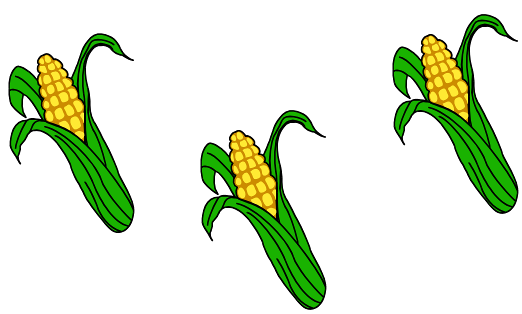
PROCEEDINGS:

CROP CONGRESS
AT
MINER INSTITUTE



February 1, 2017

The farmer-driven Northern New York Agricultural Development Program provides small grants for on-farm research and technical assistance projects in Clinton, Essex, Franklin, Jefferson, Lewis and St. Lawrence counties. More than 100 regional farmers serve on the Program committee that identifies and prioritizes projects for attention. Funding for the Northern New York Agricultural Development Program is supported by the New York State Senate and administered by the New York State Department of Agriculture and Markets. Project results are available online at www.nnyagdev.org, by RSS feed, and by text. To receive email or text updates please email your email or cellphone contact information to karalynn@gisco.net with NNYADP Updates in the Subject Line.

Today's program includes updates on Northern New York Agricultural Development Program-funded projects evaluating ways to manage corn rootworm and western bean cutworm, tips for growing BMR dwarf brachytic forage sorghum under Northern New York conditions, and a tile drainage research update. The 2017 Crop Congress in Canton also includes an update on the field trial of late summer-planted oats as a forage option.

Project leaders receiving funding from the farmer-driven Northern New York Agricultural Development Program in 2016 included Cornell University and State University of New York faculty, and personnel with Cornell Cooperative Extension, the Cornell Willsboro Research Farm, Willsboro, NY; W. H. Miner Agricultural Research Institute, Chazy, NY; Quality Milk Production Services, Canton, NY; and Uihlein Maple Research Forest, Lake Placid, NY.

Crop Congress at Miner Institute

Wednesday, February 1, 2017

BERC Auditorium, 586 Ridge Road, Chazy, NY

10:00 AM	**Dr. Elson Shields**, "Managing Corn Rootworm and update on alfalfa snout beetle control"
11:00 AM	**Mike Hunter**, "Managing Western Bean Cutworm with Bt's: Reality check"
12:00 PM	**Lunch** available for $5.00
1:00 PM	**Dr. Quirine Ketterings,** "Double cropping economics"
2:00 PM	**Dr. Eric Young**, "Research updates"
2:30 PM	**Laura Klaiber**, "Tile drainage impacts on phosphorus losses"
3:00 PM	Adjourn

Corn Rootworm: Today, Tomorrow, Forever

Elson Shields, Dept of Entomology
Cornell University, Ithaca

CRW Resistance to BT: Current Status

Deciphering GM Corn Technology

Source of GMO-RW Insect events:

1) YieldGard – Rootworm (Monsanto) (Cry3Bb1)
2) Syngenta – Rootworm (mCry3A, eCry3.1Ab)
3) Herculex – Rootworm (Dow) (Cry 34/35)
4) SmartStax – Rootworm (Cry3Bb1 + Cry 34/35)
5) AcreMax - XTreme (mCry3A + Cry 34/35)

April 2016
Bulletin posted at www.msuent.com

Handy Bt Trait Table

With questions or corrections, contact:
Chris DiFonzo, Field Crops Entomologist
Michigan State University, East Lansing, MI

Table 1: Bt corn 'events' (transformations of one or more genes) and their Trade Names

Trade name for trait	Event	Protein(s) expressed	Insect Target or *Herbicide Activity*
Agrisure CB/LL	Bt11	Cry1Ab + *PAT*	corn borer + *glufosinate tolerance*
Agrisure Duracade	5307	eCry3.1Ab	rootworm
Agrisure GT	GA21	*EPSPS*	*glyphosate tolerance*
Agrisure RW	MIR604	mCry3A	rootworm
Agrisure Viptera	MIR162	Vip3A	broad lep control (but not corn borer)
Herculex 1 or CB	TC1507	Cry1Fa2 + *PAT*	corn borer + *glufosinate tolerance*
Herculex RW	DAS-59122-7	Cry34Ab1/Cry35Ab1 + *PAT*	rootworm + *glufosinate tolerance*
Roundup Ready 2	NK603	*EPSPS*	*glyphosate tolerance*
YieldGard Corn Borer	MON810	Cry1Ab	corn borer
Yieldgard Rootworm	MON863	Cry3Bb1	rootworm
Yieldgard VT Pro	MON89034	Cry1A.105 + Cry2Ab2	broader lep control
YieldGard VT Rootworm RR	MON88017	Cry3Bb1 + *EPSPS*	rootworm + *glyphosate tolerance*

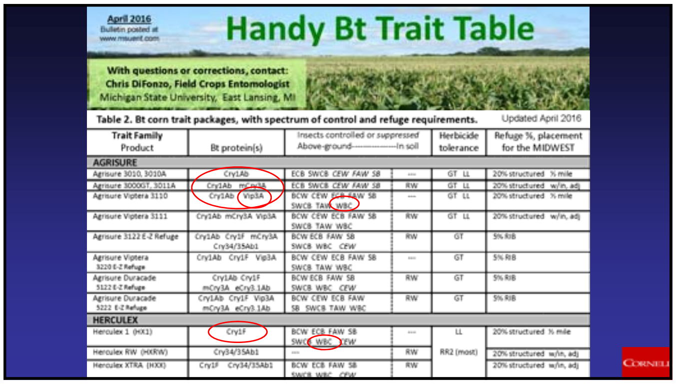

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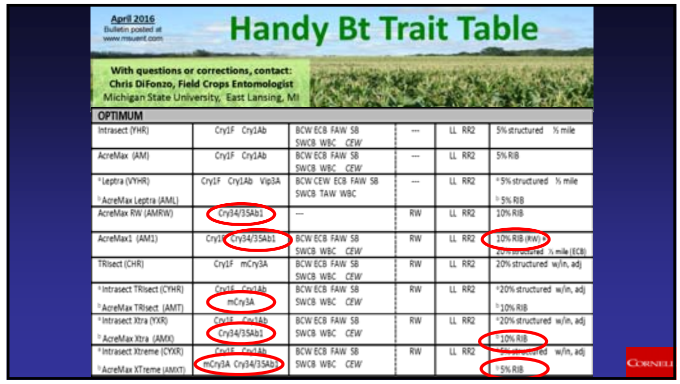
Table 2. Bt corn trait packages, with spectrum of control and refuge requirements.
Updated April 2016
AGRISURE
HERCULEX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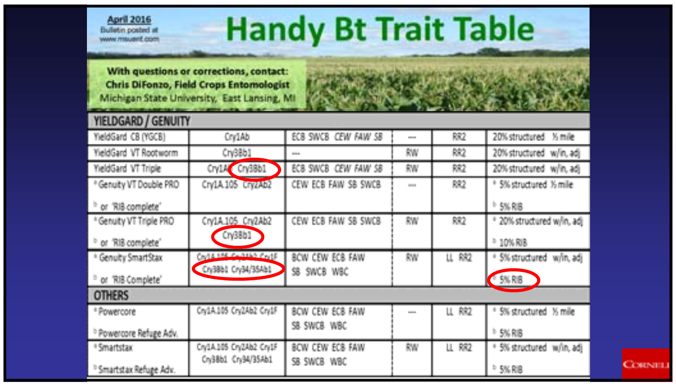
OPTIMUM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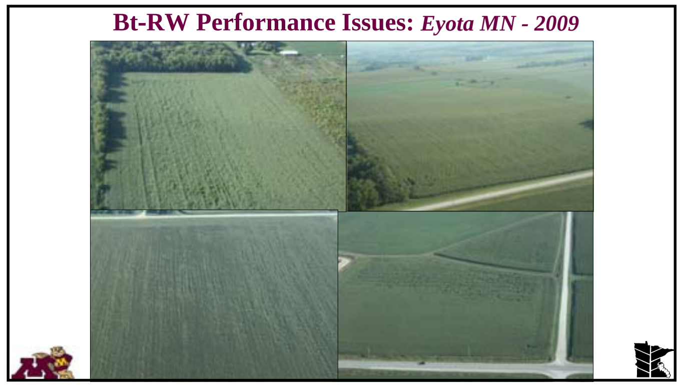
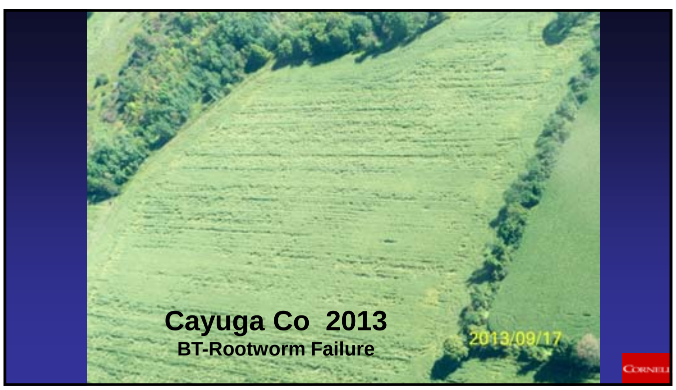
YIELDGARD / GENUITY
OTHERS


Bt-RW Performance Issues: Eyota MN - 2009


Cayuga Co 2013
BT-Rootworm Failure
2013/09/17


Smart Stak
Cry 3Bb1
2013/09/17

2016 Cry 3Bb1 Failure

Resistance Status of Each Event

Cry-3Bb1 (Monsanto YieldGard)

Widespread reported failure since before 2009.

Also in the "Rotation Resistant" population in Illinois.

Resistance Inheritance is Recessive

Reported in Nebraska, Iowa, S. Dakota, Minn. Wisc, Illinois, Michigan, NY

Resistance Status of Each Event

*m*Cry3A, *e*Cry3.1Ab (Syngenta)

High Potential of Cross-Resistance with Cry 3Bb1 reported from lab studies.

Multiple control failures in Nebraska.

Three *m*Cry3A fields with control failures in central Pa. in 2014

Resistance Status of Each Event

Cry 34/35 (Dow Herculex)

First suspected widespread failure in 2013 in Northwest Texas (Irrigated corn) and fields with poor control in SE Minnesota.

Laboratory studies report the inheritance of this resistance is "additive dominant". Rs = survival of 88%

New Technology?

(to save us from ourselves)

Monsanto: RNA*i* (2020?)

Northeast is a few years behind the corn belt for new technology.

Dupont: Insecticidal protein from non-BT bacteria. (a decade?)

Strategies to Preserve the Technology

Fields with Control Problems

ROTATE! ROTATE! ROTATE!

Plant a Different Toxin with a 10% refuge. (also in surrounding fields)

DO NOT PLANT a Variety with a 5% refuge, & only 1 toxin working.

Do Not Layer a Soil Insecticide over a failing BT event

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OPTIMUM					
Intrasect (YHR)	Cry1F Cry1Ab	BCW ECB FAW SB SWCB WBC *CEW*	---	LL RR2	5% structured ½ mile
AcreMax (AM)	Cry1F Cry1Ab	BCW ECB FAW SB SWCB WBC *CEW*	---	LL RR2	5% RIB
[a] Leptra (VYHR) [b] AcreMax Leptra (AML)	Cry1F Cry1Ab Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	---	LL RR2	[a] 5% structured ½ mile [b] 5% RIB
AcreMax RW (AMRW)	Cry34/35Ab1	---	RW	LL RR2	10% RIB
AcreMax1 (AM1)	Cry1F Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	10% RIB (RW) + 20% structured ½ mile (ECB)
TRIsect (CHR)	Cry1F mCry3A	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	20% structured w/in, adj
[a] Intrasect TRIsect (CYHR) [b] AcreMax TRIsect (AMT)	Cry1F Cry1Ab mCry3A	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	[a] 20% structured w/in, adj [b] 10% RIB
[a] Intrasect Xtra (YXR) [b] AcreMax Xtra (AMX)	Cry1F Cry1Ab Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	[a] 20% structured w/in, adj [b] 10% RIB
[a] Intrasect Xtreme (CYXR) [b] AcreMax XTreme (AMXT)	Cry1F Cry1Ab mCry3A Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	LL RR2	[a] 5% structured w/in, adj [b] 5% RIB

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Do Not Layer a Soil Insecticide over a failing BT event

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Michigan State University, East Lansing, MI

Table 2. Bt corn trait packages, with spectrum of control and refuge requirements. Updated April 2016

Trait Family Product	Bt protein(s)	Insects controlled or suppressed Above-ground	In soil	Herbicide tolerance	Refuge %, placement for the MIDWEST
AGRISURE					
Agrisure 3010, 3010A	Cry1Ab	ECB SWCB *CEW FAW SB*	---	GT LL	20% structured ½ mile
Agrisure 3000GT, 3011A	Cry1Ab mCry3A	ECB SWCB *CEW FAW SB*	RW	GT LL	20% structured w/in, adj
Agrisure Viptera 3110	Cry1Ab Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	---	GT LL	20% structured ½ mile
Agrisure Viptera 3111	Cry1Ab mCry3A Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	RW	GT LL	20% structured w/in, adj
Agrisure 3122 E-Z Refuge	Cry1Ab Cry1F mCry3A Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW	GT	5% RIB
Agrisure Viptera 3220 E-Z Refuge	Cry1Ab Cry1F Vip3A	BCW CEW ECB FAW SB SWCB TAW WBC	---	GT	5% RIB
Agrisure Duracade 5122 E-Z Refuge	Cry1Ab Cry1F mCry3A eCry3.1Ab	BCW ECB FAW SB SWCB WBC *CEW*	RW	GT	5% RIB
Agrisure Duracade 5222 E-Z Refuge	Cry1Ab Cry1F Vip3A mCry3A eCry3.1Ab	BCW CEW ECB FAW SB SWCB TAW WBC	RW	GT	5% RIB
HERCULEX					
Herculex 1 (HX1)	Cry1F	BCW ECB FAW SB SWCB WBC *CEW*	---	LL	20% structured ½ mile
Herculex RW (HXRW)	Cry34/35Ab1	---	RW	RR2 (most)	20% structured w/in, adj
Herculex XTRA (HXX)	Cry1F Cry34/35Ab1	BCW ECB FAW SB SWCB WBC *CEW*	RW		20% structured w/in, adj

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YIELDGARD / GENUITY					
YieldGard CB (YGCB)	Cry1Ab	ECB SWCB *CEW FAW SB*	---	RR2	20% structured ½ mile
YieldGard VT Rootworm	Cry3Bb1	---	RW	RR2	20% structured w/in, adj
YieldGard VT Triple	Cry1Ab Cry3Bb1	ECB SWCB *CEW FAW SB*	RW	RR2	20% structured w/in, adj
[a] Genuity VT Double PRO [b] or 'RIB complete'	Cry1A.105 Cry2Ab2	CEW ECB FAW SB SWCB	---	RR2	[a] 5% structured ½ mile [b] 5% RIB
[a] Genuity VT Triple PRO [b] or 'RIB complete'	Cry1A.105 Cry2Ab2 Cry3Bb1	CEW ECB FAW SB SWCB	RW	RR2	[a] 20% structured w/in, adj [b] 10% RIB
[a] Genuity SmartStax [b] or 'RIB Complete'	Cry1A.105 Cry2Ab2 Cry1F Cry3Bb1 Cry34/35Ab1	BCW CEW ECB FAW SB SWCB WBC	RW	LL RR2	[a] 5% structured w/in, adj [b] 5% RIB
OTHERS					
[a] Powercore [b] Powercore Refuge Adv.	Cry1A.105 Cry2Ab2 Cry1F	BCW CEW ECB FAW SB SWCB WBC	---	LL RR2	[a] 5% structured ½ mile [b] 5% RIB
[a] Smartstax [b] Smartstax Refuge Adv.	Cry1A.105 Cry2Ab2 Cry1F Cry3Bb1 Cry34/35Ab1	BCW CEW ECB FAW SB SWCB WBC	RW	LL RR2	[a] 5% structured w/in, adj [b] 5% RIB

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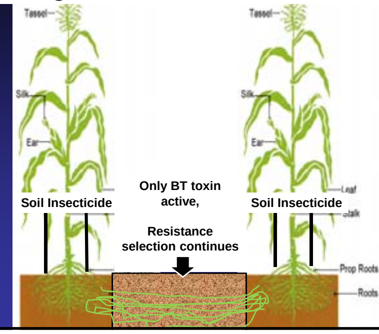
DO NOT PLANT a Variety with a 5% refuge, & only 1 toxin working.

Do Not Layer a Soil Insecticide over a failing BT event

Layering Soil Insecticide Over a BT Toxin



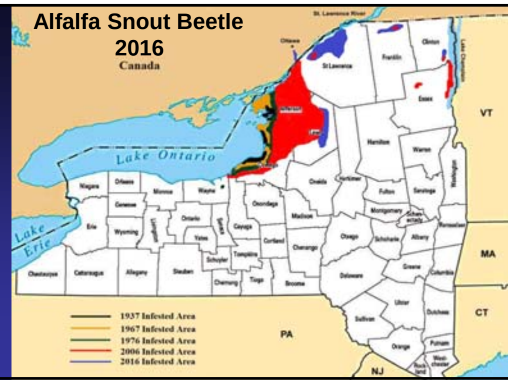
Questions?

Comments?

Discussion?

Alfalfa Snout Beetle

New York's Very Own Special Little Insect Problem



Do I have this insect?

Winter kill

Stand loss in the high spots of the field

Adult insects moving

Yellow plants in the fall

Presence of white legless larvae (fall)

Do I have this insect?

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Stand loss in the high spots of the field

Adult insects moving in early Spring

Yellow plants in the fall

Presence of white legless larvae (fall)

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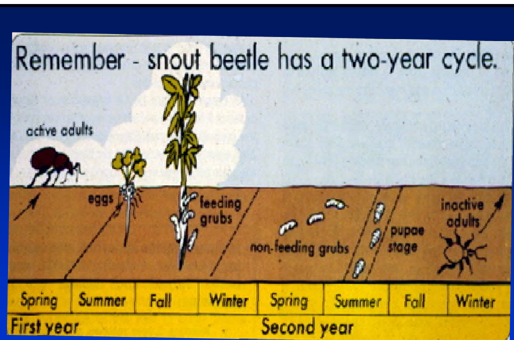
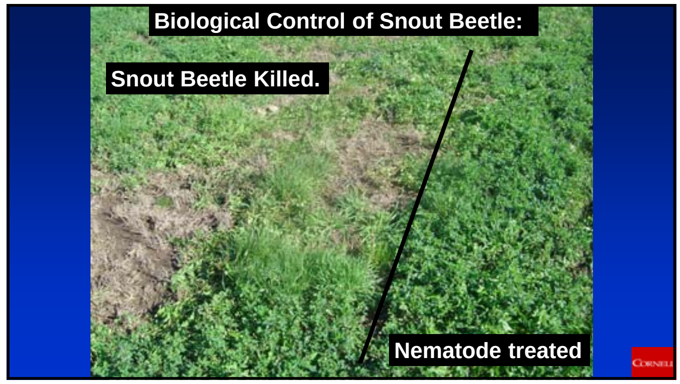


How do I Control this Insect?

1) Insecticides do not work!
2) Short alfalfa rotations – 3 years
   - Seeding year + 2 production years
3) Bio-Control Nematodes
   - Single application – Multiple year control
4) Resistant Alfalfa
   - Requires the ASB population reduced first



Cost of Biocontrol nematodes

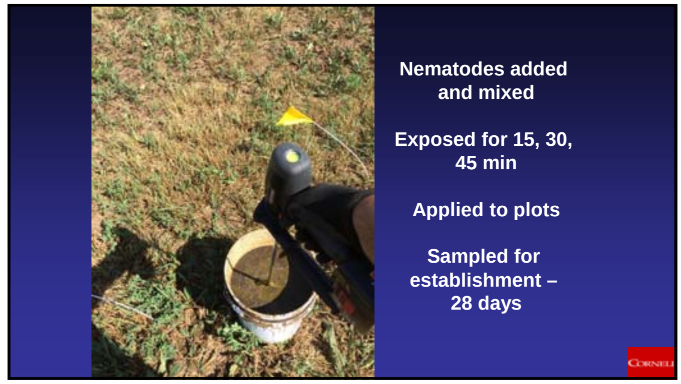
Shields' Lab – Cornell: $26/acre
(+ application costs)

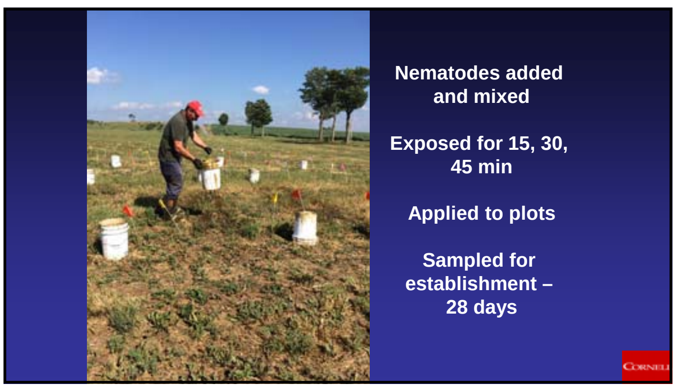
DeBeer Spraying (Mary): ?
Moira, NY

Rear Your Own: $15/ acre + your labor
(+ application costs)

How are Biocontrol Nematodes applied?

Commercial Pesticide Sprayer
- Needs cleaning
- All screens and filters removed
- Nozzles
  - Removed
  - Fertilizer Stream nozzles
  - Nitrogen Drop Tubes


Nematodes added and mixed
Exposed for 15, 30, 45 min
Applied to plots
Sampled for establishment – 28 days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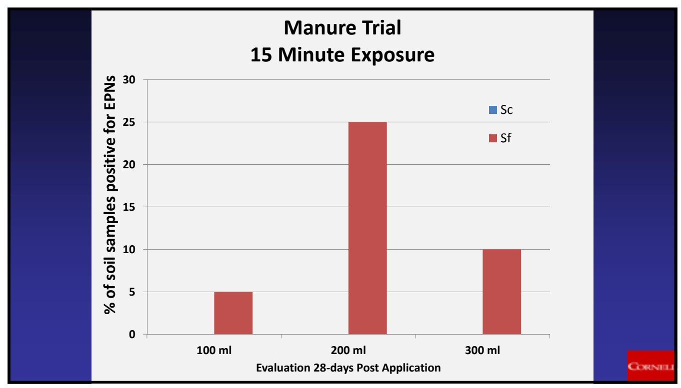
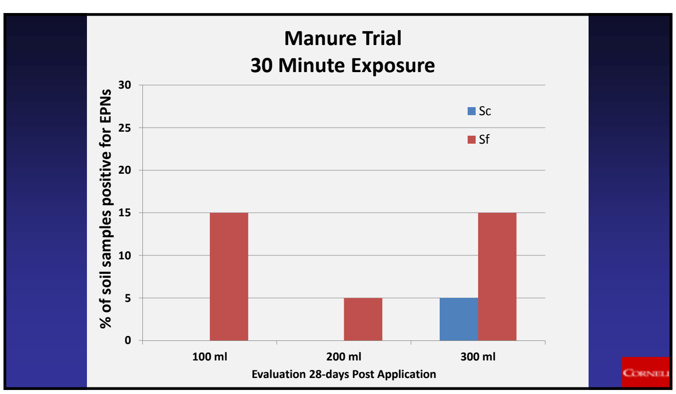
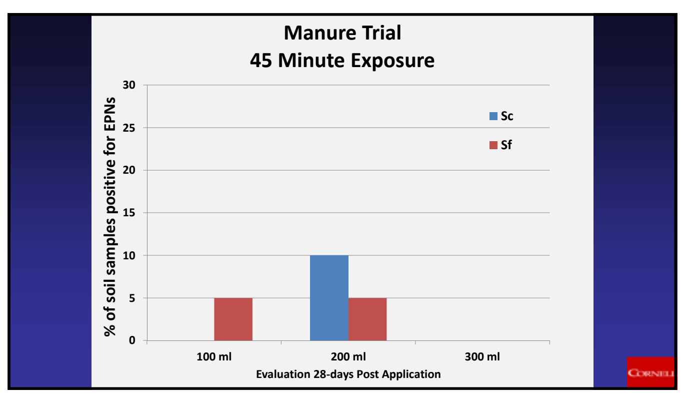

Manure Trial
15 Minute Exposure
% of soil samples positive for EPNs
0
5
10
15
20
25
30
Sc
Sf
100 ml
200 ml
300 ml
Evaluation 28-days Post Application


Manure Trial
30 Minute Exposure
% of soil samples positive for EPNs
0
5
10
15
20
25
30
Sc
Sf
100 ml
200 ml
300 ml
Evaluation 28-days Post Application


Manure Trial
45 Minute Exposure
% of soil samples positive for EPNs
0
5
10
15
20
25
30
Sc
Sf
100 ml
200 ml
300 ml
Evaluation 28-days Post Application

Program Progress

2017: 2,600 acres treated
1,400 acres – Cornell reared
(applied by producers or comm applicators)
1,200 acres – DeBeer Spraying
(Reared and applied)

2016: 4,300 acres treated

Total Treated: 14,000- 16,000 acres

Summary – Biocontrol Nematodes

Persists multiple years in alfalfa and across crop rotations

Responds to insect invasion and preserves alfalfa stands

Single application (for many years) : $15-$26/ acre

Farmers report: ASB populations are declining on their farms when multiple fields are treated.

Contacts

Cornell:
Mike Hunter: 315 788-8602, meh27@cornell.edu
Kitty O'Neil: 315 854-1218, kao32@cornell.edu
Shields' Lab (Tony Testa): 607 591-1493
at28@cornell.edu
DeBeer Spraying:
Ron: 518 353-1891
Mary: 518 812-8565

We Thank

Cooperators: 55 NNY Participating Farmers

NYFVI
NEW YORK FARM VIABILITY INSTITUTE, INC.

Managing Western Bean Cutworm with Bt's-Reality Check

Mike Hunter
Regional Field Crops Specialist
Cornell University Cooperative Extension
Northern New York Regional Ag Team

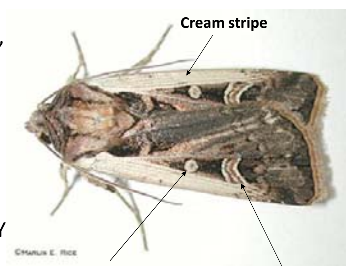
Miner Institute Crop Congress
February 1, 2017

Today's discussion

- What is the Western Bean Cutworm?
- Why should we care?
- What did we do?
- Why we did it?
- What did we learn?

Western Bean Cutworm

- Pest of field corn, sweet corn and dry beans
- Found in NYS in 2009
- Migratory and overwintering populations in NY



Egg development takes 5-7 days

white → purple

Western Bean Cutworm Larvae

Photo credit: M. Stanyard, CCE NWNY

Larval Feeding

Photo: M. Hunter, CCE of NNY

- Early instars: pollen and silks
- Later instars: kernels in ear tip
- Multiple larvae per ear
  - Not cannibalistic
  - Up to 20/plant recorded
- One larva/plant = 3.7 bu/acre loss
- Severe feeding may result in 50-60% damage of an ear's kernels

Source: J. Keith Waldron, NYS IPM

Indirect Damage

- Ear rot & fungal diseases
- Increase with humidity
- Potential mycotoxins…

Dow AgroScience

WBC Monitoring

Use moth flights to determine when to scout for larva

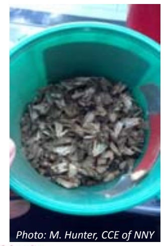


Photo: M. Hunter, CCE of NNY

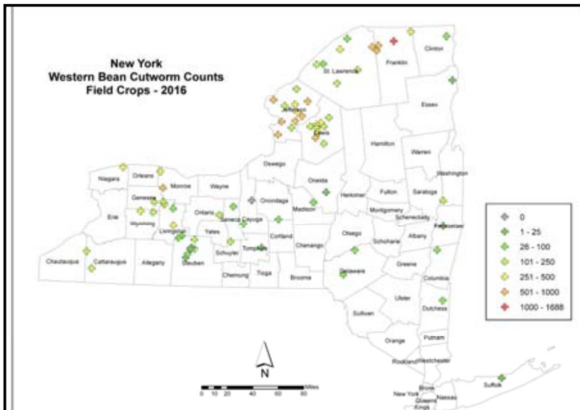
Photo Courtesy T. Baute, OMAFRA

New York Western Bean Cutworm 2010 – 2016 Collection Data Summary*

	2010	2011	2012	2013	2014	2015	2016
No. Counties	29	37	44	39	41	39	40
No. Traps	54	67	88	89	96	91	101
Avg. No. WBC / Trap	13	23	42	66	117	266	193
Range in Totals	0 - 99	0 - 165	0 - 344	0 – 853	0 – 1019	0 – 1688	0 – 1662
Peak Flight	2-Aug	2-Aug	25-Jul	21-28-Jul	3-Aug	2-Aug	31-Jul

*Data compiled from WBC trap catch information provided by field corn, sweet corn and dry bean monitoring networks across NY.

Slide courtesy of Ken Wise, NYS IPM



Slide courtesy of Ken Wise, NYS IPM

What did we do?

Planted 4 Large Bt Corn Trials in NNY

- Monitored sites with WBC trap
- Compared Bt traits for control of WBC
  - Cry 1F
  - Vip 3A
  - Cry 1F + Vip 3A
  - Cry1A.105 + 2Ab2
- Identified ear molds and rot on WBC damaged ears
- Corn samples from each treatment had mycotoxin panel screening

Why did we do this?

Increasing number of reports of Herculex and Smartstax Bt corn in Ontario, Michigan, Ohio and Indiana failing to adequately control Western Bean Cutworm

Figure 1. WBC feeding damage and mycelial growth on SmartStax corn hybrid, 2013. J. Smith

Figure 3. WBC feeding on Cry 1F corn, Thamesville, ON. Sep 12, 2014. J. Smith

Cornell University Cooperative Extension
Northern New York Regional Ag Team

2015 Highest WBC Trap Locations

County	Trap Location	WBC total Trap Count
Jefferson	Rutland	1688
Franklin	Malone	1463
Lewis	Turin	1243
Lewis	Croghan	1147
Erie	Eden	959

…And 9 of the top 10 highest traps were sites in NNY

31 traps in NNY averaged 534 WBC moths

Photo: M. Hunter, CCE of NNY

Cornell University Cooperative Extension
Northern New York Regional Ag Team

2016 Highest WBC Trap Locations

County	Trap Location	WBC total Trap Count
Franklin	Malone	1662
Jefferson	Hounsfield	947
Jefferson	Clayton	815
Franklin	Nicholville	756
Lewis	Martinsburg	657

…And 9 of the top 10 highest traps were sites in NNY

32 traps in NNY averaged 388 WBC moths

Photo: M. Hunter, CCE of NNY

Cornell University Cooperative Extension
Northern New York Regional Ag Team

Chateaugay site in Franklin County

Type of Bt(s)	WBC Damaged Ears %
Cry 1F + Vip 3A	0 a
Vip 3A	0 a
Cry 1F	1.75 a
Cry 1A.05 + 2Ab2	1.25 a

WBC Trap Count: 313
Planted May 11, 2016
Not much damage and was earliest planted field
WBC moths don't like to lay eggs on tasseled corn

Photo: M. Hunter, CCE of NNY

Cornell University Cooperative Extension
Northern New York Regional Ag Team

Copenhagen site in Jefferson County

Type of Bt(s)	WBC Damaged Ears %
Cry 1F + Vip 3A	0 b
Vip 3A	0 b
Cry 1F	21.5 a
Cry 1A.05 + 2Ab2	13.5 a

WBC Trap Count: 553
Planted May 17, 2016

Photo: M. Hunter, CCE of NNY

Cornell University Cooperative Extension
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Turin site in Lewis County

Type of Bt(s)	WBC Damaged Ears %
Cry 1F + Vip 3A	0 b
Vip 3A	0 b
Cry 1F	18.75 a
Cry 1A.05 + 2Ab2	18.00 a

WBC Trap Count: 190
Planted May 21, 2016

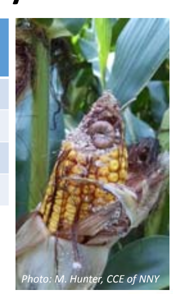

Photo: M. Hunter, CCE of NNY

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Nicholville site in Franklin County

Type of Bt(s)	WBC Damaged Ears %
Cry 1F + Vip 3A	0 b
Vip 3A	2.25 b
Cry 1F	9.75 ab
Cry 1A.05 + 2Ab2	21.25 a

WBC Trap Count: 756
Planted May 25, 2016

Photo: M. Hunter, CCE of NNY

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Identified Ear Molds and Rots

- Fusarium Ear Rot*
- Giberella Ear Rot
- Rhizopus Ear Rot
- Pennicilium Ear Rot
- Trichoderma
- Cladosporium

**Most common ear rot encountered*

Photo: M. Hunter, CCE of NNY

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Mycotoxin Screening Panel Results

- Despite as many as 21.5% of ears with WBC damage
- Mycotoxins were not an issue
- Dry growing season…unfavorable conditions??

Dow AgroScience

Cornell University Cooperative Extension
Northern New York Regional Ag Team

Other anecdotal observations

- Early planting date likely reduces WBC infestations
- At these damage levels, WBC is not likely to reduce corn yields
- Trap counts don't correlate with amount of WBC damage
- Our lowest trap count of 190 moths still had 18% damaged ears
  - Consistent with other "susceptible" fields checked this season

Cornell University Cooperative Extension
Northern New York Regional Ag Team

Special thanks to…

- Logue Farms Inc.
- Murcrest Farm
- Conway Farm
- JPL Farm
- Kitty O'Neil
- Joe Lawrence
- Harry Fefee
- Elson Shields
- Gary Bergstrom
- Jaime Cummings
- Ken Wise
- Keith Waldron

Northern New York Agricultural Development Program for funding this project

Northern New York Agricultural Development Program

Cornell University Cooperative Extension
Northern New York Regional Ag Team

Winter Triticale Forage

Winter triticale does double duty as a cover crop while producing high-quality forage (2 to 4 ton/acre dry matter harvested at flag leaf stage). Winter triticale for forage has several benefits: (1) early harvest allows for double cropping with short season corn, teff, soybeans, or sorghum x sudangrass; (2) the ground coverage in the fall and spring protects highly erodable land (HEL) and results in take-up of nutrients that otherwise might be lost to the environment; (3) when harvested at pollination will produce 25 to 30% more straw yield than rye; (4) red clover can be planted when triticale is seeded (if planted before September 5 in New York) or frost seeded; (5) establishment in August and harvest in May allows for manure spreading outside of the regular growing season and under conditions that are more favorable for manure spreading.

In this fact sheet, we present guidance on planting, fertilizer use, harvest and feed management of winter triticale harvested for forage.

Planting

A firm, well-prepared seedbed will maximize seeding success. No-till seeding into crop residues is possible if proper seeding depth and good soil-to-seed contact are achieved.

The colder the climate the earlier triticale should be planted. Recommended planting date in New York is late August or early September. Shallow or late-planted seed will have a small root system that spring-heaves and "winterkills". The later triticale is planted, the less time for tillering in the fall, and the lower the yield next spring (Figure 1).

It is recommended to drill seed 1 1/4 – 1 ½ inches deep at a rate of 100 to 125 lbs/acre. Uniform seed depth is important for optimal stand and yield.

Fertilizer

A 2 ton crop with 14% CP removes 90 lbs of N per acre, in addition to 30 lbs of P_2O_5, and 155 lbs of K_2O (double amounts for a 4 ton yield). For optimal management, band-apply 20 lbs of N/acre at seeding and use P and K according to the soil test results. Cornell phosphorus guidelines for triticale, based on the Cornell Morgan soil test, are listed in Table 1.

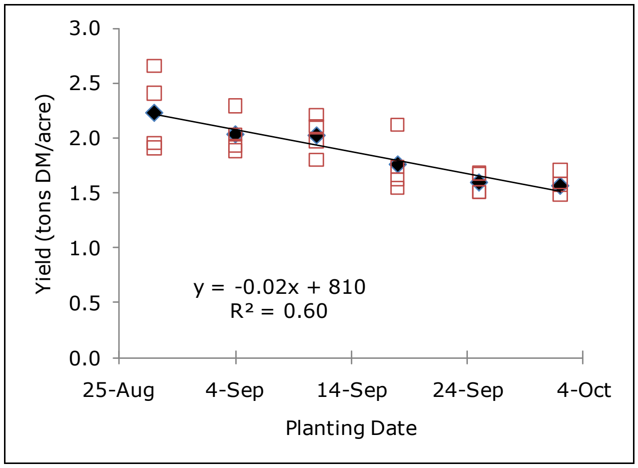

Figure 1: Effect of timing of planting on percent yield loss.

Table 1: Phosphorus guidelines for triticale.

Morgan soil test P (STP)	P recommended
lbs/acre	lbs P_2O_5/acre
50 or greater	0
40 or more but less than 50	10
30 or more but less than 40	20
20 or more but less than 30	30
10 or more but less than 20	40
Less than 10	85 – (5*STP)

To determine the K recommendations use the Cornell Morgan soil test K (lbs K/acre) and the following equation:

$$K \text{ (lbs } K_2O\text{/acre)} = (110\text{-STK})*0.70$$

So, if the soil test is 53 lbs/acre Morgan K, the recommended amount of K_2O for triticale is (110-53)*0.70=40 lbs K_2O per acre.

Additional work need to be done but findings to date indicate that too much fall-applied N produces excess growth and makes the crop susceptible to snow mold. Therefore, it is recommended to apply 100 lbs of N per acre in early spring. Spring-applied manure can be used to supply half of the N needed in the spring (and all the P and K) but commercial N fertilizer (50 lbs N per acre) remains critical because of more rapid N availability in the colder months. Applications should occur soon after green-up.

Pest Management

Geese will turn fields to bare soil if given the opportunity. Coyote or fox decoys can repel them. Deer will feed on triticale, and Hessian flies are known to cause minor damage in early fall plantings as well. The crop is harvested before other pests can do much damage so winter triticale is relatively easy to manage.

Harvest

To obtain high energy levels, harvest at stage 9 when the flag leaf is fully emerged but no heads are visible (Figure 2). Across the farm, for optimal forage quality cut triticale first, then follow with cool season grasses, alfalfa grass mixes, and clear alfalfa.

Figure 2: Harvest at stage 9 (flag leave stage) for optimal feed quality.

If harvested at flag leaf stage, triticale can yield 2-4 tons of dry matter per acre. Winter triticale can be fall/spring grazed, ensiled in a bunk silo, or baled.

Forage must be dried to proper levels for optimal fermentation. Mowing a full-width swath (like dry hay) is recommended. Conditioning is not needed. Opening the conditioner to allow the triticale to exit freely leaves a loose porous swath that dries faster. As soon as the top layer turns gray, tedd to expose the lower layers. If the mower does not leave a swath 80% of cutter bar width or more, tedd soon after mowing to get full spread. Ensiling should occur the same day as mowing because most of the nutrients are in rapidly metabolized sugar form that degrade quickly and reduce feed value. On a normal drying day, same-day haylage can be made but it will require tedding to speed up drying. Allowing a narrow swath to sit on the field for 2-3 days will result in poorly fermented, high-butyric, low-sugar, mediocre silage.

Feeding Management

The neutral detergent fiber (NDF) content of the forage can be high but the NDF is usually highly digestible. Properly ensiled haylage is high in sugar content and will be eaten rapidly by cows. It is recommended to base the ration on wet chemistry.

Additional Resources

- 2011 Cornell Guide for Integrated Field Crops Management. Electronically accessible at: http://ipmguidelines.org/Fieldcrops/.

Disclaimer

This fact sheet reflects the current (and past) authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this fact sheet does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

For more information

Cornell University Cooperative Extension

Nutrient Management Spear Program
http://nmsp.cals.cornell.edu

Tom Kilcer, Jerry Cherney, Karl Czymmek, Quirine Ketterings

2010

Guidance for Growing BMR Brachytic Dwarf Forage Sorghum

Introduction

Brown midrib (BMR) brachytic dwarf sorghum (Figure 1) is a high-quality forage species that tolerates drought and resists lodging. It has higher digestibility than conventional sorghum due to the BMR-6 gene, a naturally occurring gene mutation that reduces the lignin content compared with normal sorghum. The brachytic dwarf plant type has a shortened internode (stem) which decreases vulnerability to lodging, while maintaining the same number of leaves as taller sorghum varieties. In the Northeast, BMR brachytic dwarf forage sorghum can be used as a short season (85-89 days), single-cut forage crop alone, or as part of a double crop system with winter forages such as triticale or cereal rye. Yield assessments in the past couple of years have shown that this forage sorghum variety has the potential to compete in yield with corn silage. This factsheet gives guidance on planting, field management, and harvest of forage sorghum.

Figure 1: Brown midrib (BMR) brachytic dwarf forage sorghum in the field.

Planting Date

As sorghum is a warm-season crop, seeds need to be planted when the soil temperature is above 60°F and increasing. In New York, this is typically around June 1. Lower temperatures during germination and emergence can depress growth by causing cold-shock and may kill the seedling.

Seeding Rate, Row Spacing and Depth

The seeding rate and row spacing depend on the planting equipment available. Grain drills work well and growers should plant 8 lbs seed per acre with 15-inch row spacing, or 8-10 lbs seed per acre with 7.5-inch row spacing. For corn planters with sorghum plates or otherwise equipped to plant sorghum, 5 lbs seed per acre with 30-inch row spacing is recommended. Consistent seed dispersal is important independent of row spacing. Use sleeved drop tubes instead of corrugated tubes in grain drills to avoid seed clumping. A higher seeding rate (>10 lbs per acre) can cause thin stems and increase vulnerability to lodging. Recommended seeding depth is 0.5-1 inch.

Fertilization

For nitrogen, preliminary research results conducted in the past four years show that 1 ton of dry matter removes about 23 lbs of nitrogen (N). Average BMR forage sorghum yields at the most economic rate of nitrogen (MERN) under New York growing conditions was 7.5 tons of dry matter per acre, with a crude protein content of 7%. Because soil organic matter will supply some N to the crop, limit applications to 100-150 lbs of N per acre and apply sod and manure credits similar to corn. Research is ongoing to determine where a response to N addition is less likely. For phosphorus (P), fertilization should be based on soil test results (Table 1). For potassium (K), soil test results and knowledge about the soil type of the field is needed to determine the best application rate (see 'Additional Resources'). Maintain soil pH above 6.0.

Table1: Phosphorus recommendations for forage sorghum.

Cornell Morgan soil test P	Recommendation
lbs P per acre	lbs P_2O_5 per acre
<1	50
1	45
2	40
3	35
4	30
5	25
6-39	20
40 or more	0

Weed Control

Available pre-emergence herbicides for sorghum include metolachlor, S-metolachlor, acetochlor, and atrazine. Read the label of these and any other approved materials for instructions for use in forage sorghum. Preplant incorporated or pre-emergence applications of metolachlor, S-metolachlor, and acetochlor require use of sorghum seed treated with a seed safener. The rapid establishment of canopy shade is critical for post-emergence weed control in forage sorghum as no post emergent grass herbicides are available. Narrow row spacing can be used to accelerate canopy closure and provide early shading over weeds.

Insect Control

Army worm can cause economic damage in forage sorghum. Feeding can result in numerous ragged holes when the blades unfurl. Check in the whorl of young plants and the inside of the grain heads of mature plants.

Harvest Time

For silage production, sorghum should be harvested at the soft dough stage when plant moisture content is 68-72%. The soft dough stage can be identified when the head color changes from green to tan (see sample 4 in Figure 2). Harvesting more than three weeks prior to soft dough reduces overall yield and results in excess moisture. Ensiling wetter forage (>72% moisture) is possible but will require additional inoculant and longer length of cut to minimize or capture leachate. Late harvest (after soft dough) decreases forage quality as mature sorghum seeds become hard and indigestible.

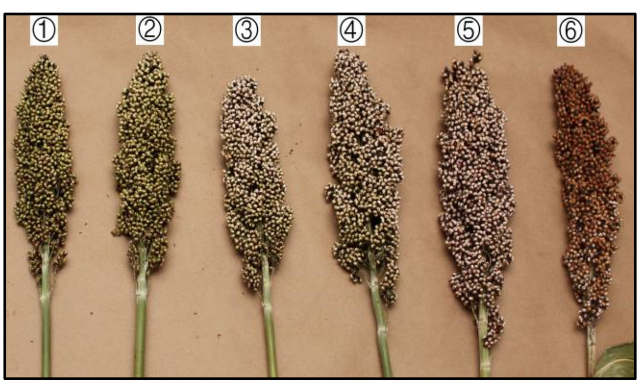

Figure 2: Six sorghum heads of different maturity are pictured in chronological order. (1) Green color indicates milk stage, too early to harvest; (2 and 3) Transition from milk to soft dough stage; (4) Tan color indicates soft dough stage, the optimal time for harvest; (5) Transition from soft dough to hard dough stage; (6) Hard dough stage, seeds are mature and almost indigestible at this time.

Harvest Equipment and Chopping

Brown midrib forage sorghum can be harvested using corn choppers. Rotary or bidirectional head type corn choppers can harvest sorghum planted in any row width. For sorghum planted in 30-inch rows a conventional row corn chopper is required. Chopping length is usually longer than for corn silage, varying from 0.75 to 1 inch or more, using sharp knives. Longer chopping length can save fuel, reduce sugar loss and leachate, and help to avoid rumen problems, but it will be more difficult to pack when the moisture content is low. If bagging, make sure that press fingers are square and not worn to reduce mashing of the forage.

Avoid Nitrate and Prussic Acid Toxicity

The fermentation process reduces the risk of nitrate and prussic acid toxicity in most cases. For green chopping, avoid harvesting within days after drought or frost to allow for decline in nitrate or prussic acid levels. Test suspect forage for nitrate content before feeding.

Summary

Brown midrib brachytic dwarf sorghum can supply farmers with a high-quality forage. It is lodging-resistant, drought-tolerant, and highly-digestible. Keys to successfully growing forage sorghum are warm temperatures at planting, proper seeding rate, spacing and depth, pre-emergence weed control, and timely harvest.

Additional Resources

- Advanced Agricultural Systems (Tom Kilcer) newsletters: advancedagsys.com/newsletters/
- Potassium guidelines for field crops in New York: nmsp.cals.cornell.edu/publications/extension/Kdoc.pdf

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http://nmsp.cals.cornell.edu

Chutao Liu, Quirine Ketterings, Karl Czymmek, Tom Kilcer, Jerry Cherney, Mike Hunter, Kitty O' Neil and Sarah Lyons

2016

Forage Quality Parameters Explained

Introduction

Some understanding of forage quality parameters for ruminant animals can help agronomists and crop consultants that are working with dairy farms to better manage forage production on the farm. Many things influence forage quality, including plant maturity at the time of harvest, variety selection, and crop species. Forage quality tests should be utilized to quantify and compare components, but results often include many acronyms. The focus of this fact sheet is to help agronomists understand the main forage quality components related to carbohydrates, fat, protein, and mineral content of forage.

Dry Matter

The first line of a forage quality report is the percent dry matter (DM). This is the material remaining after the sample is dried to remove water. To be useful for determining actual DM content of a forage on farm, seal the sample and mail it to the laboratory right after it is collected to minimize moisture loss during transport. Forage quality parameters are reported on a DM basis, or per unit weight of DM, unless otherwise noted.

Carbohydrates

Carbohydrates include fibrous and non-fibrous carbohydrates. Fibrous carbohydrates (fiber) are compounds that make up cell walls. Fiber enables rigidity in plants, is a major energy source for livestock, and promotes rumen health and cud chewing. A diet high in fiber is more slowly digested and decreases overall feed intake because the animal remains full longer. A balance between slowly digested fiber and rapidly digested carbohydrates is necessary.

Fiber can be broken down into three categories: cellulose, hemicellulose, and lignin. All three increase with plant maturity because cell walls thicken with age (Figure 1). Cellulose and hemicellulose are mostly digestible in the rumen. Lignin, an indigestible fiber component, often binds to cellulose and hemicellulose, blocking digestion. Brown midrib (BMR) crop varieties have lower lignin content, which increases digestibility.

Two indicators of fiber content are acid detergent fiber (ADF) and neutral detergent fiber (NDF). The names reflect a laboratory procedure: "neutral detergent" is isolated using a neutral wash, as opposed to an acid wash that is used to determine acid detergent fiber.

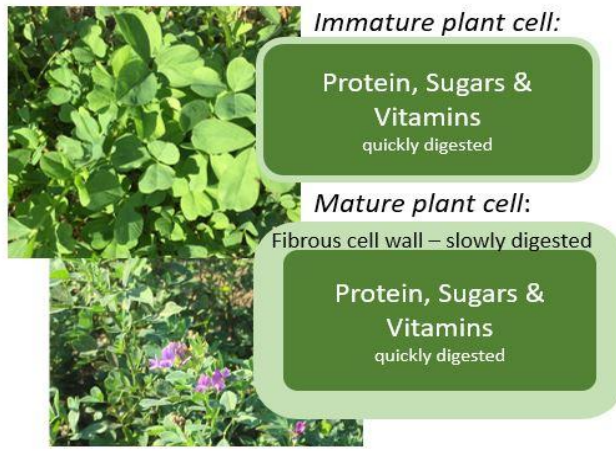

Figure 1: Mature plant cells have thickened cell walls, which increases fiber content, but decreases digestibility.

Acid detergent fiber is the measure of the cellulose and lignin content. Neutral detergent fiber is a measure of cellulose, hemicellulose, and lignin, and correlates well with animal feed intake. Issues arise if a forage has high levels of either proteins or soil contaminants, which can falsely inflate NDF estimates in the lab because these contaminants are left behind by the neutral wash. Energy content is estimated using NDF, so falsely inflated NDF leads to underfeeding of animals. If extra steps to remove non-organic contaminants and proteins are taken, it will result in an estimate of "aNDFom," a value that better represents fiber and energy content than NDF. The "a" stands for amylase, an enzyme, and "om" stands for organic matter. When contaminants are present, aNDFom is often lower than NDF. These corrections are important if a forage sample is particularly high in protein, or was harvested on sandy soil or during wet field conditions. Neutral detergent fiber digestibility (NDFD) describes the digestible portion of NDF. Digestion over different amounts of time are reported for NDFD, usually 24, 30, and 48 hours. When reported as percentage of NDF, NDFD will range from 40-60%, but it can be reported on a DM basis as well, resulting in lower values. Un-digestible neutral detergent fiber digestibility (uNDFD) describes the un-digestible portion, as percentage of NDF or DM.

Table 1: Appropriate ranges for high quality hay (grass and alfalfa mixtures) and corn silage in NY.

Feedstuff	Hay crop	Corn silage
NDF	48-55%	38-44%
Crude protein	15-25%	7-9%
Ash	<9%	<5%

http://ccedelaware.org/wp-content/uploads/2016/09/How-to-Interpret-a-Forage-Analysis-report.pdf

Non-fibrous carbohydrates, or NFC, are carbohydrates that do not make up the cell wall and can be digested quickly. This includes starches, sugars, and some acids. Non-fibrous carbohydrates are quickly digested in the rumen and used as energy by rumen microbes, or digested in the hindgut if they escape the rumen. Water soluble sugars (WSC) and ethanol soluble sugars (ESC) are two measures of simple sugar content, which range from 3% to 8% in good quality forage. Starch is found in the grain portion of forage crops and is energy dense. Starch ranges from 30 to 40% in corn silage, but is very low in hay.

Fat
Fats are essential to animal health to absorb some vitamins, provide insulation, protection, and for neural functions. Crude fat (CF) is a measure of all fat molecules, but it can include contamination from plant pigments, esters, and aldehydes. Total fatty acid (TFA) is a measure of fat that does not include these contaminants.

Protein
Crude protein (CP) is the total nitrogen (N) content of a forage, which is slightly higher than total protein because it includes non-protein N. See table 1 for appropriate CP ranges for hay and corn silage. Protein can be divided into subgroups. Soluble protein (SP) is an estimate of true protein and non-protein N that is digested in the rumen and used by microbes as a source of N. Soluble protein is targeted at 55% of crude protein or less. Rumen degradable protein (RDP) includes soluble protein as well as some other proteins that are partially digested in the rumen. This contrasts with RUP (rumen un-degradable protein) that bypasses the rumen. Neutral detergent insoluble crude protein (NDICP) describes RUP that is digested in the hindgut, as protein is in non-ruminant animals. Acid detergent insoluble crude protein (ADICP) is protein that is unavailable for digestion, most likely due to heat damage. On a forage quality report, ADICP is subtracted from CP to find available protein.

Minerals
Ash is the total mineral content in a forage, which includes inorganic compounds in the plant as well as soil contaminants. A high ash content indicates significant contamination by soil, which can inflate NDF. See table 1 for appropriate ash values for hay and corn silage. Mineral nutrients essential for metabolic functions are included in a forage report, including but not limited to Ca, P, Mg, K, Na, Fe, Zn, Cu, Mn, Mo, S, and Cl.

Summary
Carbohydrates, fat, protein, and mineral composition contribute to forage quality. These parameters vary based on crop species, environment, nutrient management, harvest time, and more. Testing forage for key quality parameters aids in creating a balanced ration.

Additional Resource
- "Understanding and Significance of Forage Analysis Results" by Dairy One: http://dairyone.com/wp-content/uploads/2014/01/Understanding-Significance-of-Forage-Results.pdf.
- "Understanding a Forage Analysis Report" by Cornell Cooperative Extension: http://ccedelaware.org/wp-content/uploads/2016/09/How-to-Interpret-a-Forage-Analysis-report.pdf.

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2016

Improving Aggregate Stability

Soil Aggregates

Aggregates are granules or clumps of soil made up of sand, silt, and clay glued together by organic matter (Figure 1). Soil structure refers to the size and shape of soil aggregates and the pore spaces between them, arranged in a layer of soil. Soil structure is an important indicator of workability and permeability; soils that are well aggregated have "good soil tilth" and drain better than poorly aggregated soils.

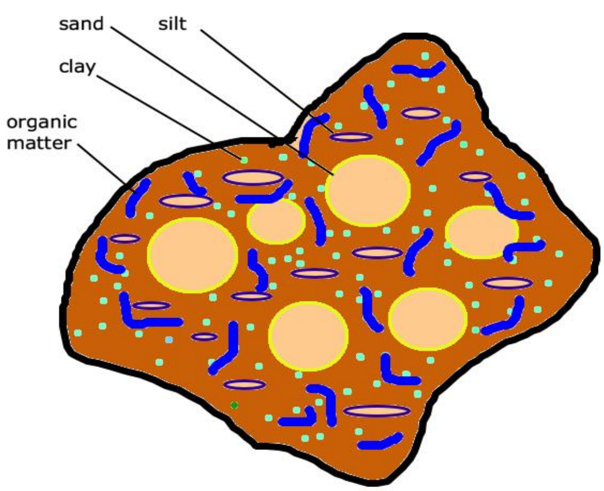

Figure 1. Aggregate structure and components.

Why is Aggregate Stability Important?

Ideally, soil aggregates are stable and resist collapsing into smaller pieces or particles due to tillage and erosive forces such as wind and rain. Stable aggregates house and protect organic matter, improving soil structure, water holding capacity, and drought resistance. Soils that have a diversity of stable aggregate sizes are well-structured. They are expected to retain more moisture, have more organic matter, and allow more infiltration of rain. Well-structured soils can hold more water, and crops are less prone to drought as water can be drawn to the surface from the subsoil and roots may penetrate deeper. Soils with fewer stable aggregates are considered poorly structured and more prone to problems such as compaction, erosion, crusting, poor infiltration, water logging, drought, poor root health and/or root diseases. Unstable aggregates collapse, filling soil pores with smaller aggregates and fragments potentially leading to soil crusting, sealing, and reduced permeability (Figure 2). This can result in decreased infiltration capacity and less water penetrating the soil profile, contributing to increased ponding, runoff and erosion. Additionally, a loss of soil structure and fewer pores can limit root development.

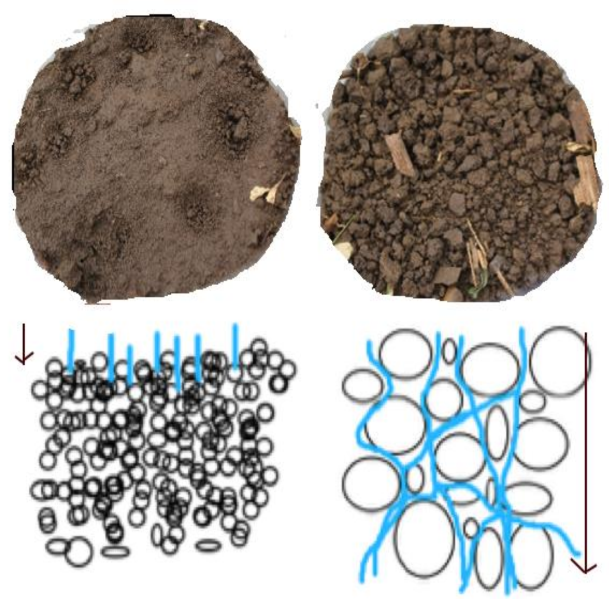

Figure 2. Unstable aggregates lead to reduced infiltration and surface sealing (left). Stable aggregates permit better infiltration (right).

Properties that Affect Aggregate Stability

Soil texture, climate, and the health, quantity, and diversity of soil organisms affect aggregate stability.

Texture

Aggregate stability is impacted by texture because silt and clay can bind particles together better than sand. Texture is determined primarily by the geological material the soil is derived from (such as shale, or sandstone) as well as the forces that formed the soil (such as glacial action, wind, etc.).

Climate

Both temperature and the amount and intensity of rainfall, can impact aggregate stability.

Irregular rainfall events with varying intensities can lead to aggregate breakdown and result in an increased risk of water erosion. Warmer temperatures can also increase the rate of organic matter decomposition, thereby reducing the amount of organic matter in the soil, contributing to a loss of aggregate stability.

Soil Life

In healthy soils, aggregate strength is enhanced by organic "glues" produced by plants, animals, and soil microbes. Plant roots and soil microbes release sticky organic compounds that bind soil particles together. Soil organisms including bacteria, fungi, and larger species such as earthworms, contribute to aggregate strength stability over time. Diverse and active soil organism are beneficial because they excrete a range of compounds that can work together to improve aggregate stability.

Field Management and Aggregate Stability

Field management, including tillage operations, addition of organic amendments, and planting and harvesting methods, can impact both aggregate size distribution and stability.

Tillage

Tillage destroys aggregates in two ways: (1) by physically breaking the aggregates apart and (2) by stirring air into the soil, stimulating microbes to increase the rate of organic matter decomposition. Soil organic matter is lost to the atmosphere as carbon dioxide and, over time, this can result in less organic material to bind aggregates together. Conservation practices that reduce the amount of soil disturbance such as zone or strip tillage, or no-till planting methods can reduce the loss of organic matter and aggregate destruction.

Organic Matter Additions

Adding organic materials, such as manure or mulch residues, can provide the soil with both nutrients and organic matter, while improving aggregate stability over time. The latter is a result of greater amounts of organic carbon combined with greater microbial activity, enhancing the production of aggregate glues.

Crop Rotation

Main crop selection, crop rotation, and use of cover crops can also impact aggregate stability. For main crops grown in the Northeast, those that leave surface residues (such as corn stalks) minimize the impact of rain and wind by creating a barrier to physical destruction (runoff and direct surface impact) of surface aggregates. Cover crops and sod crops (such as grass or alfalfa hay) keep the soil covered, allowing for accumulation of soil organic matter over time. Once established, perennial crops cannot be tilled. In addition, these crops will develop deep and extensive root systems. Thus, cover and sod crops in a rotation contribute to organic matter buildup over time. This addition of organic matter promotes aggregate stability.

Summary

Aggregate stability is crucial for soil health. Soils with good aggregate stability are less susceptible to erosion and have improved infiltration. Aggregate stability increases with organic matter content in the soil and can be improved through a combination of management practices such as reduced tillage, adding organic matter amendments, and increasing the amount of crop residues and organic matter retained in the soil. Avoid extensive tillage and reduce physical disturbances to prevent the destruction of soil aggregates. By keeping soil covered with surface residues, erosive impacts can be minimized as well.

Additional Resources

- Soil Quality Indicators: Aggregate Stability. NRCS. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052820.pdf
- Manure Injection in No-Till and Pasture Systems. pubs.ext.vt.edu/CSES/CSES-22/CSES-22-PDF.pdf.

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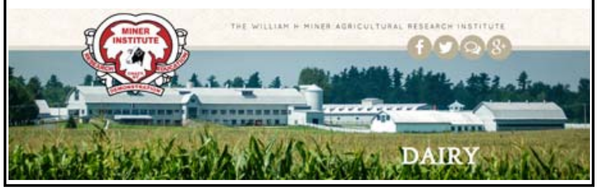
Amir Sadeghpour, Amy Langner, Kitty O'Neill, Aaron Gabriel

2016

Research Updates

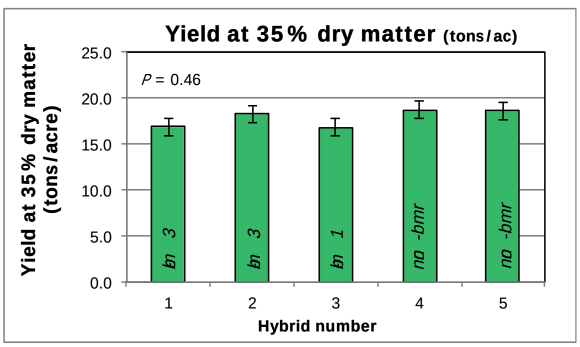
Eric Young
William H. Miner Agricultural Research Institute



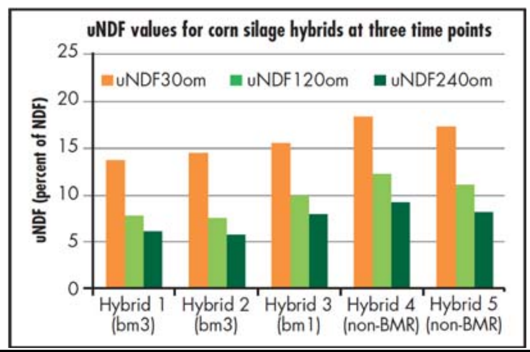
Agronomy and Nutrient Management Projects

- **Forage Quality:**
  - **Brown midrib vs. non-BMR** (3 yr)
  - **Winter rye and triticale quality**
- **Edge-of-field water quality studies**
  - **NRCS- surface/subsurface tile** (6 yr)
  - **NNYADP- tile vs. undrained** (multi-yr)
  - **NNYADP- winter rye & runoff** (2 yr)

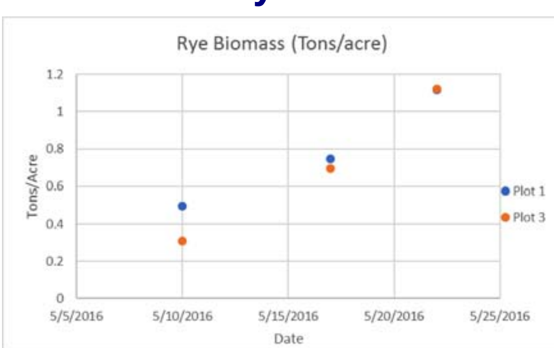
BMR/Non-BMR Yields



BMR/Non-BMR uNDF profiles



Winter Rye after Corn

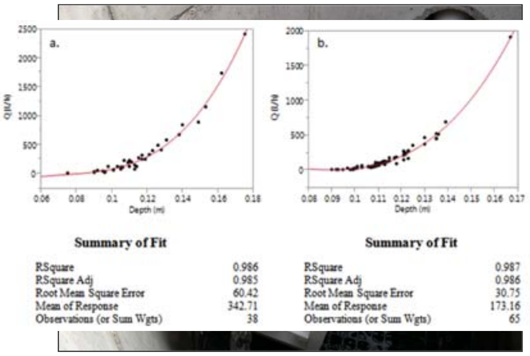


Rye after Corn: Yields

Corn Silage	Tons/Acre at 35%DM	% Crude Protein	%ADF	%aNDF
Cover	14.7[A]	9.63[A]	23.08[A]	41.21[A]
Control	18.8[B]	9.15[A]	20.76[A]	36.30[A]

- **Need 2 weeks after glyphosate application prior to planting corn**
- **No-till likely compounded the issue**

Measuring runoff



Rye after Corn: Water Quality

Mean Load	Nitrate	SRP	TN	TP	TSS	Flow
	mg-N	mg-P	mg-N	mg-P	mg	L
Cover Tile	**29.6**	**31.6**	**34468**	**156**	**26294**	**2699**
Control Tile	61.5	29.64	74570	86.3	14910	3823
Cover Surface	**0.34**	**28.62**	**380**	**36.9**	**7073**	**277**
Control Surface	1.0	56.3	1053	54.2	29909	626

USDA Edge-of-Field monitoring

- Small paired watersheds (5 and 9 acres)
- 2-year baseline, 4-year treatment period
- Sediment, N, & P losses
- Crop yields, nutrient budgets
- BMP = controlled vs. free subsurface drainage

Site Location

Soils and Drainage

Timeline of Activities

- **2013**
  - Fields selected for NRCS contract
  - Wetland determination…
- **2014**
  - Tile drains installed
  - Subsurface manholes
  - Surface water flumes
- **2015**
  - Flow and sampling instruments
  - Full monitoring October 2015

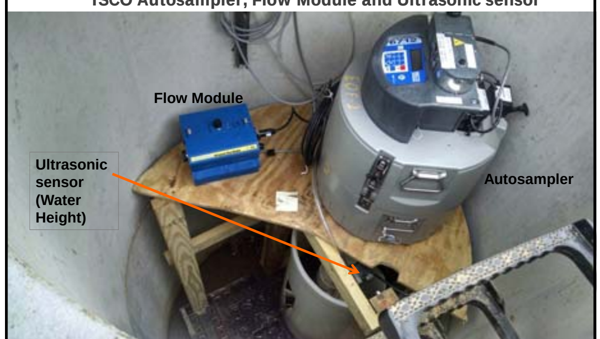
Surface Water Instruments

- 200 mL sample taken / 0.70 mm of runoff
- Total suspended solids, total N, nitrate-N, ammonium-N, total P, and soluble reactive P

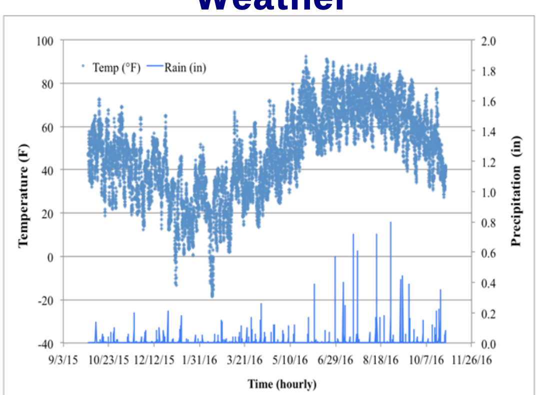
Subsurface Tile Drain Setup

55 Ga plastic drum with 5 in. V notch weir

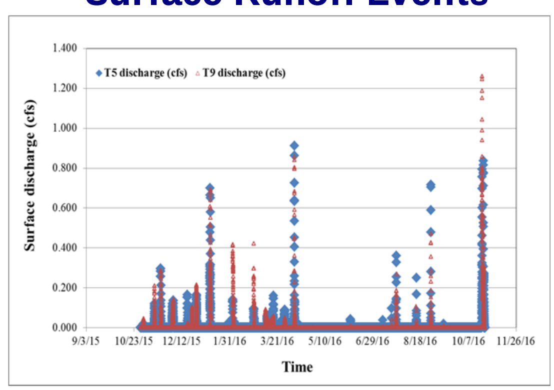
ISCO Autosampler, Flow Module and Ultrasonic sensor



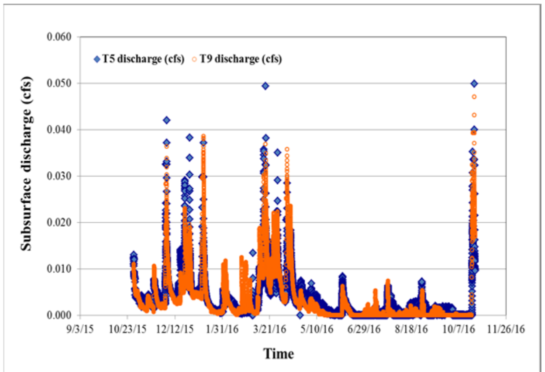
Weather



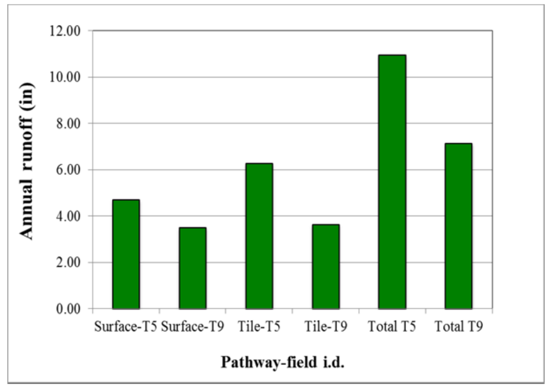
Surface Runoff Events



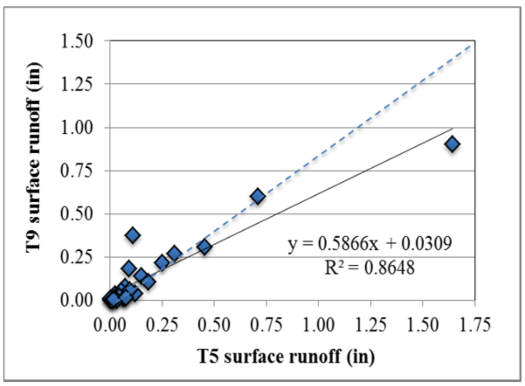
Subsurface Runoff Events



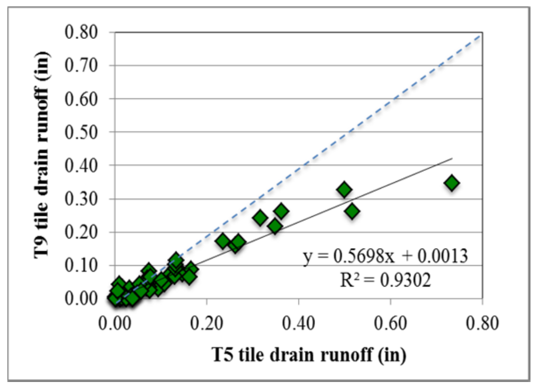
Annual Runoff



Surface Runoff Calibration



Tile Runoff Calibration



Annual Nutrient Loads

Pathway/Field	SRP load (lb/ac/yr)	TP load (lb/ac/yr)	TSS load (lb/ac/yr)	Nitrate-N load (lb/ac/yr)	TN load (lb/ac/yr)	Ammonium-N load (lb/ac/yr)
Surface-T5	0.32	0.62	115	0.69	2.02	0.07
Surface-T9	0.10	0.44	71	0.24	1.70	0.06
Tile-T5	0.01	0.06	13	8.04	10.52	0.05
Tile-T9	0.01	0.04	8	4.97	6.48	0.05
Total T5	0.34	0.69	127	8.7	12.5	0.12
Total T9	0.11	0.48	79	5.2	8.2	0.11
T5 % Tile	**4.4**	**9.4**	**10**	**92.1**	**83.9**	**38.9**
T5 % Surface	**95.6**	**90.6**	**90**	**7.9**	**16.1**	**61.1**
T9 % Tile	**10.4**	**9.0**	**10.3**	**95.4**	**79.2**	**47.3**
T9 % Surface	**89.6**	**91.0**	**89.7**	**4.6**	**20.8**	**52.7**

N and P Efficiency

Field	100 lb/ac 23-12-18	80 lb/ac sidedress N	Total N input (lb/ac/yr)	Total P input (lb/ac/yr)	Total K input (lb/ac/yr)
T5	YES	YES	114.5	7.9	22.0
T9	YES	YES	114.5	7.9	22.0

Field	% N efficiency	% P efficiency
T5	89.1	91.3
T9	92.5	93.2

Summary and Future Work

- Surface runoff losses:
  - Sediment
  - TP and SRP
- Tile drainage runoff losses:
  - Total N and nitrate-N
- How will controlled drainage affect nutrient losses and crop yield?

Tile drainage impacts on phosphorus losses

Laura Klaiber, Eric Young, Stephen Kramer, Donald Ross

Crop Congress

February 1, 2017

Tile Drainage and Water Quality

- Results mixed – site, climate, and management dependent
- Tile drainage water – lower concentrations of sediment and P than surface runoff; higher runoff volumes
- Total P export from tiles (mineral soils) – 0.4 kg ha^{-1}y^{-1} to 1.6 kg ha^{-1}y^{-1} (King et al., 2015)

Objective

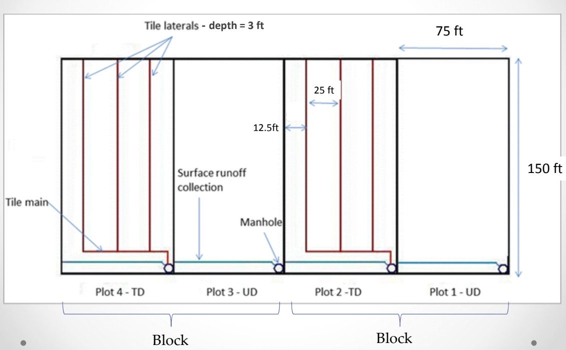
- Quantify export of water, soluble reactive P (SRP), unreactive P (UP), total P (TP), and total suspended solids (TSS) from four side-by-side corn plots under two different management scenarios:
    - Subsurface tile drainage: surface + subsurface runoff
    - Natural drainage: surface runoff

Site Characteristics

- 5% Slope
- Upslope: Well-drained outwash soils (Colosse-Trout River Complex)
- Toeslope: Poorly-drained silty-clay (Adjidaumo)
- No prior history of drainage, manure applications
- Long-term grass field
- 2 lb/ac soil test P
- Monitoring began during 1st year corn

Plot 4 Soil Pit

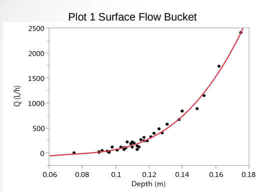
Plot Design



Runoff Collection & Measurements

- Water flow continuously monitored – 5 gal buckets modified with v-notch weirs and pressure transducers
- Rating curves → relationship between water depth and measured flow
- Water quality samples collected weekly during low flow and hourly during high flow events
  - o analyzed for TP, SRP, and TSS; UP estimated by TP - SRP.
- Nutrient loads = runoff volume x concentration

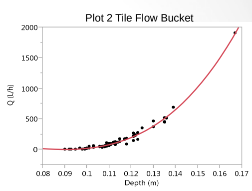
Rating Curves
Field Data



$y = -253.784 + 12814.592x + 259905.13(x - 0.11437)^2 + 2092942.2(x - 0.11437)^3$

Summary of Fit

R^2	0.986
R^2 Adj	0.985
Root Mean Square Error	60.42
Mean of Response	342.71
Observations (or Sum Wgts)	38

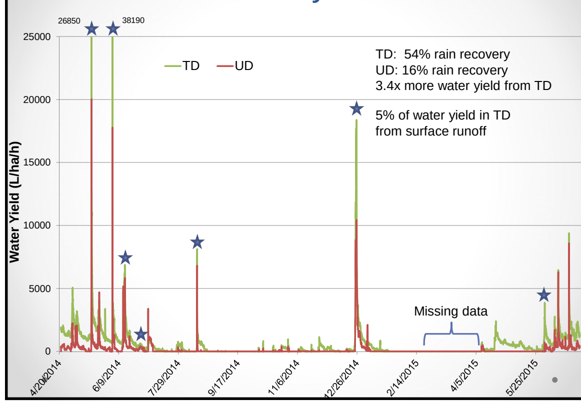


$y = -1114.649 + 10826.456x + 308017.64(x - 0.11358)^2 + 2200297.4(x - 0.11358)^3$

Summary of Fit

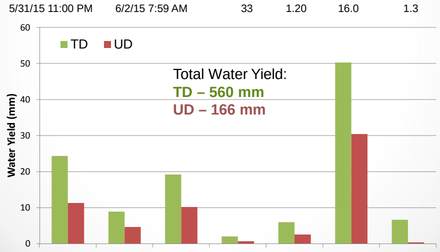
R^2	0.987
R^2 Adj	0.986
Root Mean Square Error	30.75
Mean of Response	173.16
Observations (or Sum Wgts)	65

Water Yield by Treatment

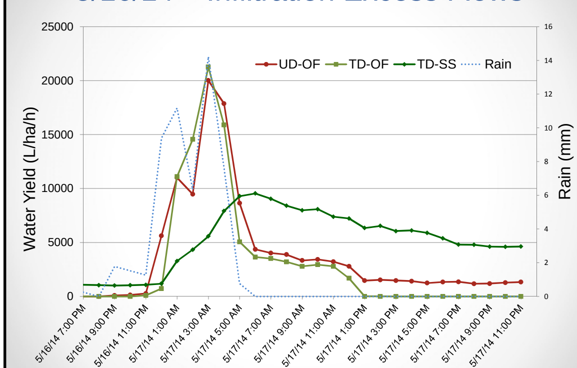


Runoff Events

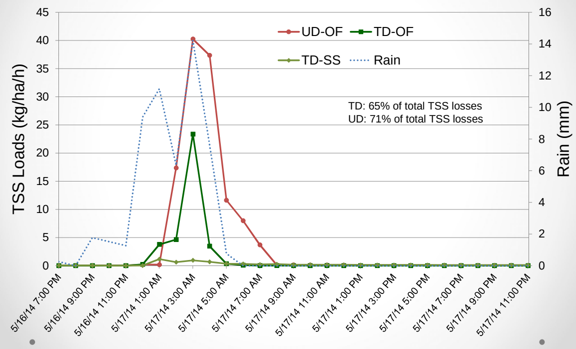
Event Start	Event Finish	Duration h	Rain in	Rain Recovery (%) TD	Rain Recovery (%) UD
5/16/14 7:00 PM	5/17/14 11:59 PM	29	2.14	22.8	20.8
6/3/14 4:00 PM	6/4/14 3:59 PM	24	1.10	23.3	16.7
6/11/14 4:00 PM	6/14/14 4:59 PM	73	2.06	25.4	19.5
6/24/14 6:00 AM	6/26/14 8:59 AM	51	0.43	1.7	6.7
8/13/14 7:00 AM	8/14/14 11:59 PM	41	2.13	11.1	4.8
12/24/14 8:00 AM	12/26/14 11:59 PM	64	0.45	389.9	266.4
5/31/15 11:00 PM	6/2/15 7:59 AM	33	1.20	16.0	1.3



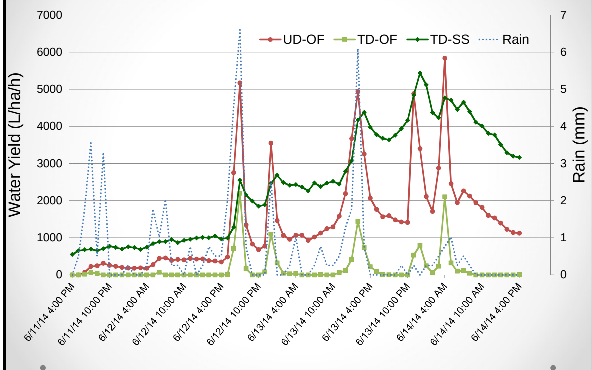
5/16/14 – Infiltration Excess Flows



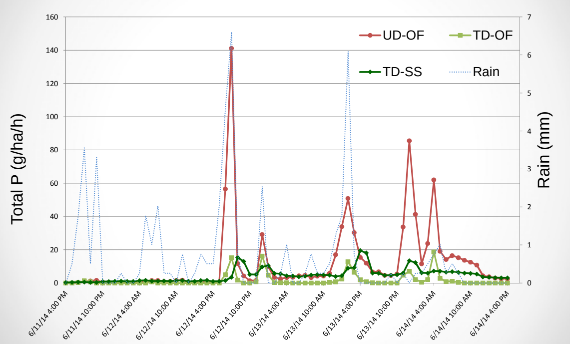
5/16/14 – Soil Loss



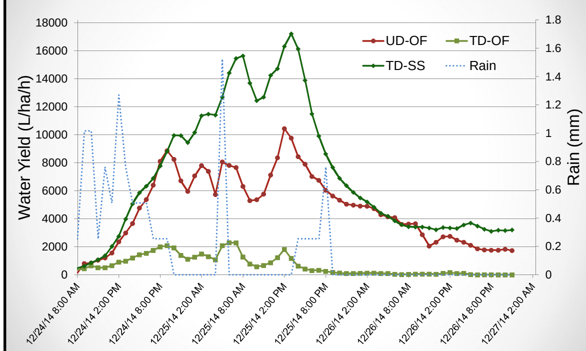
6/11/14 - Saturation Excess Flows



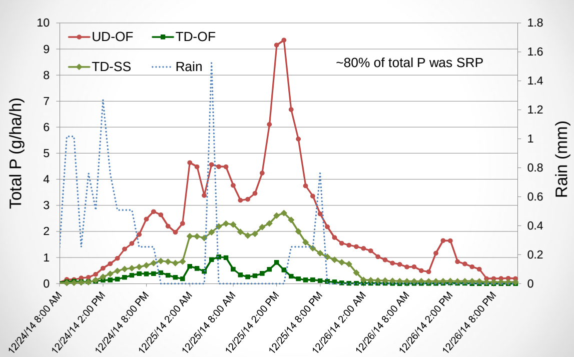
6/11/14 – Total P Loss



12/25/14 - Snowmelt



12/25/14 Event – Total P Loss



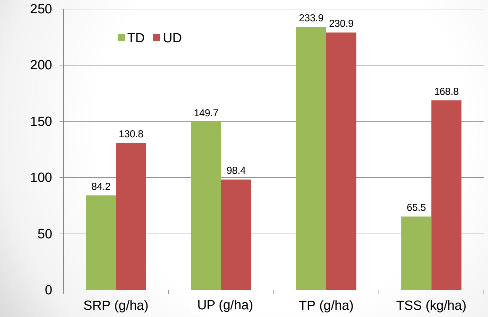
P and TSS Loads by Treatment

Event Date	Treatment	SRP	UP	TP	TSS
		g ha^{-1}	g ha^{-1}	g ha^{-1}	kg ha^{-1}
5/16/2014	**TD**	**13.63**	**62.23**	**72.95**	**42.67**
5/16/2014	**UD**	**1.30**	**14.25**	**15.55**	**113.21**
6/3/2014	TD	0.49	15.73	16.22	14.47
6/3/2014	UD	0.50	5.21	5.70	9.91
6/11/2014	TD	0.47	3.87	4.34	1.21
6/11/2014	UD	2.07	7.40	9.48	7.21
6/24/2014	TD	0.04	0.13	0.17	0.01
6/24/2014	UD	0.02	0.06	0.08	0.04
8/13/2014	TD	1.62	2.45	4.08	0.33
8/13/2014	UD	1.73	2.49	4.22	0.84
12/25/2014	**TD**	**51.58**	**14.00**	**65.58**	**1.21**
12/25/2014	**UD**	**110.45**	**27.75**	**138.19**	**2.70**
5/31/2015	TD	0.86	0.90	1.76	0.18
5/31/2015	UD	0.15	0.20	0.34	0.05
Events as % of Total Losses	**TD**	**81.6**	**64.4**	**70.6**	**91.8**
Events as % of Total Losses	**UD**	**88.9**	**56.6**	**75.0**	**83.2**

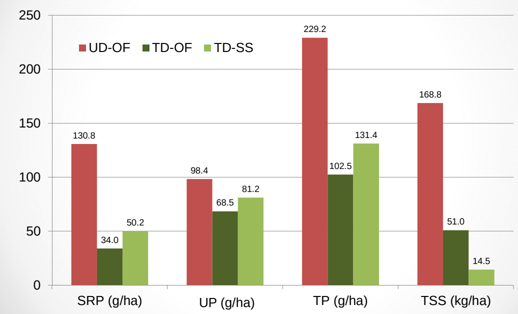
P and TSS Loads by Treatment and Hydrologic Pathway

Event Date	Treatment	Pathway	SRP g ha^{-1}	UP g ha^{-1}	TP g ha^{-1}	TSS kg ha^{-1}
5/16/2014	**UD**	**surface**	**1.30**	**14.25**	**15.55**	**113.21**
5/16/2014	**TD**	**surface**	**13.12**	**47.18**	**60.31**	**36.04**
5/16/2014	**TD**	**tile**	**0.50**	**15.05**	**12.64**	**6.63**
6/3/2014	UD	surface	0.50	5.21	5.70	9.91
6/3/2014	TD	surface	0.36	10.87	11.23	13.63
6/3/2014	TD	tile	0.13	4.86	4.99	0.84
6/11/2014	UD	surface	1.87	6.54	8.41	2.32
6/11/2014	TD	surface	0.13	0.94	1.08	0.34
6/11/2014	TD	tile	0.39	2.88	3.27	0.29
6/24/2014	UD	surface	0.02	0.06	0.08	0.04
6/24/2014	TD	surface	0.01	0.06	0.07	0.00
6/24/2014	TD	tile	0.03	0.07	0.10	0.01
8/13/2014	UD	surface	1.73	2.49	4.22	0.84
8/13/2014	TD	surface	1.27	1.17	2.44	0.17
8/13/2014	TD	tile	0.35	1.28	1.63	0.16
12/25/2014	**UD**	**surface**	**110.45**	**27.75**	**138.19**	**2.70**
12/25/2014	**TD**	**surface**	**11.28**	**2.08**	**13.36**	**0.21**
12/25/2014	**TD**	**tile**	**40.30**	**11.92**	**52.22**	**1.00**
5/31/2015	UD	surface	0.15	0.20	0.34	0.05
5/31/2015	TD	surface	0.56	0.25	0.81	0.02
5/31/2015	TD	tile	0.30	0.66	0.96	0.16

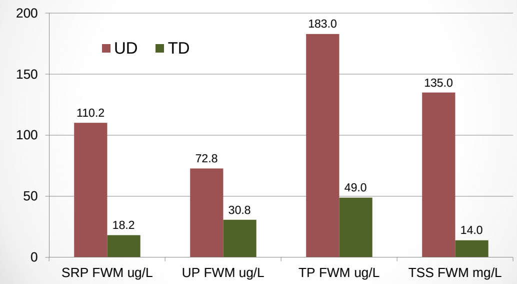
Cumulative P and TSS Loads by Treatment



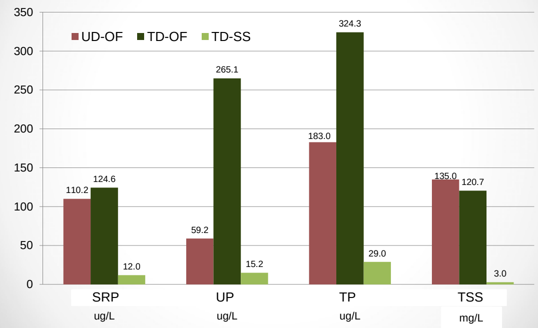
Cumulative P and TSS Loads by Treatment and Hydrologic Pathway



Flow-Weighted Mean Concentrations



Flow-Weighted Mean Concentrations



Summary of Key Findings

- 36% and 61% reductions in SRP and TSS, respectively in tile-drained plots
- Manure management is key
  - 12/25/14 snowmelt event: 80% of cumulative SRP losses from tiles; 84% of cumulative SRP losses from UD
- 23% of total rain fell during 7 intensively monitored events; responsible for majority of losses
  - TD: 82% of SRP, 70% of TP, 92% of TSS
  - UD: 89% of SRP, 75% of TP, 83% of TSS
- TP and SRP FWM concentrations lower in tile flow
- P status of soil likely to influence: P fraction lost, effect of tile drains on water quality

Implications

- Small window of time responsible for majority of losses
  - Development of BMPs to target these periods
- Manure management
  - Avoid manure application prior to large runoff events
  - Incorporate manure following application – manure to soil contact promotes sorption/immobilization of P and can minimize loss regardless of transport pathway
- Snowmelt event → importance of snowmelt runoff
  - Difficult to monitor, less research during these periods; critical to understanding P loss dynamics
  - Tile drainage may mitigate P losses during snowmelt
- Minimize P accumulation in soils to reduce risk of P exports