A Life Cycle Analysis (LCA) Comparison between Conventional and Biotech Sweet Corn

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INTRODUCTION

- With heightened consumer awareness toward environmental impacts of food choices, agricultural producers will need information on how to reduce greenhouse gas (GHG) emissions
- Further, governmental regulations and pressure from marketers such as Wal-Mart on GHG reductions will increase down stream pressure on agricultural producers
- Use of biotechnology traits such as VT Triple PRO™ or those found in Performance Series™ Sweet Corn (**PSSC** for short) to enhance GHG efficiency in agricultural production is a potentially effective way to lower GHG emissions per acre and per unit of output
- Fresh sweet corn provides an interesting case study for use of bio technology traits vs. GHG interactions because of:
  - High reliance on insecticides to combat ear worms and other similar pests (Fig. 1)
  - High incidence of down grading and waste in fresh corn markets due to insect damage
  - **PSSC** provides effective embedded insect control thereby lessening damage and reducing/eliminating the need for insecticide which can lower GHG emissions
- Production data on sweet corn from 7 different test plots have been collected to compare conventional and **PSSC** by variety and location
- This study presents GHG estimates per acre and per ear of marketable corn based on spatial production differences
- GHG emissions or "carbon footprint" is collected from planting to the farm gate

OBJECTIVES

- Estimates of GHG emissions differences (in their carbon equivalent) between conventional sweet corn and **PSSC** across two varieties for test plots in Florida, Georgia, Mississippi, and Wisconsin
- Analysis of three levels of insecticide application regimes
  - **Full** application of extension recommendations (100%) for conventional production (every 2 days after tasseling)
  - 50% of extension recommendations (cutting number of applications in **half** or every 4 days after tasseling)
  - **Zero** insecticide applications
- All other practices including irrigation, field bed preparation, weed control and harvest were identical across varieties and production technology
- Yield was calculated as % of subsample without worm damage multiplied by total ears harvested in the plot and scaled to per acre yields

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Fig. 1 Earworms

Sources for Photos: Left AgMRC (Marketable Cob) and Right Texas A&M (Ear Worm Infested)

DATA

- 2009/10 field test plot results from 7 different test plots, in partnership with Monsanto and university researchers were analyzed
- Mississippi State field preparation and equipment data were used across locations with larger scale equipment used in GA and FL
- All plots were hand harvested and carbon footprinted up to crating the ears in a box
- Varieties were Monsanto's Passion® and Obsession® hybrid varieties that are available both as isolines (**conventional** seed technology) and with **PSSC** technology to capture the seed technology effect across varieties
- Production practices for each area were based on extension recommendations with the exception of different number of insecticide applications
- Treatment differences were compared statistically using PROC GLM in SAS for the two sets of trials:
  - Variety trials: main effect insecticide with sub effects of variety and seed technology (Mississippi, Georgia and Felda, FL – 2 reps)
  - Regional trials: main effect insecticide with sub effect of seed technology (Florida, Georgia and Wisconsin – 4 reps)

PROCEDURES

- A scan level Life Cycle Analyiss (LCA) was implemented to track GHG emissions in their carbon equivalents (C.E.)
  - C.E. estimates GHG emissions of CO_2 and N_2O from input use, emissions from applied N fertilizer and biomass decomposition
  - Using extension budget information an application of insecticide uses 0.09 gal of diesel per acre with a C.E. footprint of 7.01 pounds per gal and 6.44 pounds of C.E. per pint of insecticide
  - Other main inputs include fertilizer, fuel for field work and irrigation, and chemicals applied using C.E factors per unit applied as published in Nalley et al. (2011) using IPCC standards
- Both irrigation use and variation in insecticide application efficiency were model as uncertain parameters yielding uncertain estimates of C.E.

RESULTS

- Figure 2 illustrates how total GHG emissions per acre decline slightly from the **full** to **zero** insecticide treatments

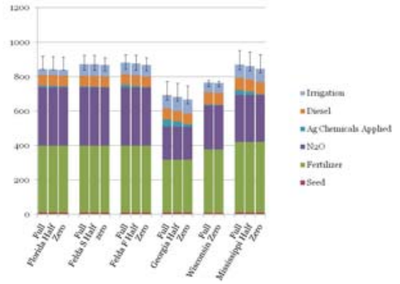

Figure 2. Total GHG Emissions Per Acre By Production Location

- Error bars in Figure 2 were based upon variation in diesel fuel required for the insecticide application and the variation in diesel required for pumping water for wet and dry years
- Analysis of variance and mean yield comparisons for the variety and regional trials, treating location as a random effect, showed significant seed technology and seed technology x variety effects in the variety trials (Top of Table 1 and Table 2). While large and consistent with expectations, only numerical differences were observed in the regional trial (Bottom of Table 1 and Table 3)
- Analysis of variance and mean C.E. per ear comparisons for the variety trials showed statistically significant insecticide, seed technology and insecticide x seed technology effects in the variety trials (Top of Table 4) but LS mean comparisons were not statistically significant at the 10% level (Table 5). Regional trial differences were large and consistent but not statistically significant (Bottom of Table 4 and Table 6)

CONCLUSIONS

- Primarily on the basis of increased marketable yields **PSSC** outperforms their conventional counterparts. Pending seed technology cost, results suggest that producers would opt for **PSSC** given higher yield with significantly lower insecticide use
- C.E. per acre differences are relatively small for reductions in insecticide use when compared to emissions from other sources and the simulated variation in fuel use
- Marketable yield differences between isoline and **PSSC** technology are remarkable and lead to sizable reduction in downgrading and ears left in the field due to insect damage
- While not statistically significant across region and production environment, two to threefold reductions in C.E. per ear GHG numbers are expected to aid consumer acceptance of vegetables with biotechnology traits
- Collection of additional data at the larger field level will allow making producer recommendations under alternative seed cost and marketable ear price scenarios
- Given the robustness of the seed technology results across location, sweet corn production may move to locations where pest pressure previously made sweet corn impractical

Table 1. Analysis of Variance Results on Marketable Ear Yield with Location as Random Effect for Variety Trials at Mississippi, Felda, FL and Georgia as well as Regional Trials at Florida, Georgia and Wisconsin.

Trials	Effect	Degrees of Freedom Num.	Degrees of Freedom Denom.	F-value	p-value
Variety Trials	Insecticide	2	6	2.12	0.201
	Variety	1	3	0.64	0.482
	Insecticide x Variety	2	6	0.28	0.768
	Seed Technology	1	3	20.29	**0.020**
	Insecticide x Seed Technology	2	6	2.52	0.161
	Variety x Seed Technology	1	3	9.49	**0.054**
	Insecticide x Variety x Seed Technology	2	6	2.86	0.134
Regional Trials	Insecticide	2	3	0.11	0.450
	Seed Technology	1	1.99	4.32	0.174
	Insecticide x Seed Technology	2	3	3.15	0.183

Table 2. Mean Marketable Ear Yield Comparisons by Variety and Seed Technology for Variety Trials.

	Seed Technology			
Variety	N	Isoline	N	**PSSC**
Obsession®	24	10,381	24	17,878
Passion®	24	8,734	24	18,657

Notes: $LSD_{0.10}$ = 6,436– to compare isoline with **PSSC** for a particular variety
$LSD_{0.10}$ = 4,727 – to compare isoline or **PSSC** of one variety with isoline or **PSSC** of another variety.

Table 3. Mean Marketable Ear Yields by Insecticide and Seed Technology for Regional Trials.

	Seed Technology			
Insecticide	N	Isoline	N	**PSSC**
Full	12	11.305	12	19,772
Half	8	6,192[a]	8	14,174
Zero	12	4,437[b]	12	20,664

Notes: The lack of half insecticide treatments from Wisconsin partially explains the drop in yield for that treatment under the PS column in the table. Note further, that using no insecticides at all lead to higher yields than when the crop was sprayed with insecticide at full frequency. Excessive plot traffic with spraying equipment can lead to soil compaction and plant damage and are offered as an explanation for those results

[a] Three of the eight yield observations had zero yield (Georgia)

[b] Eight of the twelve yield observations had zero yield (Georgia and Wisconsin)

Table 4. Analysis of Variance Results on C.E. per Marketable Ear with Location as Random Effect for Variety Trials at Mississippi, Felda, FL and Georgia as well as Regional Trials at Florida, Georgia and Wisconsin.

Trials	Effect	Degrees of Freedom Num.	Degrees of Freedom Denom.	F-value	p-value
Variety	Insecticide	2	6.41	4.07	**0.072**
	Variety	1	3.05	0.84	0.676
	Insecticide x Variety	2	5.95	1.06	0.403
	Seed Technology	1	3.04	5.71	**0.096**
	Insecticide x Seed Technology	2	6.19	3.77	**0.085**
	Variety x Seed Technology	1	2.98	3.31	0.167
	Insecticide x Variety x Seed Technology	2	5.05	1.14	0.390
Regional	Insecticide	2	0.02	16.28	0.932
	Seed Technology	1	0.81	3.98	0.339
	Insecticide x Seed Technology	2	0.98	0.49	0.712

Table 5. Mean C.E. per Marketable Ear Comparisons by Insecticide Level and Seed Technology for Variety Trials.

	Seed Technology			
Insecticide	N	Isoline	N	**PSSC**
Full	16	0.161	16	0.048
Half	16	0.134	16	0.054
Zero	12	0.255	16	0.046

Notes: $LSD_{0.10}$ = 0.255 – to compare isoline with **PSSC** at an insecticide level for comparisons with same N
$LSD_{0.10}$ = 0.276 – to compare isoline with **PSSC** at an insecticide level for comparisons with different N
$LSD_{0.10}$ = 0.191 – to compare isoline with **PSSC** across insecticide levels for comparisons with same N
$LSD_{0.10}$ = 0.206 – to compare isoline with **PSSC** across insecticide levels for comparisons with different N

Table 6. C.E. per Marketable Ear Means by Insecticide Level and Seed Technology for Regional Trials.

	Seed Technology			
Insecticide	N	Isoline	N	**PSSC**
Full	12	0.112	12	0.044
Half	5	0.187	8	0.062
Zero	4	0.070	12	0.040