Integrating Winter Annual Cereal Rye or Triticale into a Corn forage Biofuel Production System

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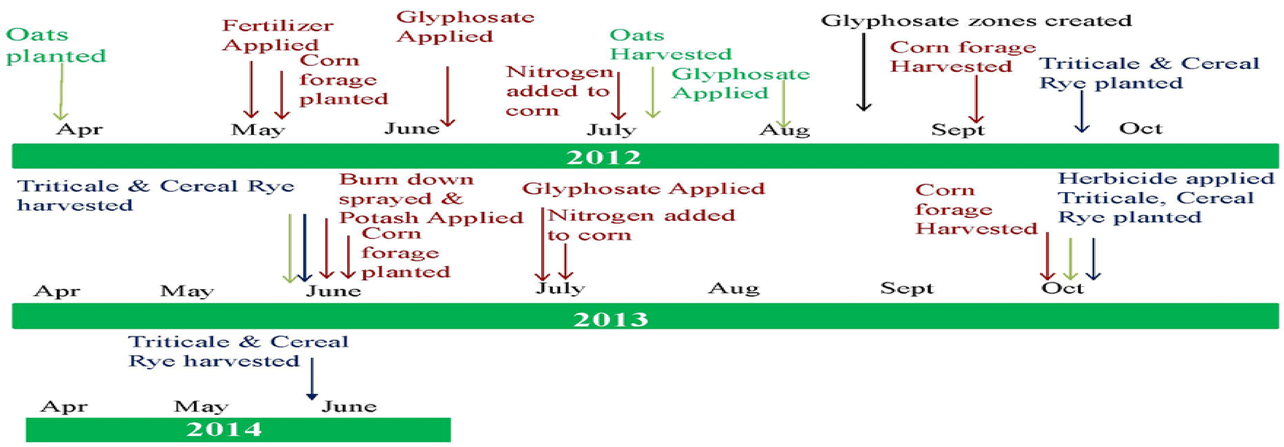
Introduction: Integrating cover crops into the corn (*Zea mays* L.) forage-production system could enhance growers' profitability and improve ecosystem services. Field plots were established at two locations in Michigan during 2012-14 to evaluate ethanol production, estimate carbon and energy balance, and the economics of corn forage plus cover crop, cropping systems. In the 2012-13 crop cycle, the cereal rye (*Secale cereale* L.), and triticale (*Triticale hexaploide* Lart.), cover crops increased cropping system biomass yield by 44%, and total ethanol yield by 28% relative to the no-cover control. During the 2012-13 cycle, cover crops provided sufficient biomass to result in a profitable harvest as a biofuel feedstock. However, following a harsh winter, such as that experienced in the 2013-14 cycle, cover crop yield was compromised to the point that harvest was not economically justified. Incorporating cover crops into a corn forage cropping system increased total biomass and potential biofuel yield and generated a very favorable net ecosystem carbon and energy balance.

Objectives: To evaluate the biomass and ethanol yield of a corn forage plus winter annual cover crop, double-crop system. Field plots established were used to evaluate ethanol production, estimate carbon and energy balance, and the economics of corn forage plus cover crop, cropping systems.

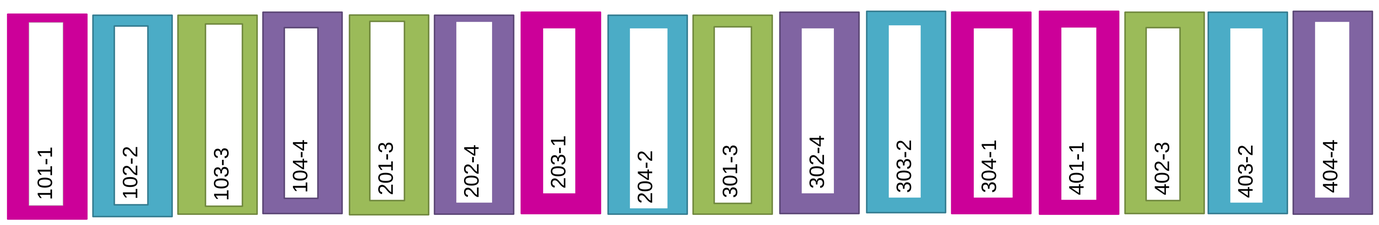
Materials and Methods:

- Four treatments were evaluated at two locations (E. Lansing and MSU/KBS) using a randomized complete block design with four replications.
- In 2012 and 2013 silage corn was no-till planted.
- All treatments were managed using the same fertility, weed, and pest control practices.
- Corn was harvested at the recommended stage for corn silage.
- Cereal rye, and triticale were no-till drilled in the corn silage stubble after harvest.
- Following spring rye harvest, glyphosate herbicide was used to control rye regrowth.

Timeline for field activities, 2012 – 2014 growing cycles



Randomized complete block design field plot layout for the four cropping systems



Corn silage, cover crop, and total system ethanol yield for the 2012-13 and 2013-14 crop cycles as affected by cover crop species and growing cycle (P=0.05)

Crop System	2012-13			2013-14		
	Corn	Cover	Total	Corn	Cover	Total
	dm Mg hectare^{-1}					
Corn forage + no cover	8.0a†	0.7d	8.7c	19.5a	0.1c	19.8a
Corn forage + cereal rye	8.3a	6.5b	14.8b	17.8a	1.6a	19.4a
Corn forage + triticale	8.5a	8.1a	16.6a	17.5a	1.2b	18.8a

Crop System	2012-13		2013-14	
	Corn	Cover	Corn	Cover
	Liter ethanol Mg^{-1}			
Corn forage + no cover	289.6a†	161.5a	284.6a	130.2b
Corn forage + cereal rye	274.1a	138.5a	267.0b	194.0a
Corn forage + triticale	285.8a	156.0a	287.1a	208.7a

Crop System	2012-13			2013-14		
	Corn	Cover	Total	Corn	Cover	Total
	Liter ethanol hectare^{-1}					
Corn forage + no cover	2385.3a†	113.2c	2497.5c	5584.3a	22.44c	5603.0a
Corn forage + cereal rye	2301.0a	893.3b	3199.0b	4705.0a	312.4a	5013.7a
Corn forage + triticale	2488.1a	1276.8a	3769.6a	4864.0a	249.7b	5116.6a

Net cropping system carbon balance, energy balance, and revenue return to land and management for the 2012-13 and 2013-14 crop cycles as affected by cover crop species. Data are averaged across the KBS and E. Lansing locations

Crop System	2012-13			2013-14		
	Corn	Cover	Total	Corn	Cover	Total
	Carbon balance (sequestration) CO_2 eq kg ha^{-1}					
Corn forage + no cover	2954a	163c†	3117c	8897a	-12c	8885a
Corn forage + cereal rye	2831a	1585b	4416b	7344a	383a	7727a
Corn forage + triticale	3148a	2295a	5443a	7594a	260b	7854a
	Energy balance MJ ha^{-1}					
Corn forage + no cover	48197a	1632c	49829c	123342a	-496b	122846a
Corn forage + cereal rye	46269a	15490b	61760b	102654a	1834a	104488a
Corn forage + triticale	50658a	24483a	75141a	106451a	360b	106811a
	Net return to land and management $ ha^{-1}					
Corn forage + no cover	-60a	-151b†	-211b	1132a	-186a	946a
Corn forage + cereal rye	-44a	103a	59a	937a	-220b	717a
Corn forage + triticale	-22a	145a	122a	916a	-316c	600a

Results and Conclusions:

- Incorporating cover crops into a corn forage cropping system improved ecosystem services while increasing total biomass and potential biofuel yield.
- This experiment demonstrated that a corn forage plus winter annual cover crop, cropping system was plausible under growing conditions associated with the U.S. Great Lakes Region.
- The inclusion of the winter annual cover crop significantly de-risked the cropping system with regard to total biomass and ethanol yield.
- In the 2012-13 crop cycle, the cereal rye and triticale cover crops increased cropping system biomass yield by 44% and total ethanol yield by 28% relative to the no-cover control.
- The corn forage biomass had higher conversion efficiency to ethanol relative to the cover crops because of the presence of grain component in the corn forage biomass.
- A corn forage plus cover crop bioenergy cropping system generated a very favorable net ecosystem carbon balance and also a very favorable net energy balance.
- In a typical Michigan winter-spring cycle, such as that experienced in 2012-13, cover crops provided sufficient biomass to result in a profitable harvest as a biofuel feedstock.
- However, following a harsh winter, such as that experienced in the 2013-14 cycle, cover crop yield was compromised to the point that harvest was not economically justified.

Acknowledgements

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