

† Relative Maturity

‡ Seed Treatment Abbreviations: C = Cruiser, P250 = Poncho 250, CLR = Cruiser LR, AC = Acceleron, C250 = Cruiser 250, MXL = Maxim XL

§ Lodging Score Ratings: 0 = 0%, 1 = < 20%, 2= 20 - 50%, 3 = > 50

¶ Corn yields have been adjusted to 15.5% moisture

Bold, Italicized yields are not significantly different from the highest yielding variety within that column

Figure 5: Variety trial results for glyphosate resistant corn hybrids.

Population Study

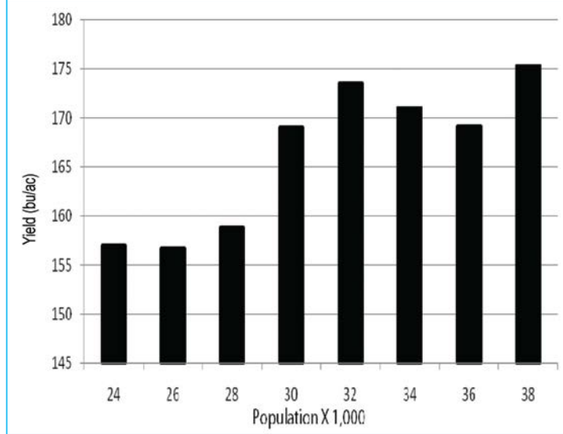

Figure 6: Results from the corn population trials.

For the 2010 TARE study, six corn trial sites and three soybean trial sites were planted. Each trial site included six rows, planted 30 inches apart and 100 feet long, and were replicated four times. In total, 94 corn hybrids and 78 soybean hybrids were evaluated. Studies were conducted on nitrogen fertilizer rates and starter fertilizer. Figure 5 shows the corn variety trial results for the glyphosate resistant 85-94 growing day corn.

In addition to the variety trials in 2010, corn populations were also studied at the TARE project. Figure 6 shows the results.

"The populations ranging from 30,000 to 38,000 yielded the same statistically, while populations at 24,000 to 28,000 were significantly lower," said Bob Battel, TARE Project Leader.

Tuscola County Nitrogen Rate Study

Total N	Moisture	Yield @ 15.5%†
— lb N / a —	%	— bu / a —
0	12.8	107.8 c
40	13.8	108.3 c
80	13.5	117.4 bc
120	13.4	135.9 a
160	13.3	126.8 ab
200	14.1	131.1 a
240	13.6	131.4 a
LSD @ 0.05		14.7
C.V. %		7.9

† Yields with the same letter are not significantly different from each other

Figure 7: Results from the Tuscola County nitrogen rate trial.

The study also looked at sidedress nitrogen rates.

"The purpose of the sidedress study was to determine economic optimum nitrogen rate rather than just fertilizing to meet yield goals," Gerstacker said. "By addressing economic optimum nitrogen rate it will give growers a maximum return to nitrogen."

Figure 7 illustrates the sidedress rates used in the study and the resulting yields.

"No significant difference was observed between sidedress nitrogen application rates above 80-120 lbs/acre," added Battel. "Economic optimum nitrogen rates were lower in 2010 that 2009. This is an outcome of 2010's warmer, dryer spring that resulted in lower in-field nitrogen loss."

The full results of the research were published in Thumb Ag Research & Education, 2010 Field Trials, which is available online at www.micorn.org.

GENTICALLY-MODIFIED CORN HYBRIDS PROTECT AGAINST PESTS

As the invasive Western Bean Cutworm (WBC) continues to impact corn fields across Michigan, the state's nearly 12,000 corn farmers continue to search for the best method of protection against this destructive pest. Native to the western United States, WBC larvae invade corn ears late in the season and cause significant kernel damage due to feeding, which results in a loss in yield for the farmer. This damage often leads to a reduction in grain quality by promoting the growth of harmful fungi and increasing the potential for mycotoxins. The effects of WBC infestations have resulted in economic damage in certain locations and fields in Michigan since 2007 and the threat continues to spread each year.

With so much at stake, many seed and insecticide companies have developed products which offer WBC control options. One such product which is escalating in popularity is the genetically modified (GM) corn hybrid with built-in genetic protection against WBC. These WBC control GM hybrids, available in brand names such as Herculex and SmartStax, contain a gene from a soil bacterium that is harmless to humans and almost everything else, with the exception of certain corn-eating pest insects like WBC. Shown in numerous research trials to be effective, these GM hybrids are being planted in increasingly large numbers as farmers combat a growing WBC population in Michigan.

While years of experience and repeated scientific research efforts have confirmed that GM corn is safe for people, animals and the environment, the growing use of GM corn with WBC control has led some environmentalists to once again

GM CORN... CONTINUED ON PAGE 10

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express concern for Michigan's diverse ecosystem. To help quiet these growing fears, the CMPM partnered with Michigan State University (MSU) to assess the ecological effect of WBC control GM corn hybrids versus other WBC control methods in Michigan. The results of a two-year study by Dr. Mark Whalon, principal researcher and professor of entomology at MSU, shows that GM corn designed to help control WBC is more beneficial ecologically than a WBC insecticide spray and offers a range of other environmentally friendly benefits as well.

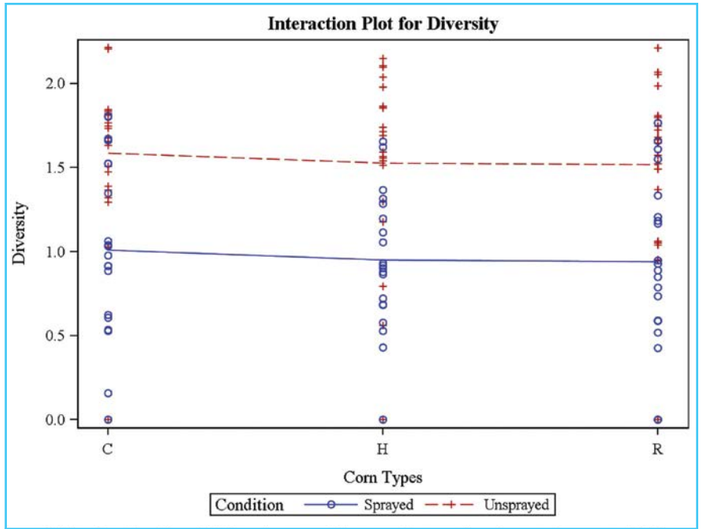


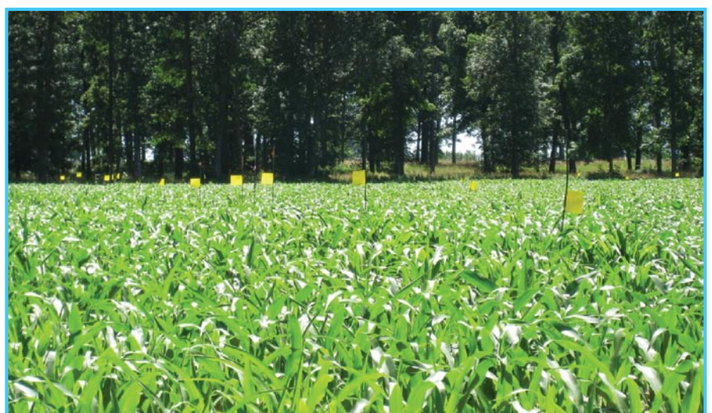
Figure 8: The diversity of beneficial species present in sprayed conventional corn and unsprayed genetically-modified corn.

To identify the ecological impact of WBC control GM hybrids versus WBC control insecticides, Whalon sprayed conventional corn with a WBC insecticide and compared the diversity of beneficial species in that field against the beneficial species in an unsprayed conventional corn field and an unsprayed WBC control GM corn field. The ecological monitoring systems tracked 32 beneficial species to measure the ecological health of each field. These beneficial species can be predators, parasites, pollinators or good pathogens that keep the harmful species (such as WBC, other pests or corn diseases) in check. While both are necessary in a thriving ecosystem, a healthy balance (meaning the beneficials outweigh the detrimentals) is important to ensure an abundant harvest at the end of the season. By testing the ecological diversity of the three fields, Whalon was able to establish the different ecological impacts of the two WBC control methods.

Figure 8 illustrates the diversity of beneficial species present in sprayed conventional corn (blue line) and the unsprayed GM corn (red line).

The results of Whalon's scientifically replicated studies show there was no difference between the GM corn and the conventional corn in terms of diversity when insecticides were not used. In other words, the presence of the genes for resistance to pest insects in the GM corn did not hurt the overall abundance and diversity of beneficial species in the corn field. On the other hand, when insecticides were used in the conventional corn to control WBC, the beneficials were set back while the GM corn, which did not have to be sprayed to control the WBC, remained high in beneficial diversity.

This newly found benefit to GM crops joins a growing number of other GM advantages. GM crops have also been shown to make good water and soil erosion stewardship practices, such as minimum tillage and no-till systems, easier to implement for growers. These environmentally friendly farming techniques reduce a farmer's fuel use, soil erosion and insecticide applications and help them to preserve the natural resources they utilize year after year.



A group of newly hatched western bean cutworm larvae.

This data will help the corn industry in Michigan, as well as the environmentally-concerned public, to better understand GM corn crops and their impact.

"As farmers, the environment is a top priority for us," said Pat Feldpausch, CMPM president, and a corn grower from Fowler. "We want to ensure the public that we are growing feed, fuel and fiber in the most environmentally responsible ways possible. This research will help us show that one of the best tools available today, GM hybrids, are a safe and effective way to produce a bountiful harvest."

Ethanol Research

The Corn Marketing Program of Michigan (CMPM) board of directors understands the importance of new uses and new markets. As they look to the future, they are keenly aware of the increasing crop yields being projected. Some projections are as large as 200-300 bushel per acre corn yields. As the crop size continues to increase, it also becomes even more critical to examine new markets and uses. Traditional markets including livestock are very important, but they are also relatively stable in their crop usage. As we look at new markets like ethanol, it is important to continue research to ensure their development and maturity so these new markets become as efficient as possible. It is also important to stay focused on the goal of the project, as it does take time and patience to see a project evolve into a new product.

Consolidated Bioprocessing: Corn as a Whole-Plant Cellulosic Bioenergy Feedstock

As interest in cellulosic ethanol continues to grow, corn remains a primary focus as a cellulosic feedstock. Many of the most advanced cellulosic research facilities utilize corn stover and corn cobs as their raw materials. This feedstock has traditionally been harvested through conventional harvest methods, with the stover and cob components harvested separately from the grain in the field. The two components are then processed separately at different biorefineries that are starch-based (grain) or cellulosic-based (stover/cob). The separate harvest of the grain and stover results in more equipment crossing the field and higher input costs, including the fuel necessary to operate machinery. In an effort to increase efficiencies for the farmer and the ethanol plants, new research is being done to analyze the benefits of harvesting and processing the whole corn plant together in a procedure known as consolidated bioprocessing.

Should the primary research on the new consolidated bioprocessing system prove to be effective, farmers who sell their crop to ethanol facilities will have new options for crop harvest and storage. In order to help Michigan's corn farmers understand the new process and what harvest and storage methods are most profitable, the Corn Marketing Program of Michigan (CMPM) has partnered with Michigan State University (MSU) to conduct consolidated bioprocessing research. The main objective of the study was to determine if the consolidated system is a viable method for ethanol production and if it is more efficient than the traditional dual systems of separate harvest and fermentation.

- **Locations:** Zone 1 - Branch
  Zone 2 - Ingham
  Zone 3 - Huron
  Zone 4 - Menominee
- Four replications in each location
- Harvest Strategies

	Description	Fraction
S1	whole plant at green	1A - fresh; 1B - ensiled
S2	separate grain and stover harvest at maturity	2A - grain; 2B – stover; 2C cob
S3	whole plant at maturity	3A

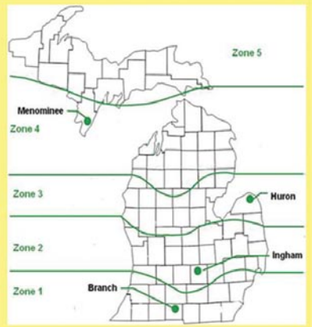


Figure 9: Experiment design and harvest methods implemented.

To accomplish these objectives, Dr. Kurt Thelen, principal researcher and crop and soil science professor at MSU, set up a four-zone research project that spanned across the state of Michigan. Harvest sites were located in Branch, Huron, Ingham and Menominee counties. Three different strategies were assessed to determine if consolidated bioprocessing is a viable alternative to conventional separate processing. First, the study was split into traditional (separate) and whole-plant (consolidated) bioprocessing. The consolidated bioprocessing method utilizes an ammonia fiber explosion (AFEX) pretreatment plus a broad spectrum enzyme treatment for specifically tailored microbial fermentation. Second, the study looked at timing of harvest to determine which time was optimal — green phase or mature phase. Green phase harvest is when corn is traditionally chopped for silage (prior to dry-down) and mature phase harvest is when the plant has dried-down and is typically harvested for grain. Additionally, green whole-plant corn was tested to assess when maximum ethanol yields were obtained; when processed fresh or after ensiling.

Figure 9 shows the harvest methods implemented.

The results of the study show detailed information on sugar content, an important component of ethanol production, and ethanol yield from different corn fractions and harvest strategies. The sugar content of green-cut, whole-plant corn

Bioprocessing... Continued on page 12

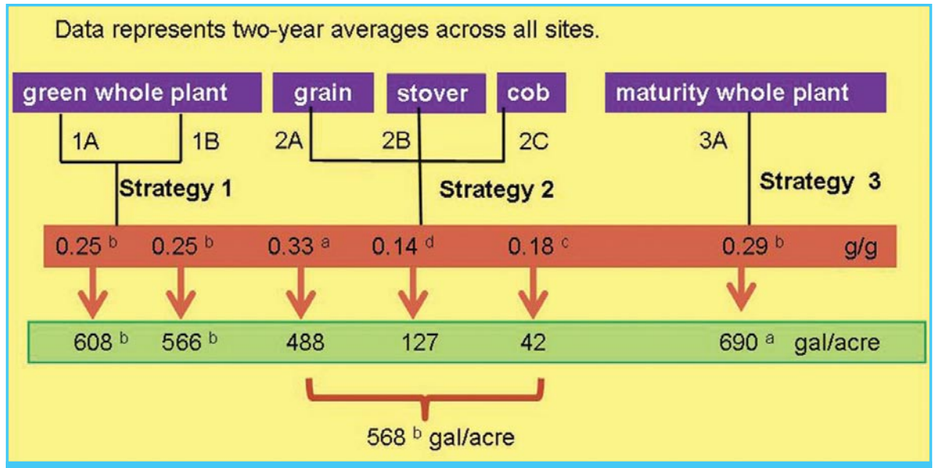


Figure 10: Ethanol yield from various harvest strategies.

Bioprocessing... From page 11

showed no difference when processed fresh or ensiled. Additionally, all whole-plant samples, both fresh and ensiled green-cut and mature, were higher in sugar content than separated fractions. The ethanol production results showed that mature whole-plant corn produced higher yields than those from both types of green whole-plant processes and grain and stover fractions. This indicates that the consolidated system surpasses the existing source-separated system in terms of ethanol yield and efficiency. Figure 10 shows the ethanol yield from the four harvest strategies.

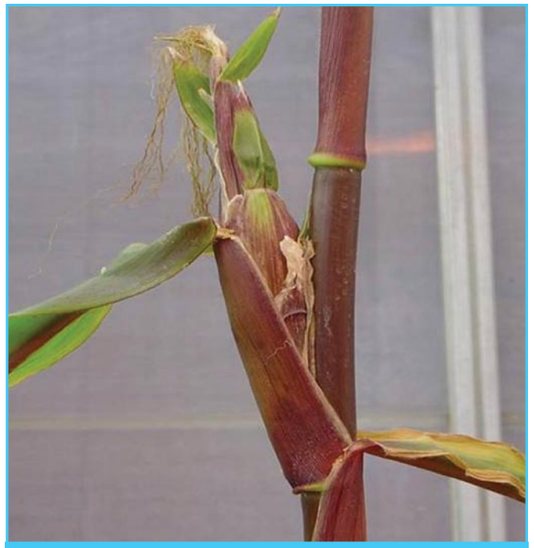
When comparing the two green-cut methods against one another, six percent dry biomass loss was estimated during the ensiling process. However, there was no significant decrease in ethanol yield from the ensiling harvest strategy compared to the green-cut fresh processed strategy. This result indicates that ensiling may be an effective post-harvest storage method that would facilitate a year-round feedstock supply to the bioprocessor. An additional benefit of a green-cut system is an earlier harvest time which facilitates integration of a cover crop, manure applications, or other strategies to augment carbon loss associated with whole-plant harvest.

"Dr. Thelen's research will help Michigan's farmers be better prepared for future advancement in combined bioprocessing and new harvesting strategies," said Clark Gerstacker, CMPM board member, National Corn Growers Association Corn Board member and a corn grower from Midland. "The gained efficiencies of the one-pass harvest and single bioprocessing strategy, such as faster harvest, ability to store in on-farm bunker silos and the eliminated need for in-field stover pick-up mechanisms, make the consolidated approach an attractive alternative to the current strategy of separating the starch and cellulosic feedstocks. With Dr. Thelen's work proving viable yields using the consolidated process, ethanol plants can now give the single stream method serious consideration for the future. Should they implement consolidated bioprocessing, corn farmers across the state will have options to help increase ethanol plant productivity and lower input costs while reducing environmental impacts through new consolidated harvest and storage methods."

Corn Gene Therapy Decreases Cost of Ethanol Production

The ever-increasing price of petroleum fuel has not only undermined the United States' economic strength, but has also threatened our national security. To help decrease U.S. dependence on foreign oil, various biofuels have been developed in recent years, with corn ethanol standing out as the leader in the industry. As compared to gasoline, ethanol is readily biodegradable and releases significantly less air-borne pollutants than petroleum. The majority of ethanol is derived from the starch of corn kernels, but much research is being done to expand ethanol production to include cellulosic ethanol, which can be produced from other parts of the corn plant, such as stalks and cobs.

Dr. Mariam Sticklen in her low lignin corn greenhouse at MSU.



The second generation low lignin/high cellulose corn plants with their rustic brown mid-ribs, stems and husks.

Research has shown that just as the starch of corn kernels can be converted into ethanol, corn stalks left in the fields can be transformed into fermentable sugars for ethanol production. The conversion of corn stalks into ethanol would further expand the revenue streams of corn farmers and assist the U.S. in the pursuit of energy independence. However, past research attempts have shown one major hurdle; the process of converting corn stalk residue into fermentable sugars for ethanol production is very costly.

In an effort to find an effective means of reducing the cost of converting corn stalk residue into ethanol, the CMPM partnered with Dr. Mariam Sticklen of the Department of Crop and Soil Sciences at Michigan State University (MSU) to conduct research on corn stalk residue conversion into cellulosic biofuel.

"As we look to lessen our dependence on foreign oil and grow our economy here in Michigan, these types of biofuel projects continue to be invaluable," said Mark Kies, CMPM vice president and a corn grower from Allen. "However, to be a viable fuel alternative, new cellulosic fuels like those made from corn stover need to be cost competitive, which is why the process needs further refining."

Corn stalks, like other crop residue, contain several different components that must be broken down for the ethanol production process. The first is a soft fiber called cellulose, which is an organic compound composed of sugars connected together by chemical bonds. After corn stalks are ground and treated, the chemical bonds can be broken into fermentable sugars for the production of cellulosic ethanol. The second component of crop residue is a harder fiber called lignin. Unlike cellulose, lignin contains no sugar, but rather is an organic matter consisting of a series of complex molecules. In order to produce ethanol from crop residue such as corn stalks, chemical and/or extreme heat pre-treatment processes are necessary to break-down and remove lignin. Depending on the method used, pre-treatment processes can cost from $1.15 to $2.25 per gallon of cellulosic ethanol. In addition to expenditures associated with crop production, harvest, storage, cellulose treatment, and the fermentation of sugars into ethanol, the lignin treatment is an excessive cost which restricts expansion of the industry.

Through her research, Dr. Sticklen has developed a patented corn plant containing lower lignin and relatively higher cellulose. Although the plant has about ten percent less lignin, it maintains the same kernel yield, height and strength. Lower-lignin corn plants have the potential to significantly reduce the cost of converting stalk residue into fermentable sugars, ultimately lowering the cost of cellulosic ethanol production.

The technology used by Dr. Sticklen is much like human "gene therapy," as it reduces the effect of undesirable traits. Several of the corn plants that underwent gene therapy contain a higher amount of cellulose, meaning it shifted the energy normally utilized to make lignin and has redirected it into making more cellulosic fibers. In the case of corn gene therapy, the second generations of lower lignin/higher cellulose corn plants develop a rustic brown coloration indicating its decreased lignin.

Based on her research, Dr. Sticklen believes her new corn crop could be utilized for more than just low-cost corn stover cellulosic ethanol production. She believes the crop would also serve as an excellent corn silage feed for livestock as the lower lignin corn will be digested faster by animals, while the higher level of cellulose will increase an animal's energy levels. Additional testing and further research will be done in the future to expand other potential uses for her corn crop.

"We are grateful for the work Dr. Sticklen has done at MSU regarding the low lignin/higher cellulose corn crop and its potential uses," Kies said. "The results from this project show great promise for the cellulosic corn stover ethanol industry and will create another value-added market for Michigan-grown corn. As corn farmers continue to increase their efficiencies and produce more corn each year, new and emerging technologies such as this will be an important avenue for our crop."

A comparison of Dr. Sticklen's low lignin corn (right) with wild type corn on the left.

The Benefits of Ethanol-Blended Fuels in Recreation

The Kettering University Formula SAE Vehicle on display at the annual MCGA Ethanol Night at the Races event.

The production of ethanol and its use continues to expand across the United States, including here in Michigan. By extending our fuel supply and reducing our dependence on foreign oil, consumers can be grateful for the relief ethanol provides at the pump and to the environment. Many consumers realize the addition of ethanol to our gasoline has resulted in savings at the pump. In fact, consumers would be paying 89 cents more per gallon if ethanol was to disappear and gas prices could rise by as much as 92%, according to the Center for Agricultural and Rural Development (CARD) study.

Besides pricing, ethanol-blended fuels have several advantages over gasoline in terms of power output and emissions. Also, in comparison to gasoline, ethanol is safer to transport since alcohol is water soluble and biodegradable. Kettering University has spent the last several years educating the public about the benefits of using ethanol-blended fuels, while developing new technologies to help shape the future of ethanol-blended fuels in snowmobiles and the racing industry.

"Funding projects that educate the engineers of tomorrow about the advantages of ethanol are very important to our organization," said Carl Barth, CMPM treasurer and a corn grower from Three Rivers. "These students have the opportunity to see first-hand the impact of ethanol and how to harness this resource to fully utilize its octane."

Dr. Gregory K. Davis, the Director of the Advanced Engine Research Laboratory & Professor of Mechanical Engineering at Kettering University, partnered with the Corn Marketing Program of Michigan to provide his students an opportunity to work with ethanol.

"Our students have the opportunity to design and build motor vehicles adapted to operate with ethanol-blended fuels ranging from E15 to E85," Davis said.

Students designed an ethanol-friendly snowmobile that showed reduced emissions and noise characteristics. Several components were upgraded or added including the fuel pump; filter; and an ethanol-compatible, adjustable-fuel pressure regulator. The students also used a three-way catalytic converter to reduce emissions formed in the engine. In the end, the snowmobile managed to achieve substantial emission reductions. Carbon monoxide emissions dropped 79 percent and at the same time the combined emissions of unburned hydrocarbons and oxides of nitrogen fell by 89 percent. While running on an E21 blended fuel, the students achieved 20 mpg, which is a large improvement over existing commercial snowmobiles. Although there are still no commercially available flexible-fuel snowmobiles or snowmobiles operating on E85, Kettering University hopes to continue leading the way by demonstrating the benefits of using ethanol-blended fuels.

Figure 11 shows emissions of Kettering University's snowmobile operating on E21 compared to the 2012 Federal Emissions Standards.

Snowmobile / Std	CO, g/kW-hr	HC+NOx, g/kW-hr
2012 Federal Emissions Standards	275	90
2012 Kettering University CSC	59.1	9.5
Percent Reduction	79%	89%

Figure 11: A comparison of Kettering University's snowmobile operating on E21 to the 2012 Federal Emissions Standards.

The Kettering students have expanded their research to include the development of an E85 Formula SAE Vehicle they designed and built for competition. With the successful conversion of the engine to run on E85, Dr. Davis has educated even more future engineers at Kettering University regarding the use of ethanol-blended fuels. In February of 2010, the students also successfully implemented a fuel-injection system on a single cylinder engine. The engine was converted to run on E85, so the students could take advantage of ethanol's high-octane rating with spark tuning.

Aside from their work in engineering, the Kettering University students are striving to increase knowledge about ethanol-blended fuels among consumers and law-makers. They have participated in various promotional events and trade shows to educate the public about the use of ethanol-blended fuels in snowmobiles and cars alike in hopes of raising awareness and demand for ethanol. Additionally, the students and their vehicles have been featured on many local television news broadcasts and are regular stops on all University tours.

Figure 12 shows a comparison of the physical fuel properties of gasoline, ethanol and E85 blended fuels.

"We are grateful for the hard work Dr. Gregory Davis and his students at Kettering University have put in to their projects using ethanol-blended fuel in recreational vehicles and providing education," said Barth. "The results from this project will not only increase public awareness of ethanol, but also create another value-added market for Michigan-grown corn."

Physical Fuel Properties

	Gasoline - Regular Unleaded	Ethanol	E85
Formulation	C_4 TO C_{12} H/C-chains	C_2H_5OH	85% ethanol (by volume) 15% gasoline (by volume)
Average Analysis (% mass)	C: 85-88 H: 21-15	C: 52 H: 13 O: 35	C: 57 H: 13 O: 30
Octane (R+M)/2	87	98 - 100	96
Lower Heating Value kJ/kg (Btu/lb_m)	43,000 (18,500)	26,750 (11,500)	29,080 (12,500)
Lower Heating Value kJ/liter (Btu/gal)	32,250 (115,700)	21,240 (76,200)	22,830 (81,900)
Heat of Vaporization kJ/kg (Btu/lb_m)	330 - 400 (140 - 170)	842 - 930 (362 - 400)	812 (349)
Stoichiometric A/F (mass)	14.7	9	10
Conductivity mhos/cm	1×10^{-14}	1.35×10^{-9}	1.4×10^{-9}

Figure 12: Physical fuel properties of gasoline, ethanol and E85 blended fuels.

Ethanol-Fueled Drag Race Engine Development

Due to the fact that performance racing enthusiasts are historically tied to gasoline and have limited information available to them that shows ethanol as an option, the CMPM partnered with Muskegon Community College to develop an ethanol-fueled drag race engine. Many factors contribute to the reluctance of racers to use ethanol as a fuel, but lack of knowledge is the leading reason and the CMPM board felt that the knowledge gained from this research will help to push ethanol forward into the performance racing markets.

"Technical knowledge must be available to convince these racers to switch their vehicles over to ethanol," said Brian Kreps, CMPM secretary and a corn grower from LaSalle. "For this reason we felt that it was important to fund not only the development of this engine, but also the data collection that would prove the viability of ethanol to this industry. "

Muskegon Community College's ethanol-fueled drag race car.

Baseline tests of the engine in stock form have been completed and engine measurements were done prior to assembly of the stock engine. Track data and chassis dynamometer data have also been collected and have been used to determine a baseline for the stock engine. A new engine with enhanced compression ratio and camshaft profiles that are designed for the characteristics of ethanol is in the testing phase. Two sets of custom high compression pistons have been created for the engine. The pistons were designed with ethanol burn characteristics and compression ratio in mind. Final test results are not available but present data is very positive.

Co-Product Research

The Corn Marketing Program of Michigan (CMPM) board of directors recognizes that not only are new uses important, but the co-products from those new uses are very important, too. As we look to the future, we need to ensure that all co-products from processing are utilized to their fullest extent. Many times through additional research, a co-product can prove to be as valuable, or even more valuable, than the original development. As we look back over history, there have been some amazing developments, where processing of byproducts that originally had no use or market are now the desired product. The board is looking for those opportunities as well as looking to ensure that corn processing uses all components of the corn, the process and the co-products. If we can develop products with zero waste, we are even further ahead.

Distillers Grains with Solubles Research to Mitigate Green House Gas Emissions

Corn growers and livestock producers have had a mutually beneficial relationship since the very beginning of animal agriculture. With the growing demand for corn for ethanol, some livestock producers are concerned that this long-established corn supply may soon run out. However, today's ethanol process allows corn farmers to produce feed and fuel from the same bushel, thus satisfying both markets simultaneously.

Distillers grains with solubles (DGS) are a co-product of the ethanol production process which contain the highly nutritious parts of the corn kernel. During the dry milling process, the primary way in which ethanol is processed in the U.S., starch is removed from the corn kernel leaving oil, crude protein, fiber and other minerals such as sulfur and phosphorus. These nutrients are nearly three times more concentrated within DGS as compared to corn, making it a valuable and nutritious feedstuff for cattle, poultry and other livestock. The availability and use of DGS in cattle diets has enhanced the ability of the industry to remain competitive with elevated corn prices. Use of 40 percent DGS in the ration lowers the ration cost by 15 to 20 percent. Additionally, the manure from cattle fed DGS is fortified with higher nutrient levels than manure from cattle-fed traditional diets, consequently giving the manure more value when used as a fertilizer.

With the growing availability and reasonable price of DGS, the livestock industry has increased the amount of DGS in cattle diets. While this substitution has its benefits, feeding high levels of DGS to livestock may increase nitrogenous gases and sulfur concentrations that theoretically could increase greenhouse gas emissions. In order to help Michigan's farmers understand the potential impact of feeding DGS on the environment, the Corn Marketing Program of Michigan (CMPM) partnered with Michigan State University (MSU) to conduct DGS research. The study sought to determine if greenhouse gas emissions are influenced by feeding cattle DGS and if so, what nutritional or management practices could be implemented to reduce these emissions.

To accomplish these objectives, Dr. Steven Rust and Dr. Wendy Powers, principal researchers and animal science professors at MSU, set up a gaseous emissions monitoring system for cattle fed DGS. The study was conducted at MSU's Animal Air Quality Research Facility (AAQRF). Environmentally controlled rooms at AAQRF monitor incoming ambient and outgoing air from each of twelve rooms for concentrations of ammonia (NH3), methane (CH4) and hydrogen sulfide (H2S), which are gases of concern for greenhouse emissions.

Two different trials were conducted at AAQRF. In both, twelve Holstein steers were placed into environmentally controlled rooms with four steers in each trial receiving a different dietary treatment. Three levels of DGS (zero percent, 40 percent and 60 percent) replaced corn in a finish diet in Trial 1. In Trial 2, two levels of DGS were fed (zero percent and 40 percent). In trial 2, the third feed treatment was identical to the 40 percent DGS mix, but contained six parts per million (ppm) molybdenum and sixty ppm copper. The latter treatment was called 40 percent DGS Plus. Figure 13 shows the effects of different levels of distillers grains with solubles (DGS) on performance.

The purpose of Trial 1 was to determine if increased inclusion levels of DGS would cause an increased emission of hydrogen sulfide gas. Additionally, the effect on ammonia and methane emissions was also considered. In Trial 2, hydrogen sulfide, ammonia and methane gases remained the focal point. However, dietary treatment of 60 percent DGS was replaced with 40 percent DGS plus, which served as a potential strategy to mitigate hydrogen sulfide emissions. The third objective was to determine the origin of the greenhouse gaseous emissions; whether they evolve directly from the animal (enteric) or from the manure (mixture of urine and feces). The collection of manure for both trials was separated into two phases to determine emissions from manure and urine mixture versus manure and urine separated.

	Control (0%)	40% DGS	60% DGS
Avg. BW (lb)	594	585	572
DMI (lb/day)	13.57	13.73	13.11
ADG (lb)	2.00[ab]	2.33[a]	1.56[b]
Feed/Gain	6.78	5.89	8.39

Avg. BW - Average beginning weight
DMI - Dry matter intake
ADG - Average daily gain

Feed/Gain - Feed fed per pound of gain
[ab] Means with unlike superscripts differ.

Figure 13: Effects of different levels of distillers grain with solubles (DGS) on performance.

Results from this research project demonstrated ammonia and hydrogen sulfide emissions were increased when 40 percent DGS or greater was added to high grain diets. Additionally, the study showed separation of urine and feces drastically reduced emission of these gases. This separation limits the access of bacteria and enzymes to the soluble components in the urine, the interaction of which causes release of the gases. The increased emission when urine and feces are mixed illustrates that methods of storage and land application will have a large effect on the amount of nitrogen and sulfur retained in the manure. Moreover, manure handling and removal procedures may impact gas release and further research is needed to determine strategies to reduce emissions. It was also shown through the study that feeding high levels of DGS does not increase methane emissions, as most of the methane was produced from enteric fermentation in the rumen and hindgut of the steers. Lastly, addition of molybdenum and copper to the diet was shown to have no significant effect on lowering greenhouse gases.

	Trial 1		Trial 2		
	Phase 1	**Phase 2**	**Phase 1**	**Phase 2**	
Ammonia (g/kg DMI/d)	1.51	0.56	0.97	0.37	Control (0%)
	3.16	0.73	2.27	0.18	40% DGS
			2.81	0.27	40% DGS+
	3.01	0.69			60% DGS
Methane (g/kg DMI/d)	7.44	7.66	5.29	7.56	Control (0%)
	6.55	5.35	6.05	6.95	40% DGS
			4.71	7.24	40% DGS+
	7.93	8.73			60% DGS
Hydrogen Sulfide (mg/kg DMI/d)	2.40	-7.68	4.51	-5.79	Control (0%)
	19.06	-1.78	37.47	-3.81	40% DGS
			34.32	-1.82	40% DGS+
	15.69	-3.56			60% DGS

Figure 14: Comparison of gas emissions for phases one and two of both trials.

Figure 14 shows the comparison of gas emissions for phases one and two for both trials.

"As a result of this study, Michigan's farmers are better informed about distillers grains, nutrient management and the threshold at which DGS can be fed," said Randy Poll, CMPM board member and a corn grower from Hamilton. "We are grateful for the work Drs. Rust and Powers have done regarding DGS. The results from their project will allow corn and livestock farmers across the state to increase their productivity and decrease their greenhouse gas emissions."

Developing New Opportunities for Michigan's Corn

A mound of DDGs as they fall from the conveyor at an ethanol plant. Dr. Rawle Hollingsworth uses DDGs to create other new products.

As farmers in Michigan continue to produce over 300 million bushels of corn per year, the CMPM is working to find and develop new products and markets for those bushels. As part of its mission, the CMPM utilizes the penny per bushel contribution from the state's corn farmers to fund research looking at ways to not only enhance traditional markets like livestock feed and exports, but also to cultivate new market opportunities such as corn-based plastics, fibers and pharmaceuticals.

"The CMPM has been working with AFID Therapeutics, Inc. to develop exciting new opportunities for Michigan's corn," said Clark Gerstacker, CMPM board member, NCGA Corn Board member and a corn farmer from Midland. "AFID Therapeutics has developed a large repertoire of carbohydrate-based chemistries, primarily from corn, dried distillers grains (DDGs), and even sugar beets."

Aerospace Applications

AFID Therapeutics, Inc. has created a high-purity reactant from corn and its co-products. The corn is put through a chemical transformation, creating an advanced glycol-based reactant. AFID Therapeutics, Inc. has already received three orders from leading aerospace companies for their high-tech product.

"It is especially gratifying to see success in using chemical technology to bridge the aerospace and agricultural industries," said Rawle Hollingsworth, president and founder of AFID Therapeutics, Inc. "Michigan is the perfect place for this kind of development in which agriculture is placed at the center of a budding scientific, technical and economic

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revolution. In many respects, this is the future chemical industry for Michigan and its corn farmers."

Pharmaceutical Applications from Corn

In addition to its high-purity reactant, AFID Therapeutics, Inc. has also developed a platform of carbohydrate-based chemical compounds, primarily used as the building blocks for drug substances. Since 2005, AFID Therapeutics, Inc. has introduced more than 300 new chemical entities into practice for internal use and use by pharmaceutical companies around the world, including Merck, Pfizer, Novartis and Johnson & Johnson.

"Now that the platform has been created, we are focusing in on a special class of compounds, known as the pyrrolidines. These are highly-specialized compounds that are being used to develop drugs for antiviral, cancer and autoimmune therapies," said Hollingsworth.

The pharmaceutical chemistry developed by AFID Therapeutics, Inc. is being used by more than 100 pharmaceutical research and development companies around the world, in countries such as China, Japan, India, Germany, France, Switzerland and the UK.

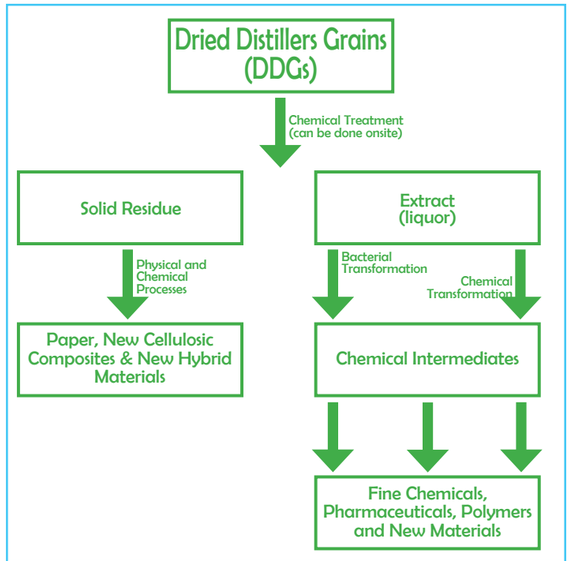

Figure 15: Commercialization streams for converting DDGs into chemicals and materials.

Chemical Intermediaries from Dried Distillers Grains

As Dr. Hollingsworth was creating his chemical platform for pharmaceutical applications, the Michigan ethanol industry expanded from one plant to five, producing 250 million gallons of ethanol and 671,000 metric tons of dried distiller's grains (DDGs). With this influx of DDGs on the market, Dr. Hollingsworth began developing a chemical intermediate platform from DDGs. These chemical intermediates can be used in areas ranging from pharmaceuticals to paints, polymers, coatings and other industrial materials.

Dr. Hollingsworth has created two commercialization streams from DDGs, leading to either fine chemicals, pharmaceuticals, and polymers or leading to paper, new hybrid materials and other cellulosic composite materials.

"As of right now, we can prepare lactic acid, glycolic acid, hydroxybutyric acid and dihydroybutyric acid from DDGs," Hollingsworth said.

Figure 15 shows the commercialization streams Dr. Hollingsworth created which converts Dried Distillers Grains into chemicals and materials.

"The research being conducted by Dr. Hollingsworth focuses on enhancing the uses of corn and DDGs by moving them into markets that are usually very energy intensive, are non-renewable, and have a very large negative environmental impact," added Gerstacker, who also serves on the National Corn Board. "This research moves us one step closer to realizing our long-term vision of having an agricultural-based carbon economy."

ENVIRONMENTALLY FRIENDLY BACTERIAL STRAIN DEVELOPED TO PRODUCE SUCCINIC ACID FROM CORN

As petroleum prices continue to increase, so does our desire to be less dependent on foreign oil. This has led the United States to look for products which provide an alternative to those made from petroleum. In addition to its major use as a motor fuel, petroleum is utilized for many non-fuel uses including the manufacturing of petrochemicals, which accounts for 10 to 15 percent of total petroleum use. As an alternative to these petrochemicals, the sugars and starches derived from plants like corn during the fermentation process, can serve as feedstocks for microorganisms which can be utilized in bio-chemical production. Depending on the strain of microorganism and how it is fermented, microorganisms can produce a wide range of bio-chemicals with the same composition and function as petrochemicals.

"As we look to lessen our dependence on foreign oil and grow our economy here in Michigan, these types of projects continue to be invaluable," said Brian Kreps, CMPM secretary and a corn grower from LaSalle. "It seems that as petroleum dependence changes, we can look to these new technologies."

Prior to the petroleum boom in the 1960's, many chemicals were manufactured using the fermentation process. This process was put aside when the cost of manufacturing petrochemicals became less expensive. Today, there is a growing movement to again produce chemicals from biological processes, primarily using fermentation. Ethanol is one such product that has become very successful, but others, particularly those used as chemicals, are emerging as well.

Significant research and development is underway to bring more bio-chemicals into production — all of which must compete with existing petrochemicals. The main competitive hurdles to breaking into those markets include the need to understand, discover and modify microorganisms to produce the bio-chemicals; the design of cost-effective processes; the availability of sugars, starches and other feedstock; the assurance that products are more environmentally-friendly than their petroleum-based counterparts; and increasing the public's preference for bio-based products. Ultimately, the replacement of petrochemicals with bio-chemicals will shift the type of chemicals used on a day-to-day basis, helping to reduce toxicity and U.S. dependence on foreign oil.

In order to assist Michigan's farmers in understanding the potential benefits of bio-chemical production, and how their crop can play a vital role in the blossoming bio-chemical market, the CMPM partnered with Working Bugs, LLC to conduct succinic acid research. Bio-based succinic acid serves as an important platform chemical for numerous products, including personal care products, environmentally safe solvents, fuel additives, engine coolants and more. The study sought to develop a new, environmentally friendly strain of bacteria to produce succinic acid from corn which could be used in large-scale commercial production.

To accomplish these objectives, Dr. Cory DeMattei, a researcher at Working Bugs, LLC, worked with a newly developed strain of bacteria with altered deoxyribonucleic acid (DNA) in a naturally occurring bacterial strain. Dr. DeMattei hoped to force an optimal balance between high amounts of succinic acid and high growth rates, to create the highest amount of succinic acid possible. From reviewing past research efforts, several potential complications were identified. First, selective markers such as antibiotic-resistance are normally used to determine if the genetic work was performed properly, however, the resistance to antibiotics also poses environmental concerns. Another common issue with other strains developed has been their requirement for cost-prohibitive nutrients to obtain sufficient concentrations of succinic acid. The new strand developed by Working Bugs, LLC through their CMPM-funded research does not present either of these problems, giving their bio-chemical succinic acid a significant market advantage.

To ensure an environmentally stable bacteria was produced, DeMattei used a non-antibiotic system which does not utilize the traditional method of adding selective markers for antibiotic resistance. This innovative, commercial bacteria strain for producing succinic acid was accomplished by removing specific genes in order to divert the organism's use of sugar away from other pathways and towards the production of succinic acid. This process does not produce a genetically modified organism (GMO), as defined in most regulatory agencies, because there is no transgenic recombination (outside genes being introduced) being performed; all the genes utilized originated within the bacterial species. The new strain was brought to full development using numerous lab-scale fermentation runs to bring about maturity in the strain. Working Bugs, LLC now plans to use the final mature strain in scale-up and pilot production. Figure 16 shows the fermentation process as it would apply in a biorefinery, producing both ethanol and succinic acid for use by consumers.

"We are grateful for the work Working Bugs, LLC has done regarding succinic acid and its co-products. The results from this project will not only create another value-added market for Michigan-grown corn, but it will also allow corn farmers and consumers across the state to decrease their dependence on foreign petroleum products, as well as their environmental impact, by using a renewable resource—corn," Kreps said.

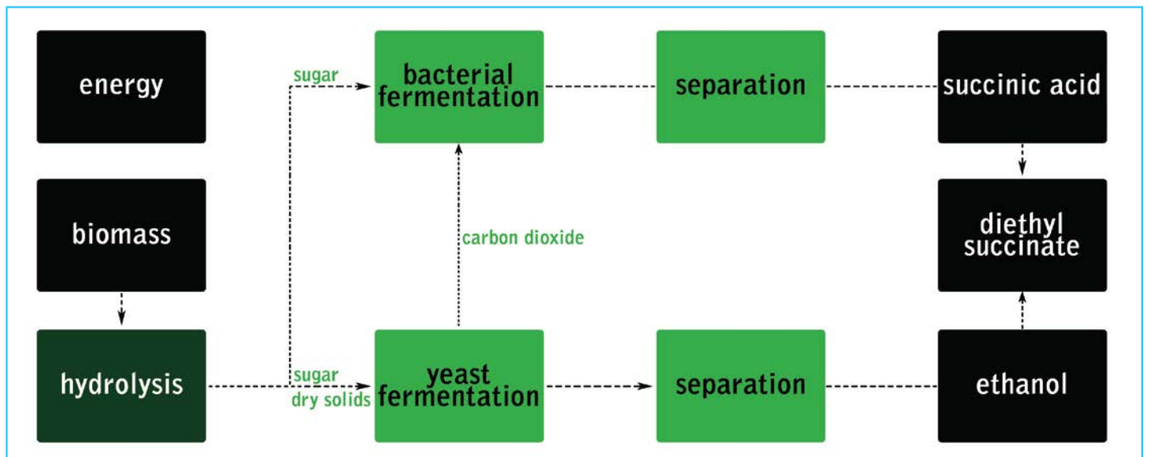

Figure 16: The fermentation process in a biorefinery that is producing both ethanol and succinic acid for use by consumers.

Corn Marketing Program of Michigan
13750 S. Sedona Parkway, Suite 5
Lansing, MI 48906