Spring Ranchers Forum Proceedings

a program by the

Central Florida Livestock Agents Group

Thursday, March 19, 2015

Yarborough Ranch

1355 Snow Hill Rd.

Geneva, Florida 32732

UF | IFAS Extension
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CENTRAL FLORIDA LIVESTOCK AGENTS GROUP

Spring Ranchers Forum
March 19, 2015
Proceedings

Central Florida Livestock Agents Group

Agents

Jonal Bosques-Mendez (Marion)
Megan Brew (Lake)
Ashley Fluke (Osceola)
Sharon Fox-Gamble (Volusia)
Ed Jennings (Multi-County Livestock)
Dennis Mudge (Multi-County Livestock)
Mark Shuffitt (Marion)
Joe Walter (Brevard)
Mark Warren (Flagler)

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SPRING RANCHERS FORUM

a program by the
Central Florida Livestock Agents Group
THURSDAY, MARCH 19, 2015
YARBOROUGH RANCH
1355 Snow Hill Road, Geneva

AGENDA

8:30 **Arrival and Registration**

9:00 **Live Animal Demonstration: "Effective Body Condition Scoring of Florida Horses"**
Megan Brew, Livestock Extension Agent, UF/IFAS Extension Lake County
Ashley Fluke, Livestock Extension Agent, UF/IFAS Extension Osceola County

9:40 **Trade Show Break**

10:35 **Manure Biodigester Demonstration**
Dr. Ann Wilkie, Soil & Water Science Professor, University of Florida
Marco Pazmino, PhD Candidate, Ag + Bio Engineering, University of Florida
Eleanor Foreste, Natural Resources Extension Agent, UF/IFAS Extension Osceola County

11:15 **Hay Selection: Test your Hay Buying Skills**
Sharon Gamble, Livestock Agent, UF/IFAS Extension Volusia County
Dennis Mudge, Livestock Agent, UF/IFAS Extension Multi-County

12:00 **Official Welcome**
Dennis Mudge, Chair, 2015
Hosts: Imogene Yarborough and Lynn Hanshew
Steak Lunch -Yarborough Family & Local Cattlemen

1:00 **CFLAG Agent Panel: Troublesome Weeds**
Jonael Bosques-Mendez, Megan Brew, Ashley Fluke, Sharon Gamble, Christine Kelly-Begazo, Dennis Mudge, Mark Shuffitt, Joe Walter, Mark Warren

1:45 **Pasture Weed Herbicide Update & Dealing with the Troublesome Weeds**
Dr. Brent Sellers, Associate Professor of Agronomy, ONA Cattle Research Center, University of Florida IFAS

2:30 **University Mole Cricket Update**
Chris Kerr, PhD Candidate, Plant Medicine, University of Florida

3:00 **Evaluation and Final Give-Aways**
Dennis Mudge

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Equine Body Condition Scoring

Ashley Fluke, UF/IFAS Osceola County Livestock Agent
Megan Brew, UF/IFAS Lake County Livestock Agent

The Body Condition Score (BCS) system was developed by Dr. Henneke et al. (1983) as a tool to estimate the nutritional status of horses. It is used universally across breeds and does not require the use of special equipment. Each evaluated individual is assigned a number from 1 to 9 based on the amount of fat cover they carry in key areas. An overall BCS of 4-6 is considered ideal; horses that score under 4 are underweight while horses scoring over 6 would be considered overweight.

Importance of Body Condition Score

BCS can be used as an aid to determine if the horse's nutritional needs are being adequately met. BCS is a valuable tool for Law Enforcement, Animal Control, and Veterinarians who are asked to assess a situation where the animal's health and well-being are in question. It can also be useful for the average horse owner as they make feeding and work plans for their herd. It is important to note that BCS is not the final determinant of a horse's overall health status. Age, reproductive status, use, and the presence disease and/or parasites also play a role in determining the overall health of a horse.

Other Important Factors

Body Condition Score is a great tool in evaluating animal health however it should not be used as the only tool. Knowing the horse's actual weight is critical when administering medications. Ideally, weight is determined by scales but if there is not a livestock scale available a weight tape can be used to provide an estimate.

How to evaluate BCS of the Horse

There are 6 points on the horse that are useful in assessing fat cover. These 6 points are:

- The Neck
- The Withers
- Loin
- Tail Head
- Ribs
- Fore Flank/Behind Shoulder

Body Condition Scoring System

Condition	Neck	Withers	Loin	Tailhead	Ribs	Shoulder
1 **Poor**	Bone structure easily noticeable, animal extremely emaciated, no fatty tissue can be felt	Bone structure easily noticeable	Spinous processes project prominently	Tailhead (pinbone) and hook bones project prominently	No fat cover over ribs.	Bone structure easily noticeable
2 **Very Thin**	Faintly discernable, animal emaciated	Faintly discernable	Slight fat covering over base of spinous processes. Transverse processes of lumbar vertebrae feel rounded. Spinous processes are prominent.	Tailhead prominent	Slight fat cover over ribs. Ribs easily discernable.	Shoulder accentuated
3 **Thin**	Neck accentuated	Withers accentuated	Fat buildup halfway on spinous processes but easily discernable. Transverse processes cannot be felt.	Tailhead prominent but individual vertebrae cannot be visually identified. Hook bones appear rounded but are still easily discernable. Pin bones not distinguishable.	Slight fat cover over ribs. Ribs easily discernable.	Shoulder accentuated
4 **Moderately Thin**	Neck not obviously thin	Withers not obviously thin	Negative crease along back	Prominence depends on conformation; fat can be felt. Hook bones not discernable.	Faint outline discernable	Shoulder not obviously thin
5 **Moderate**	Neck blends smoothly into body	Withers rounded over spinous processes	Back level	Fat around tailhead beginning to feel spongy	Ribs cannot be visually distinguished but can be easily felt	Shoulder blends smoothly into body
6 **Moderately Fleshy**	Fat beginning to be deposited	Fat beginning to be deposited	May have slight positive crease down back	Fat around tailhead feels soft	Fat over ribs feels spongy	Fat beginning to be deposited
7 **Fleshy**	Fat deposited along neck	Fat deposited along withers	May have positive crease down back	Fat around tailhead is soft	Individual ribs can be felt, but noticeable filling between ribs with fat	Fat deposited behind shoulder
8 **Fat**	Noticeable thickening of neck	Area along withers filled with fat	Positive crease down back	Tailhead fat very soft. Fat deposited along inner buttocks	Difficult to feel ribs	Area behind shoulder filled in flush with body
9 **Extremely Fat**	Bulging fat.	Bulging fat	Obvious positive crease down back	Building fat around tailhead. Fat along inner buttocks may rub together. Flank filled in flush	Patchy fat appearing over ribs	Bulging fat

From: Henneke et al. Equine Vet J. (1983) 15 (4), 371-372

Body Condition Scoring

- What is body condition?
- Why do we care about body condition?

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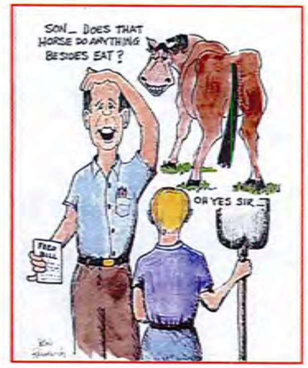
Energy Expenditures

- We know horses get energy from feed…so where does that energy go?



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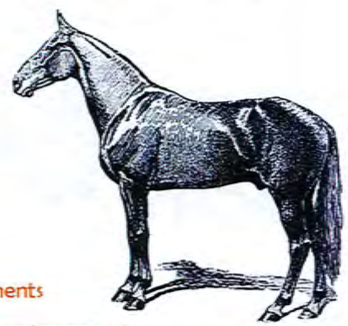
Energy Requirements

Maintenance Requirement

✓Breathe
✓Metabolize
✓Regulate Temperature
✓Normal Daily Activity
✓Reproduction
✓Growth/Development

+ Additional Energy Requirements

= Total Daily Requirement



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The Skinny on Fat

- Fat is an **energy bank**
- Deposit nutrition
- Withdrawal energy
  - When Nutrition = Requirement
    - Flat balance
  - When Nutrition > Requirement
    - Profit
  - When Nutrition < Requirement
    - Debt

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The Skinny on Fat

- The amount of fat cover a horse has tells us about the state of his energy balance



- How can we compare one horse to another given differences in height, muscle and breed type?

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Henneke Score

- Developed by Dr. Henneke in 1983
  - Repeatable, Consistent
  - Allows easy comparison between animals
- Previously a complex mathematical formula had been used, not helpful on the farm

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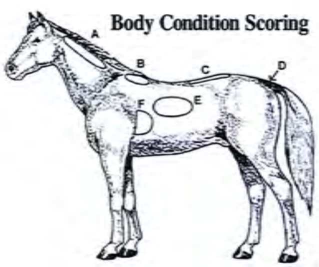
Henneke Body Condition Score

- Fat laid down in predictable patterns
  - Organs
  - Loin
  - Ribs
  - Tailhead
  - Withers
  - Neck
  - Shoulder



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Henneke Body Condition Score

- Scale of 1-9
- Allows for improved nutritional management
- Useful when conditioning athletes
- Abuse cases
- Reproduction

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Loin

- One of the first places external fat is laid down
- An extremely thin horse will have a ridge down the back
- As a horse gains weight this ridge will flatten out then become a crease

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Ribs

- An extremely thin horse will have prominent ribs, easily seen and felt
- Ideally ribs are not visible but easily felt

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Tailhead

- Prominent in thin horses
- Will begin to bulge as horse moves from fit to obese

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Withers

- Do not be fooled by naturally prominent withers

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Neck

- Fat deposited along top

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Shoulder

- Fat deposited behind the shoulder

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Evaluating BCS

- Look and Touch
  - Don't get fooled by coat thickness, conformational differences, height etc.

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Score 1 – Poor

- Extreme emaciation
- No fatty tissue can be felt
- Ribs projecting prominently
- Bone structure easily noticeable

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Score 2 – Very Thin

- Emaciated
- Ribs prominent
- Vertebrae prominent
- Bone structure noticeable

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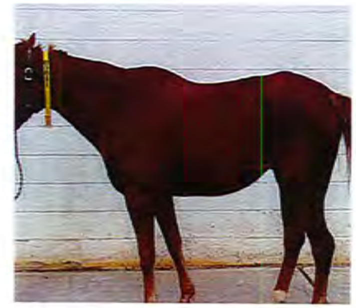
Score 3 - Thin

- Thin layer of fat over ribs
- Ribs still easily discernible
- Tailhead prominent



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Score 4 – Moderately Thin

- Faint outline of ribs discernable
- Ridge along back (negative crease)
- Fat can be felt around tailhead
- Withers, shoulders, neck not obviously thin

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Score 5 - Moderate

- Back is level
- Ribs cannot be visually distinguished, but can be easily felt
- Fat around tailhead beginning to feel spongy
- Withers appear rounded
- Shoulders & neck blend smoothly into body

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Score 6 – Moderate to Fleshy

- May have slight crease down back
- Fat over ribs feels soft and spongy
- Fat around tailhead feels soft
- Fat beginning to be deposited along sides of withers, behind shoulders & along sides of neck

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Score 7 - Fleshy

- Crease down back
- Ribs can be felt with noticeable filling of fat between ribs
- Fat around tailhead is soft
- Fat deposited along withers, behind shoulders and along neck

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Score 8 - Fat

- Crease down back
- Difficult to feel ribs
- Fat around tailhead is soft
- Fat around withers and behind shoulder
- Noticeable thickening of neck
- Fat deposited along inner buttocks

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Score 9 – Extremely Fat

- Obvious crease down back
- Patchy fat appearing over ribs
- Bulging fat around tailhead, around withers, behind shoulders, and along neck
- Fat along inner buttocks
- Flank filled and flush

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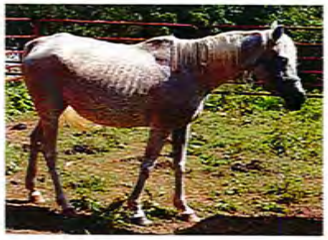
What is Ideal?

- "Each horse has his own ideal condition for his breed and occupation" – Dr. Henneke
- Broodmare: 5-7
- Breeding Stallion: 5-6
- Performance Horse: 4-6

The Danger Zone

- Which horse is more at risk?



What Impacts BCS?

- Too thin
  - Abuse or neglect
  - Poor quality feed
  - Not enough feed
  - Consumption of toxic plants
  - Tooth and jaw problems
  - Advanced age
  - Excessive energy expenditure
  - Parasites
  - Gastric ulcers

If Your Horse is Too Thin

- Rule out other health problems
- Evaluate your feeding program with the help of your livestock agent and/or vet

Improving 1 Condition Score		
Days Needed	Daily Gain	Additional Grain Needed
60	0.75 lbs/day	4.5 lbs/day
90	0.50 lbs/day	3.0 lbs/day
120	0.40 lbs/day	2.3 lbs/day

What Impacts BCS?

- Too fat
  - Too much concentrate
  - Not enough exercise
  - Mismanagement
  - Metabolic disorders

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If Your Horse is Too Fat

- Screen for metabolic disorders
- Consider minimizing or eliminating concentrates from diet
- Switch to a lower energy hay
- Increase exercise/ turnout

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Anaerobic Digesters for Manure Management at Livestock Operations[1]

Rishi Prasad, George Hochmuth, and Ann C. Wilkie[2]

The purpose of this publication is to inform farmers and Extension agents about types of anaerobic digester systems used in the United States with various manure-handling systems. We point out digester systems currently being used in Florida and the benefits of managing livestock manure with a digester system.

Introduction

Livestock wastes can be important sources of nutrients for crops, but manure must be managed properly to prevent loss of nutrients to the environment in air or ground and/or surface water. Stabilization of manure is important prior to successfully recycling the organic material back to arable lands.

Methods for stabilizing livestock wastes include composting, aerobic digestion, anaerobic digestion, lime stabilization, and heat drying. The stabilization process reduces the organic matter and water contents, unpleasant odors, concentrations of pathogenic microorganisms, and weed seeds. Anaerobic digestion (AD), which is the topic of this fact sheet, also results in the production of renewable energy in the form of methane-rich biogas.

Using an anaerobic digester on farms helps producers adopt sustainable and environmentally sound agricultural practices in livestock production systems and integrated farms. According to the US Environmental Protection Agency (2014a), there were approximately 239 anaerobic digester systems for livestock manure operating in the United States as of January 2014. An integrated crop-livestock farm is a farm where crops are produced for sale off the farm; some portions of crop also go to feed the livestock unit on the same farm, and the resulting manure nutrients are cycled back to the crop production system.

Waste generated from the livestock unit is processed through anaerobic digesters, and anaerobically digested solids (ADS) and liquid effluents (ADL) are recycled back to fields. The nutrients in the ADS and ADL supplement crop-nutrient needs (e.g., nitrogen (N) and phosphorus (P)). Another product of the digestion process is methane gas (biogas) that can be burned in an engine generator system to produce electricity to be used on the farm or sold to the power grid. The biogas can also be burned for heating water or the farm buildings.

What Is Anaerobic Digestion?

Anaerobic digestion of organic waste is a microbe-mediated process carried out in the absence of oxygen that breaks complex organic compounds in the manure into simpler compounds. The process produces biogas, which is a mixture of methane (CH_4) (60% to 70%), carbon dioxide (CO_2) (30% to 40%), and a number of other gases in trace amounts. Stabilized organic products in the form of ADS and ADL are also produced. The stabilized products have

1. This document is SL402, one of a series of the Soil and Water Science Department, UF/IFAS Extension. Original publication date March 2014. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. Rishi Prasad, graduate research assistant, Soil and Water Science Department; George Hochmuth, professor, Soil and Water Science Department; and Ann C. Wilkie, professor, Soil and Water Science Department, UF/IFAS Extension, Gainesville, FL 32611.

altered physical and chemical properties compared with the original manure, and they contain higher mineralized fractions of N and P (Field et al., 1984; Larsen, 1986; Plaixats et al., 1988).

The digestion can be carried out at psychrophilic (15°C to 25°C or 59°F to 77°F), mesophilic (30°C to 38°C or 86°F to 100°F), or thermophilic (50°C to 60°C or 122°F to 140°F) temperatures and occurs in several steps that require a consortium of microorganisms. The complex organic matter is converted to methane and carbon dioxide in four stepwise primary reactions that drive the AD process. These reactions are hydrolysis, acidogenesis, acetogenesis, and methanogenesis. During hydrolysis, polymers—such as cellulose, hemicellulose, pectin, and starch—are broken down by hydrolytic enzymes into oligomers or monomers (smaller sub-units). In the acidogenesis step, the oligomers or monomers are metabolized by fermentative bacteria into volatile organic acids, carbon dioxide, and hydrogen (H_2). During acetogenesis, the volatile organic acids are converted to methanogenic precursors, such as acetate, carbon dioxide, and hydrogen. Methanogenesis is the final step of the digestion process, during which the methanogenic bacteria produce methane from acetate or by reducing carbon dioxide with hydrogen (Smith et al., 1992; Wilkie, 2008).

Benefits of Anaerobic Digester Systems

1. Beneficial Digester By-Products: The two by-products, namely ADS and ADL, generated from AD can be used as crop fertilizers. The ADS and ADL obtained from anaerobic digestion of beef cattle manure contain high fractions of mineralized N (Prasad et al., 2014), which are readily available for plant uptake. Depending on the size of the livestock farm component, the farm may require a USDA/NRCS comprehensive nutrient management plan for storage, application, or handling of ADS and ADL. Further, the separated solids (ADS) can also be used as livestock bedding or sold as horticultural potting mix because of its high fiber content (WRAP, 2011).

2. **Reducing Pathogens and Odor:** Depending on the operating temperature, anaerobic digester systems can reduce pathogens and can also help control odors from manure during storage and spreading (Wilkie, 2005; Topper et al., 2006).

3. **Reducing Amounts of Weed Seeds:** Manures may contain weed seeds. The digestion process helps reduce the number of viable weed seeds in the resulting product (Penn State Extension, 2014).

4. Generating Energy: Biogas produced from anaerobic digestion of manure can be used to run combined heat and power systems for generating electricity. The gas can also be used as a boiler fuel or can be injected into natural gas pipelines after cleanup to remove impurities. The biogas can also be used to warm farm buildings, provide hot water, or even heat the digester. According to the EPA (2014b), U.S. farm anaerobic digesters produced approximately 840 million kilowatt-hours (kWh) of useable energy in 2013, which is equivalent to the electricity used by 74,205 homes for one year (USEIA, 2013).

5. Reducing Greenhouse Gases: In 2013, US farm digester systems reduced direct emissions from waste management systems by 1.73 million metric tons of carbon dioxide equivalent (MMTCO2e) and avoided emissions of 0.47 MMTCO2e by displacing the use of fossil fuels. The total emission reduction was equivalent to the carbon dioxide emissions generated from consuming 247.5 million gallons of gasoline or from burning 11,796 railcars worth of coal (EPA, 2014b).

Types of Anaerobic Digester Systems

There are various types of anaerobic digester systems. They differ by degree of complexity and the type of manure being digested. In Florida, two types of digesters are currently in operation: (1) Fixed Film Digester and (2) Mixed Plug Flow Digester. Some of the systems found commonly in the United States are described below.

1. **Covered Anaerobic Lagoon Digester (CALD)**: A CALD employs a flexible cover to seal the liquid in a large storage system. The biogas generated is recovered and piped to the combustion system. This type of digester is suited for flush manure management systems with solid contents of 0.5% to 2%. Retention time depends on size of the system and varies between 30 to 45 days. Retention time would be higher for cold climate regions.

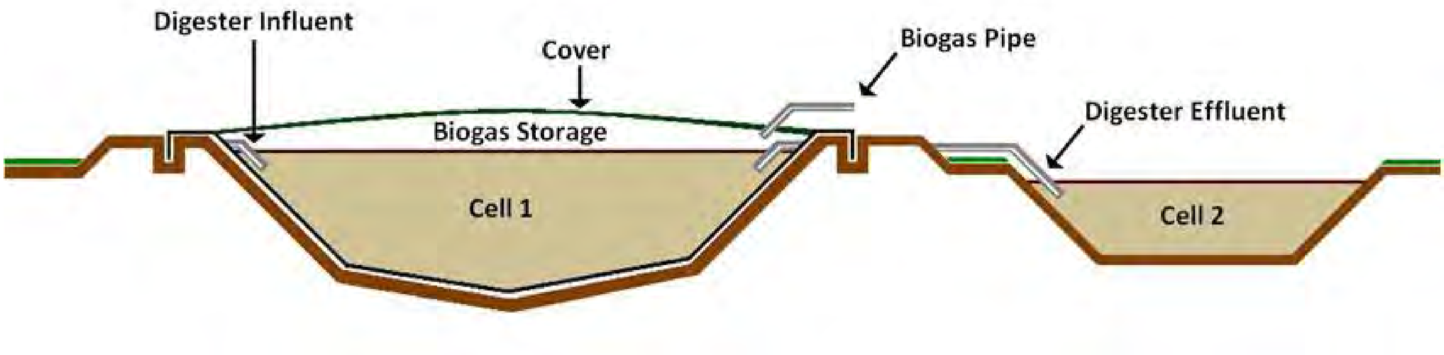


Figure 1. Schematic of a covered anaerobic lagoon digester
Credits: EPA, http://epa.gov/agstar/anaerobic/ad101/anaerobic-digesters.html

2. **Plug Flow Digester**: This type of system has long channels with a rigid or flexible cover, in which the manure moves along as a plug where the flow is constant through the digester. These systems are suitable for thicker materials, such as semi-liquid manure with 11% to 13% dry matter or higher. An example may be manure scraped from a dairy barn. The retention time is 15 to 20 days. The plug-flow system has been adapted to the digestion of manure produced by a beef cattle feeding facility and a dairy facility in Florida.

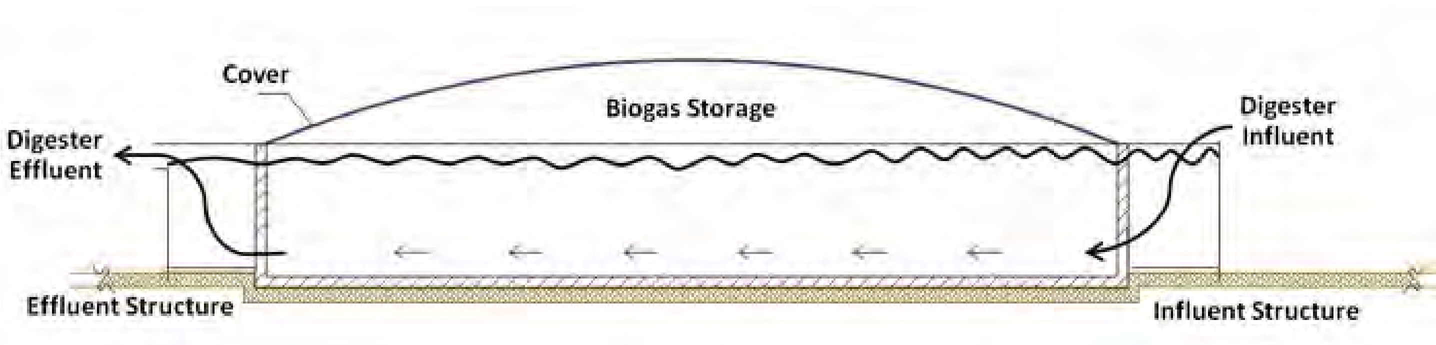


Figure 2. Schematic of a plug flow digester
Credits: EPA, http://epa.gov/agstar/anaerobic/ad101/anaerobic-digesters.html

3. **Complete Mix Digester**: This type of digester consists of a large enclosed, heated tank with a mechanical, hydraulic, or gas mixing system, where fresh material is mixed with an active mass of microorganisms. These systems are suitable for manure with lower dry matter content (4% to 12%) or manure diluted with water. The retention time is 20 to 30 days.

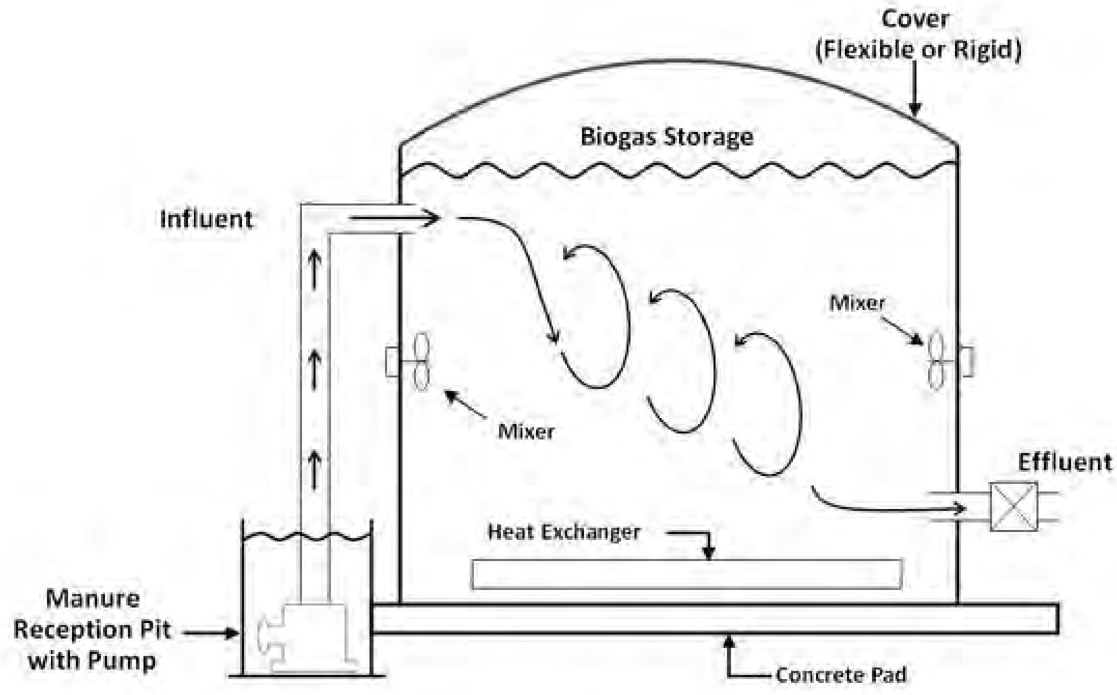


Figure 3. Schematic of a complete mix digester
Credits: EPA, http://epa.gov/agstar/anaerobic/ad101/anaerobic-digesters.html

4. **Induced Blanket Reactors (IBR)**: This is a type of digester in which a blanket of sludge is developed that retains anaerobic bacteria, through which a constant flow of influent is maintained. The flow is maintained in such a way that allows smaller particles to wash out and bigger ones to remain in the digester. This kind of system is suitable for manure with 6% to 12% total solids. The retention time is 2 to 6 days.

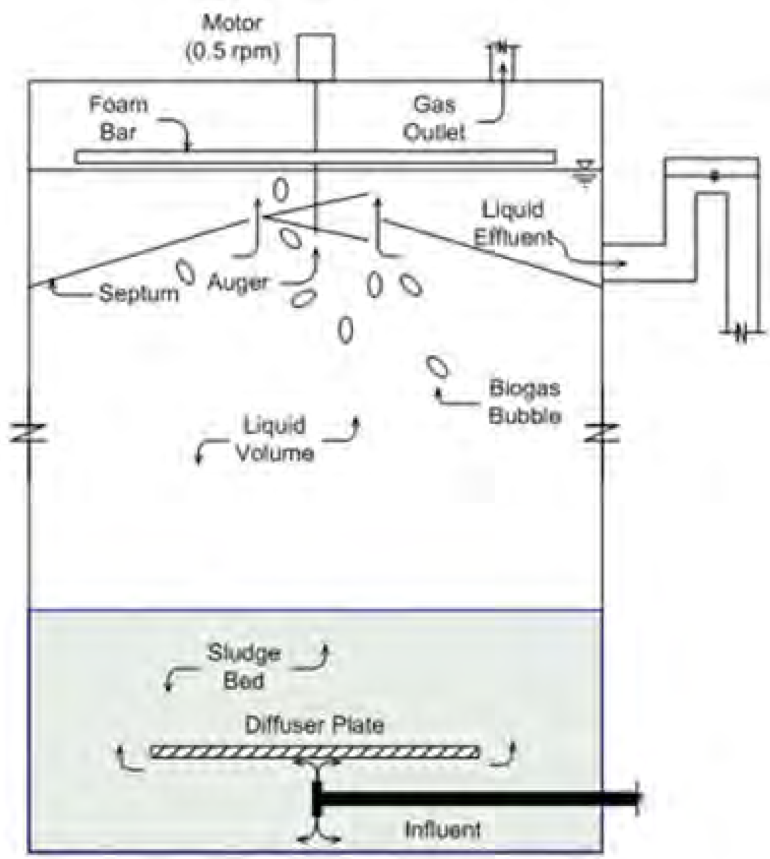


Figure 4. Schematic of an induced blanket digester
Credits: Conly Hansen, Utah State University

5. **Fixed-Film Digesters**: This type of system passes influent through a column packed with material, such as plastic media or wood chips, on which bacteria attach and grow. The effluent can be recycled back to maintain a constant upward or downward flow. A solids separator removes coarse fibrous particles from the manure before feeding the digester. The retention time can be less than five days. This kind of system is suitable for manure with 1% to 5% total solids and can be used with flushed dairy manure management systems in Florida.

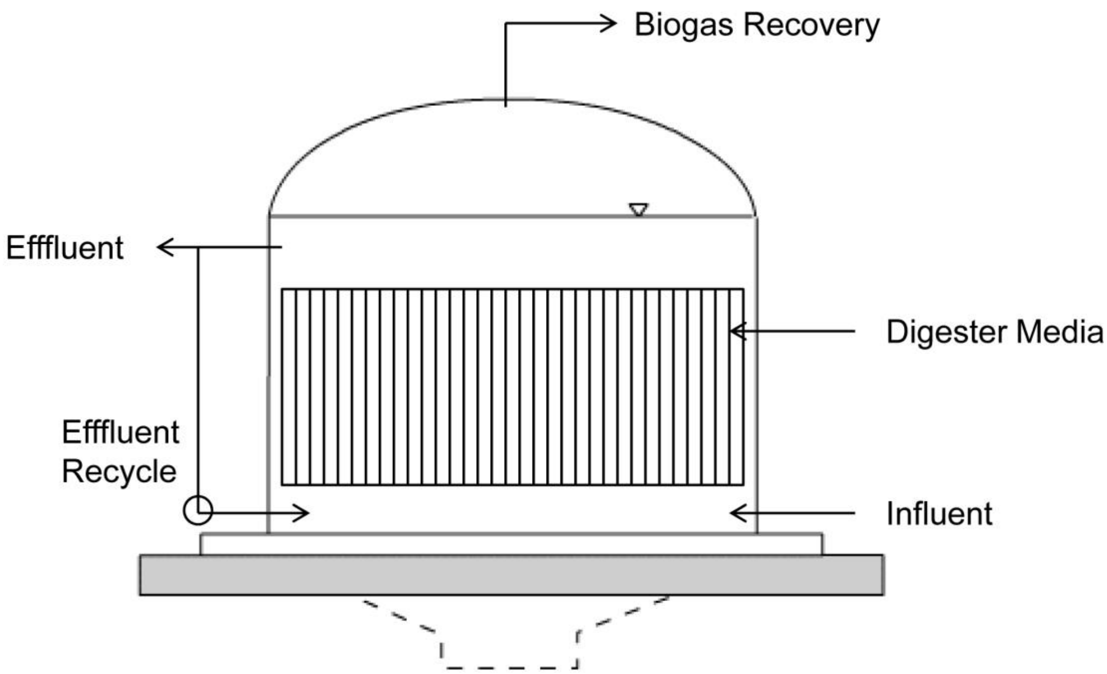


Figure 5. Schematic of a fixed-film digester
Credits: Ann C. Wilkie, University of Florida

6. **Batch Digesters**: In this system, manure is added to the reactor as a batch and removed periodically. The digester operates using four phases. First, the manure is fed to the digester, after which it is mixed with microbes and allowed to react. Subsequently, the solids settle, and the effluent is withdrawn in the fourth stage. This cycle is repeated three to four times per day. The retention time can be five days. This kind of system is suitable for manure with < 1% total solids.

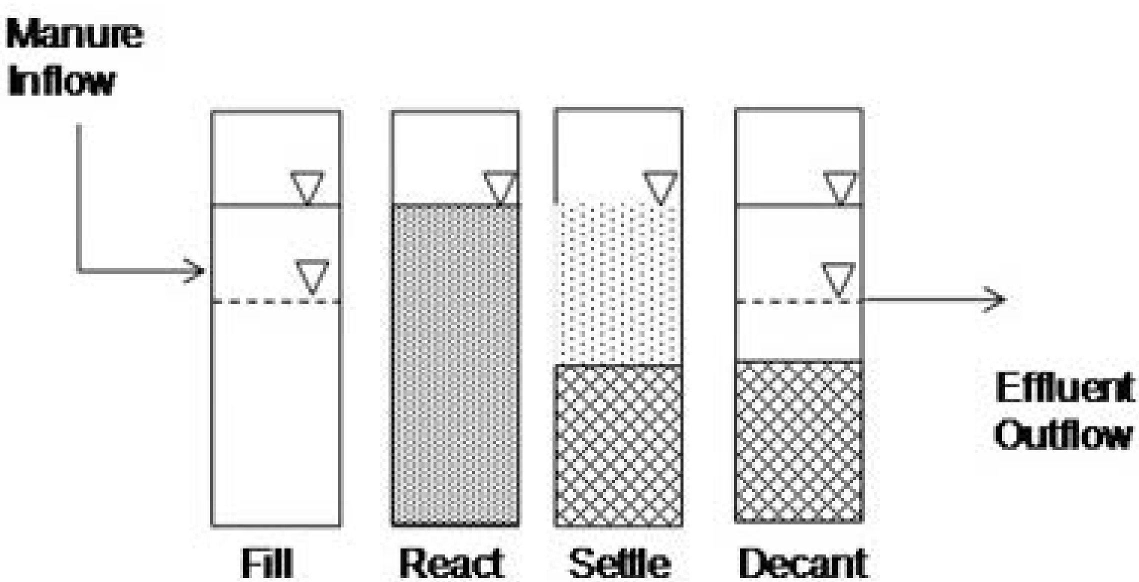


Figure 6. Schematic of a batch digester
Credits: Doug Hamilton, Oklahoma State University

A Florida example of Plug-Flow Digester and its components for a beef cattle feeding facility:

A beef cattle feeding facility in northern Florida has a manure management system comprised of five main components: (1) manure collection, (2) an anaerobic digester, (3) a biogas collection and gas utilization system, (4) storage unit for solid and liquid effluents, and (5) a land application system for solid and liquid effluents. In addition, the system also includes a chopper pump for influent homogenization, solid/liquid separation equipment, and a heat exchanger inside the digester. The five components are described below.

1. **Manure Collection:** The manure (feces and urine) is scraped out of feeding barns along with bedding material (which varies between peanuts hulls, old hay, sawdust, or spent/used horse bedding) and is fed to the digester unit.

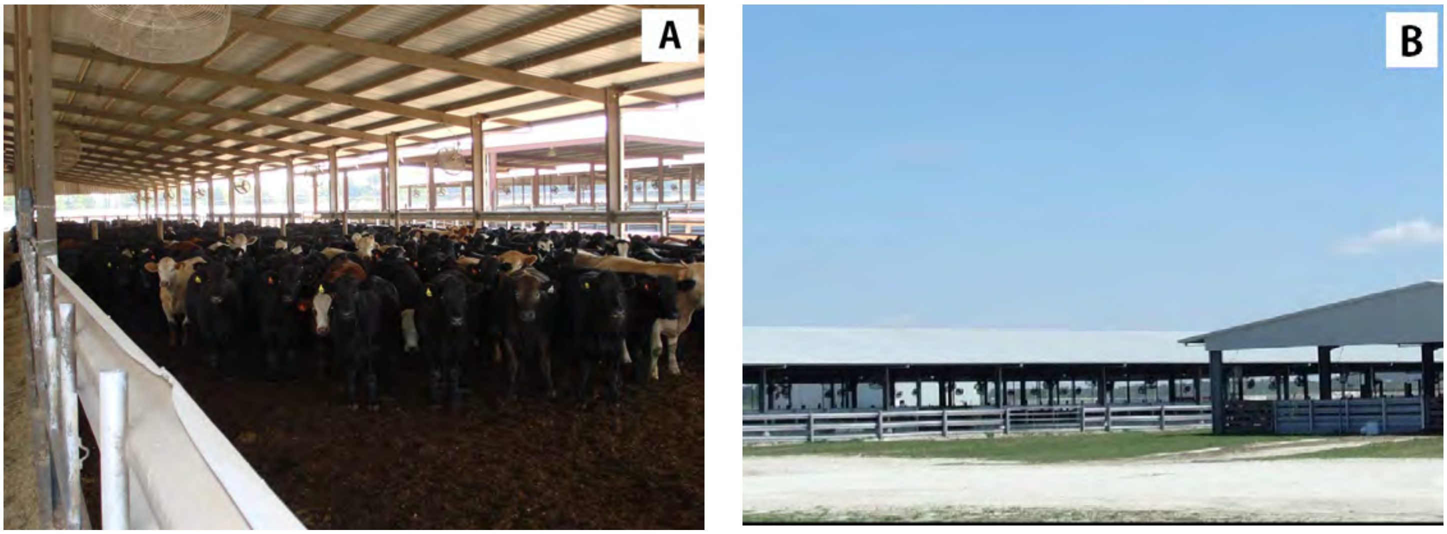


Figure 7. Manure collection: (A and B) Beef feedlot; (C and D) A tractor scraper cleaning the manure and bedding material from the feedlots and then loads the materials into a trailer to be transported to the anaerobic digester unit.
Credits: George Hochmuth, University of Florida

2. **Anaerobic Digester:** The digester used on a farm can be one of several types, as previously described; however, the selection of the digester is based on the solid content of the manure. Figure 8 illustrates a mixed plug-flow digester on a Florida beef farm, in which manure and bedding materials (influents) are mixed and allowed to stabilize via the anaerobic digestion process.

Figure 8. (A) Manure and bedding mixture is being loaded into (B) the mixed plug-flow anaerobic digester (biogas is unloaded at the far end).

3. **Biogas Collection and Utilization Unit**: This component of the system comprises the collection and transportation of biogas produced (typically, 60% CH_4 and 40% CO_2) to fuel the combined heat and power (CHP) system. Excess moisture and H_2S must be removed prior to combustion using a gas treatment system.

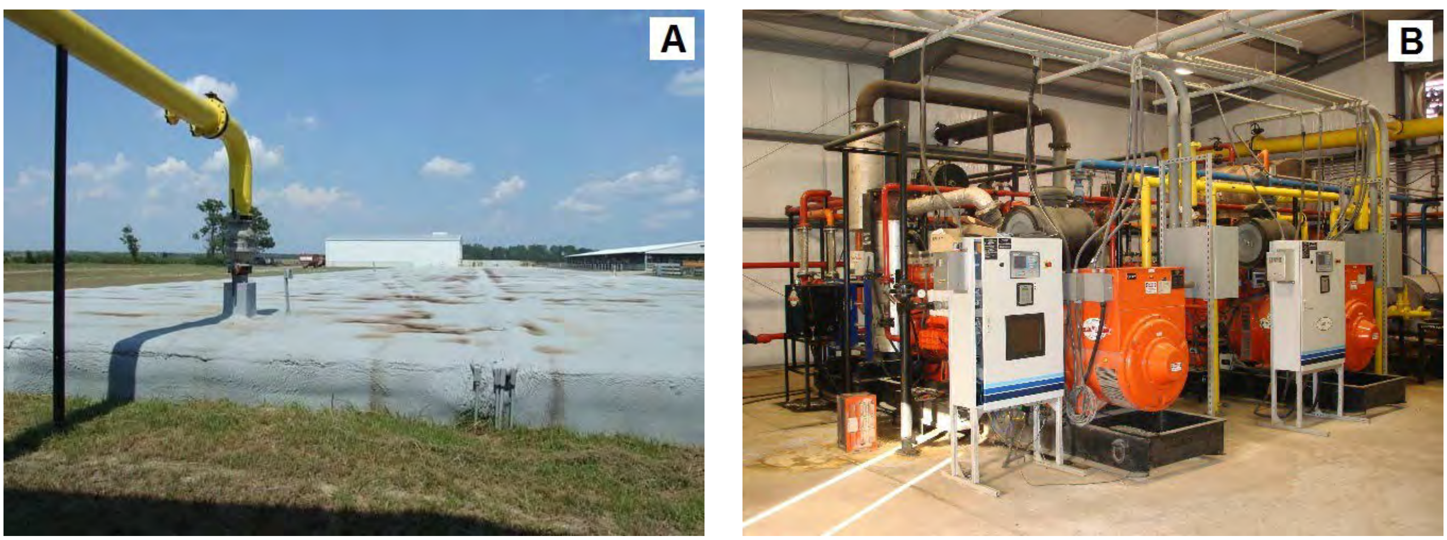
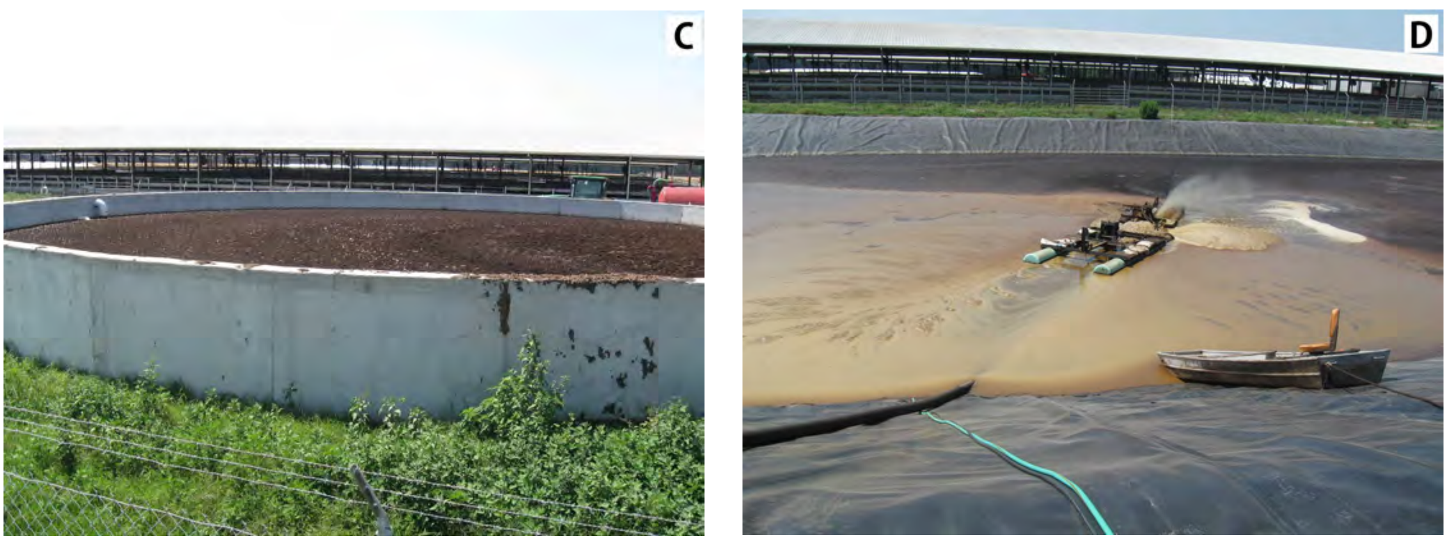


Figure 9. The biogas is transported to the CHP systems through transportation pipes (A) to the engine/generator room (B) where it is burned to turn a generator.
Credits: George Hochmuth, University of Florida

4. **Storage Units for Solid and Liquid Fractions**: There are separate storage facilities for solids and liquids resulting from the digestion process. The digested solids are separated via a screw-press mechanical separator and collected in covered storage barns. The liquid effluent is drained to a settling tank (or solids separator) where heavier fractions settle out and the liquid fraction flows to a storage pond or lagoon. Periodically, the solids are mechanically scooped from the settling tank. The liquids can be pumped from the lagoon to crop fields through an irrigation system.

Figure 10. Storage systems for (A) digested solids and (B) liquid effluents generated from anaerobic digestion of beef cattle manure. The round tank (C) further separates solids from the liquid fraction where heavier fractions settle out and the liquid flows to the storage pond where the effluent is filtered (D) before being injected into the irrigation system for field application.
Credits: Rishi Prasad and George Hochmuth, University of Florida



5. **Land Application System for Solid and Liquid Effluents**: The solids can be applied to arable land using a calibrated manure spreader. The liquid effluent from the lagoon is diluted with water and spread to the land through a center-pivot irrigation system or portable irrigation guns. The solids and liquids should be analyzed before their field application by collecting a representative sample and sending it to the nearest livestock-waste testing laboratory. The field application rates should be determined based on the nutrient content of the solids and liquids and the crop nutrient needs after accounting for losses, such as gaseous losses of N.

Figure 11. Land application of solids using a manure spreader (A) and liquid effluents through a center pivot irrigation system (B).

Issues Associated with Anaerobic Digesters

There are several issues associated with the operation of anaerobic digesters. Not all digester types are suitable for all types of manures. Producers should carefully consult with knowledgeable specialists about the potential use of anaerobic digestion on their farm in order to select the most appropriate system. Some considerations include:

1. ***Mixing.*** Proper mixing of the freshly added manure is essential for optimum digestion as well as preventing plugging, crusting, or foaming problems.

2. ***Temperature.*** Maintaining the optimum temperature range is necessary for proper digestion. Hence, cooled-down manure would require additional heating of the digester. However, this is less of a problem in Florida.

3. ***Hazards.*** There are risks of potential hazards such as explosion, asphyxiation, or hydrogen sulfide poisoning associated with digesters. The operators must be aware and properly trained to operate a digester and know how to take correct preventive measures against dangers.

4. ***Corrosive Gases:*** Hydrogen sulfide is generated during the anaerobic digestion process when the influents fed to the digester system are rich in sulfur. The gas has corrosive effects on mechanical parts and gaskets. Hence, its removal is important to prevent the corrosive action.

5. ***Souring of Anaerobic Digesters:*** This condition results when the pH of the manure undergoing digestion drops to the acidic range (pH < 6.5), resulting in inhibition of methane-forming bacteria. To avoid this kind of situation, bicarbonates could be added to maintain optimum pH (7 to 8.5).

References

Field, J. A., J. S. Caldwell, S. Jeyanayagam, R. B. Reneau, W. Kroontje, and E. R. Collins.1984. Fertilizer recovery from anaerobic digesters. Trans. ASAE. 27: 1871–1876.

Hamilton, D. 2012.Types of anaerobic digesters. Available at http://www.extension.org/pages/30307/types-of-anaerobic-digesters.

Larsen, K. E. 1986. Fertilizer value of anaerobic treated cattle and pig slurry to barley and beet. In: Kofoed, A.D., J.H. Williams, and P. L'Hermite (Eds.), Efficient land use of sludge and manure. Elsevier Applied Science Publishers, London, pp. 56–60.

Plaixats, J., J. Barcelo, and J. Garcia-Moreno. 1988. Characterization of the effluent residue from anaerobic digestion of pig excreta for its utilization as fertilizer. Agrochemica 32: 236–239.

Prasad, R., G. Hochmuth, R. Mylavarapu, and M. C. Giurcanu. 2014. In situ nitrogen release dynamics of effluents of anaerobic digestion of beef- cattle manure in sandy soil. (manuscript in preparation for Bioresource Technol.)

Penn State Extension. 2014. An introduction to anaerobic digesters. Available at http://extension.psu.edu/natural-resources/energy/waste-to-energy/resources/biogas/basics-of-anaerobic-digestion.

Smith, W. H., A. C. Wilkie, and P. H. Smith. 1992. Methane from biomass and waste - a program review. TIDE (Teri Information Digest on Energy), 2(1):1-20.

Topper P. A., R. E. Graves, and T. Richard. 2006. The fate of nutrients and pathogens during anaerobic digestion of dairy manure (G-71). Penn State Extension. Available at http://extension.psu.edu/natural-resources/energy/waste-to-energy/resources/biogas/projects/g-71

United States Energy Information Administration (USEIA). 2013. Residential Energy Consumption Survey Data, Table CE2.1 Household Site Fuel Consumption in the U.S., Totals and Averages, 2009. Available at http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption

United States Environmental Protection Agency (USEPA-AgSTAR). 2014a. Operating Anaerobic Digester Projects. Available at http://epa.gov/agstar/projects/

United States Environmental Protection Agency (USEPA-AgSTAR). 2014b. 2013 Use and Benefits of AD in the Livestock Sector. Available at http://www.epa.gov/agstar/documents/2013usebenefits.pdf

Wilkie, A. C. 2005. Anaerobic digestion: biology and benefits. In: *Dairy Manure Management: Treatment, Handling, and Community Relations.* NRAES-176, Natural Resource, Agriculture, and Engineering Service, Cornell University, Ithaca, NY, pp. 63–72. http://biogas.ifas.ufl.edu/Publs/NRAES176-p63-72-Mar2005.pdf

Wilkie, A. C. 2008. Biomethane from Biomass, Biowaste, and Biofuels. In: *Bioenergy*, Wall, J. D., C. S. Hardwood, and A. Demain (Eds.), American Society fo Microbiology Press, Washington, DC, pp. 195–205. http://biogas.ifas.ufl.edu/Publs/Bioenergy_CH16_ASM_Press_2008.pdf

WRAP. 2011. New Markets for digestate from anaerobic digestion. Available at http://www.wrap.org.uk/sites/files/wrap/New_Markets_for_AD_WRAP_format_Final_v2.c6779ccd.11341.pdf

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Chapter 16

Biomethane from Biomass, Biowaste, and Biofuels

ANN C. WILKIE

Biofuel production from agricultural, municipal, and industrial wastes is efficiently accomplished through conversion to biogas, a mixture of mostly methane (CH_4) and carbon dioxide (CO_2), via anaerobic digestion. Anaerobic digestion is a process by which a complex mixture of symbiotic microorganisms transforms organic materials under oxygen-free conditions into biogas, nutrients, and additional cell matter, leaving salts and refractory organic matter. In practice, microbial anaerobic conversion to methane is a process for both effective waste treatment and sustainable energy production. In waste treatment, this process can provide a source of energy while reducing the pollution and odor potential of the substrate. Unlike fossil fuels, use of renewable methane represents a closed carbon cycle and thus does not contribute to increases in the atmospheric concentration of carbon dioxide (Wilkie, 2005).

Microbial methane production has the potential for reducing the demand for fossil fuels like coal, oil, and natural gas that have provided the power for developing and maintaining the technologically advanced modern world. However, fossil resources are finite, and their continued recovery and use significantly impact our environment and affect the global climate. Shortages of oil and gas are predicted to occur within our lifetimes or those of our children. To prepare for a transition to more sustainable sources of energy, viable alternatives for conservation, supplementation, and replacement must be explored, posthaste.

Biogas production from agricultural, municipal, and industrial wastes can contribute to sustainable energy production, especially when nutrients conserved in the process are returned to agricultural production (Fig. 1). Little energy is consumed in the process, and consequently the net energy from biogas production is high compared to other conversion technologies. The technology for methane production is scalable and has been applied globally to a broad range of organic waste feedstocks, most commonly animal manures (Wilkie et al., 2004). However, methane production is not limited to conversion of animal manures. Biogas can be made from most biomass and waste materials regardless of the composition and over a large range of moisture contents, with limited feedstock preparation. The feedstocks for this omnivorous process can be composed of carbohydrates, lignocellulosics, proteins, fats, or mixtures of these components. The process is suitable for conversion of liquid, slurry, and solid wastes; it can even be employed for the conversion of gaseous combustion products (synthesis gas) from thermochemical gasification systems. In addition, methane production can be effectively applied to improve energy yields from other biofuel production processes including bioethanol, biodiesel, and biohydrogen production. Implementation of digestion technology at agricultural, municipal, and industrial facilities allows efficient decentralized energy generation and distribution to local markets. While traditionally applied to wastes and wastewaters, the anaerobic digestion of energy crops can also be employed in a sustainable bioenergy system.

ANAEROBIC MICROBIOLOGY

Methane is the end product of anaerobic metabolism—a metabolic sequence carried out by communities of hydrolytic bacteria and fungi, acid-producing intermediary organisms, and finally, methanogenic *Archaebacteria*. Methane-producing communities are very stable and resilient, but they are also complex and largely undefined.

Buswell and Sollo (1948) demonstrated the treatability of a range of wastes and emphasized the concept of an acid phase versus a methane phase, showing the importance of volatile organic acids as intermediates in the process. They also demonstrated the applicability of a stoichiometric equation that balanced carbon, hydrogen, and oxygen (equation 1) to predict the amount

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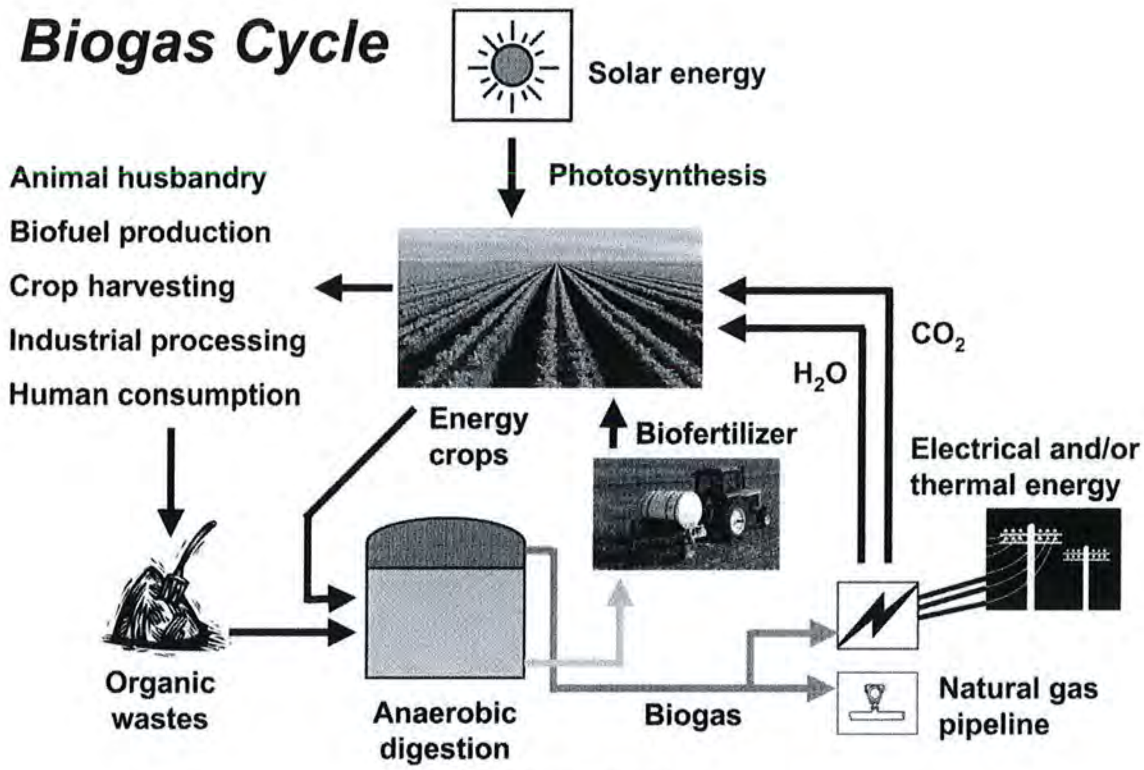

Figure 1. Biogas cycle

of methane and carbon dioxide evolved from conversion of organic compounds with a known empirical formula. Later, ^{14}C tracers were used to show that acetate was indeed cleaved to form methane and carbon dioxide, suggesting that acids were important intermediates in the conversion process.

$$C_nH_aO_b + (n - a/4 - b/2)H_2O \rightarrow (n/2 - a/8 + b/4)CO_2 + (n/2 + a/8 - b/4)CH_4 \quad (1)$$

Of great importance to the understanding of anaerobic microbiology was the discovery of Bryant et al. (1967), through isolating the elusive "S-organism" from *Methanobacterium omelianskii*, that the conversion of ethanol to methane was accomplished with a mixed culture. The discovery of other cocultures quickly followed, and the number of species isolated in pure culture increased. With the identification of closely coupled syntrophic cocultures of methanogens and other species, the earlier hypothesis of an acid phase followed by a methanogenic phase developed into a more descriptive scheme that embraces the importance of hydrogen as an intermediate in the process.

First the fermentative, or hydrolytic, bacteria and fungi hydrolyze complex organic polymers and ferment them to organic acids, hydrogen (or formate), and carbon dioxide. The hydrogen-producing acetogenic bacteria ferment the larger acids to a combination of acetic acid, one-carbon compounds, hydrogen, and carbon dioxide. The homoacetogenic bacteria synthesize acetic acid by utilizing hydrogen/carbon dioxide or one-carbon compounds or by hydrolyzing multicarbon compounds.

The methanogenic *Archaebacteria* uniquely catabolize acetic acid and one-carbon compounds to methane. The methanogens are obligate anaerobes that can pick up electrons from dead-end fermentations, through interspecies hydrogen transfer, and shuttle these electrons through a unique form of respiration which results in the reduction of carbon dioxide to methane. The organisms that use hydrogen to reduce CO_2 are commonly regarded as the earliest life forms due to their chemoautotrophic abilities.

All morphological forms are represented among the methanogens including rods, cocci, spirals, sarcinae, and filamentous organisms. Surprisingly, this diverse group of organisms is known to metabolize a very limited number of substrates including acetate, formate, methanol, acetone, methylamines, carbon monoxide, and H_2/CO_2. The substrates for methanogenesis divide these organisms into groups, two of which are notably important in active digesters: the aceticlastic methanogens, which cleave acetic acid, and the hydrogen-utilizing methanogens, which utilize hydrogen and one-carbon compounds. However, this distinction is not always useful since some species may metabolize both substrates.

For aceticlastic methanogens, low levels of acetate (<50 mg/liter) favor the growth of more-filamentous organisms (e.g., *Methanosaeta*) that must rely on a larger surface-to-volume ratio in order to improve substrate diffusion rates. High levels of acetate favor the predominance of clusters of aceticlastic methanogens (e.g., *Methanosarcina*), which have lower surface-to-volume ratios that serve to protect them from the inhibitory nature of high organic acid concentrations. Differences in maximum growth rate and substrate utilization affinities can be exploited to select for predominant methanogens. Organisms such as *Methanosarcina* should be favored for selection if high conversion rates of high-strength wastes are the primary goal, whereas *Methanosaeta* should be favored if low effluent biochemical oxygen demand is more important. In addition, these attributes can be exploited together by staging an anaerobic process with the first stage favoring high conversion rates and the next stage favoring effluent quality.

PROCESS

In practice, anaerobic digestion is the engineered methanogenic decomposition of organic matter, carried out in reactor vessels, called digesters, that may be mixed or unmixed and heated or unheated. The process uses a mixed culture of ubiquitous organisms, and due to its mixed-culture nature, there are no requirements for feedstock sterilization and no contamination concerns. Stable digester operation requires that the bacterial groups be in dynamic equilibrium, as some of the intermediate metabolites (hydrogen, propionate, ammonia, and sulfide) can be inhibitory and the pH of the system must remain near neutral. Also, methane is sparingly soluble, such that end product recovery is efficient and economical as the gas separates itself from the aqueous phase and is easily removed from the digester through piping that conveys it to storage for final use.

Current commercial-scale methods of methane production yield from 50 to 97% conversion of substrate to methane on an energy basis, depending on the feedstock. The mean oxidation state of the feedstock determines the stoichiometry of the end products. Carbohydrate substrates yield 50% methane and 50% carbon dioxide, while more-reduced feedstocks (e.g., lipids) yield higher proportions of methane. The theoretical methane yield of carbohydrates, proteins, and fats is given in Table 1. Also, carbohydrate-rich substrates yield more methane than do feedstocks with high concentrations of lignocellulose.

Table 1. Theoretical methane yield of biomass components

Component	Methane yield (liter/g of VS)
Carbohydrates	0.35
Proteins (leucine)	0.57
Fats (lauric acid)	0.95

The natural assemblages in the mixed culture have evolved to form robust and stable cultures with extremely broad substrate utilization capabilities. There is no requirement for genetically modified organisms to extend catabolic activity, so sterilization of process residuals is not necessary. Although the free energy available from anaerobic conversion of substrates to methane is low, causing low microbial-growth rates, the activity and turnover rates of substrates are higher than for aerobic metabolism. Also, anaerobic respiration of methanogens results in the production of a noninhibitory product, methane, that moves into the gaseous phase, which contrasts with other fermentation processes that produce inhibitory final products (e.g., ethanol) that remain in solution. This gives the process a distinct advantage for either continuous or batch conversion of substrates to energy products.

Of significance for the application of anaerobic digestion is the high level of energy recovery in the biogas compared to the energy content of the substrate utilized. The efficiency of this conversion is directly related to the low level of free energy of reaction available for microbial synthesis. Rather than transforming the energy in waste into sludge as in aerobic processes, a minimal amount of this energy is consumed by anaerobic cell synthesis and the rest is retained in the methane end product. This also explains the low rates of microbial growth in anaerobic systems compared to aerobic processes.

Chemical oxygen demand (COD) is a convenient measurement to estimate the organic content in a wastewater or biomass sample and, theoretically, 0.35 liter of methane is formed from 1 g of COD digested. In aerobic processes such as the activated-sludge process, the sludge yield can be as high as 0.5 kg of dry solids per kg of COD utilized, whereas the sludge yields for anaerobic processes range from 0.03 to 0.15 kg of dry solids per kg of COD consumed depending on the substrate. Sludge by-product from aerobic processes requires further treatment for stabilization in order to reduce odor and pollution potential. Furthermore, after stabilization, the sludge still requires final disposal. Anaerobic treatment processes, in contrast, produce a relatively small amount of sludge by-product which is more stable, less capable of causing odor or pollution problems, and ready for final disposition in sustainable crop production. Also, anaerobic treatment results in pathogen decimation through microbial competition and starvation.

Nutrients contained in the organic matter are conserved and mineralized to more soluble and biologically available forms, providing a more predictable biofertilizer. Since sludge production in anaerobic digestion is minimal, virtually all of the nitrogen and phosphorus contained in the original waste is retained in the treated effluent. By recycling the treated effluents back to productive agricultural lands at appropriate rates, the crops benefit from the presence of these important plant nutrients. Where insufficient cropland is available, other nutrient recovery technologies may be employed to reduce the nutrient content of the digested wastewater.

DESIGNS

The construction of anaerobic digesters for biogas production has little in common with that of industrial fermentors. The low value of energy products compared with fermentation products necessitates low-cost construction and materials. While industrial fermentation vessels are often jacketed stainless steel tanks, with baffles, agitators, and clean-in-place systems, and constructed on elevated stands, anaerobic digesters are often simple insulated concrete or carbon steel tanks constructed with low-cost materials either on or below the surface. Without the need for efficient aeration, the requirement for mixing must only meet the needs for microbial contact with substrate, uniform temperature, and prevention of solids accumulation. Since sterility is not a concern, no clean-in-place systems or provisions to prevent microbial contamination are required. Unlike other fermentations, no specific process or equipment is required for product recovery, since methane is relatively insoluble and therefore separates spontaneously.

Anaerobic digesters must be essentially gas-tight vessels with a provision for introducing feedstock and removing effluent and biogas. The classical anaerobic digester is essentially a chemostat. Tanks with rigid tops must have provisions for pressure and vacuum relief, and biogas piping must meet safety standards. Tank tops may also be floating rigid tops or flexible membrane materials. Simple heat exchangers may be placed internally or external to the tank, and mixing can employ agitators, simple recirculation of the mixed liquor, or injection of compressed biogas.

There are two broad classifications of digesters, those that rely on suspended growth of microorganisms and those that employ a mechanism for immobilization to retain active microbial biomass within the vessel. With feedstocks containing high levels of suspended solids, nonimmobilized designs are generally used including covered anaerobic lagoons, complete-mix reactors, plug-flow reactors, and anaerobic contact reactors. These digesters require relatively long hydraulic retention times (HRT) of 15 to 60 days and moderate organic loading rates (OLR), typically expressed as weight of organic matter (volatile solids [VS] or COD) per culture volume of reactor per day. The maximum OLR and minimum HRT that can be applied are dependent on operating temperature, waste characteristics, and reactor type.

Feeds with low concentrations of suspended solids ($<2\%$) can be digested in high-rate immobilized reactors such as the upflow anaerobic sludge-bed digester (UASB), anaerobic filter (AF), and fixed-film systems. These reactors retain high concentrations of immobilized microorganisms, permit low HRT without organism washout, and are particularly suited for treatment of soluble wastewaters. The tendency of microbial consortia to adhere to surfaces and grow as a biofilm spurred the development of both the aerobic trickling filter and the AF reactor (also called a packed bed). While the principle of filling a reactor with a packing media is straightforward, the selection of packing material and operational strategies may have significant effects on performance and costs. Media used for packing have included natural materials such as stones, clay, wood, bamboo, and reeds, as well as polymers made of polyvinyl chloride, polyethylene, and polypropylene. Polymers shaped as rings, bio-balls, and oriented modular media have been used in various applications. In some cases, AFs rely on trapping microbial solids within the media rather than using a true biofilm for microbial activity. Thus, the term "fixed-film digesters" should be used to designate true biofilm reactor designs.

In immobilized reactors where a highly degradable, high-COD wastewater (>20 g/liter) is fed, effluent recycling can be employed to overcome localized acidification of the microbial biomass. In addition, highly acidic wastewater can benefit from effluent recycle to minimize the requirement for added alkali by using the alkalinity of the effluent. Phased digestion is often employed for highly degradable waste, where a primary acidogenic reactor is operated at short HRT to form intermediate acids, which are then fed into a methanogenic reactor. This approach can control sharp pH swings, enhance biofilm and granular sludge activity, and lower overall process HRT. A further refinement involves staging, where reactors are employed in series to achieve higher treatment efficiencies. The first reactor is optimized to maximize biogas production (higher OLR), whereas the second reactor is optimized for treatment efficiency (lower OLR).

INOCULATION

The use of a source high in anaerobic microbes (e.g., digester effluent) to start up an anaerobic system is called inoculation. The quality and quantity of inoculum are critical to the performance, time required, and stability of biomethanogenesis during commissioning (start-up) or restart of an anaerobic digester. Much agricultural processing occurs on a seasonal basis, and at the start of a new campaign, the anaerobic treatment operation must be restarted after a period of being idled. In addition, a digester may need inoculation after maintenance operations. In manures and some wastes, the microbes needed for digestion may be already present in the waste in small numbers, albeit sufficient to act as an inoculum, and will develop into a fully functional bacterial population if the right conditions are provided, including a suitable temperature and retention time. Other wastes, especially from industry, may be relatively sterile and require the addition of inoculum. With batch and plug flow designs, inoculum must be added with the feed and low inoculum levels may lead to imbalance due to the more rapid growth rate of acid-forming bacteria (compared to methanogens) and depression of pH. Depending on the buffering capacity (alkalinity), a digester may be able to overcome low inoculum rates.

Granular sludge, the microbial by-product from UASB reactors, has been shown to be a practical source for inoculum due to its stability in storage, microbial density, and availability. Granular sludge may be used to enhance methanogen populations for start-up of complete-mix reactors and anaerobic filters as well as UASBs. Start-up of immobilized systems requires that biofilm or granule growth be optimized to achieve design performance quickly. During start-up, performance parameters (methane gas content, ratio of acids-to-alkalinity, and pH) should be carefully monitored to ensure that performance is not deteriorating. In many applications, a high inoculation rate is not feasible or digester effluent is not available. Under such circumstances, one must obtain inoculum from an anaerobic environment (anaerobic sediments or animal manure) and gradually develop and acclimate the inoculum to the level needed. The major obstacle to overcome is the fact that, during growth toward a mature population, acid formers may grow faster than methanogens, leading to an increase in volatile organic acids, reduced pH, and loss of methane production. This can be prevented by buffering the system and/or reducing the feed loading rate.

NUTRITION

Nitrogen and phosphorus are the major nutrients required for anaerobic digestion. These elements are building blocks for cell synthesis, and their requirements are directly related to the microbial growth in anaerobic digesters. An empirical formula for a typical anaerobic bacterium is $C_5H_7O_2NP_{0.06}$ (Speece, 1996). Thus, the nitrogen and phosphorus requirements for cell growth are 12 and 2%, respectively, of the volatile solids converted to cell biomass. If 10% of the degradable solids are converted into microbial biomass, this would be equivalent to a requirement of 1.2 and 0.2% of the biodegradable volatile solids, respectively, for nitrogen and phosphorus. Ammonia is also an important contributor to the buffering capacity in digesters but can be toxic to the process at high levels.

Methane production and volatile acid utilization may be enhanced when micronutrients are added to nutrient-deficient substrates. Requirements for several micronutrients have been identified, including iron, copper, manganese, zinc, molybdenum, nickel, and vanadium (Wilkie et al., 1986; Speece, 1996). Available forms of these nutrients may be limiting because of their ease of precipitation and removal by reactions with phosphate and sulfide. Limitations of these micronutrients have been demonstrated in reactors in which the analytical procedures failed to distinguish between available and sequestered forms. Other nutrients needed in intermediate concentrations include sodium, potassium, calcium, magnesium, and sulfur. Combining wastes is an effective means of overcoming nutrient limitations. Codigestion with manure often enhances the conversion of other biomass and waste feedstocks through balancing micronutrients.

CONTROL/TOXICITY

Biological methanogenesis has been reported at temperatures ranging from 2°C (in marine sediments) to over 100°C (in geothermal areas). Most applications of this fermentation have been performed under ambient (15 to 25°C), mesophilic (30 to 40°C), or thermophilic (50 to 60°C) temperatures. In general, the overall process kinetics doubles for every 10-degree increase in operating temperature, up to some critical temperature (about 60°C) above which a rapid drop-off in microbial activity occurs. Most commercial anaerobic digesters are operated at mesophilic or ambient temperatures. A higher operating temperature permits reduced reactor size.

Thermophilic digesters exhibit some differences compared to mesophilic digesters. The microbial populations operating in the thermophilic range are genetically unique, do not survive well at lower temperatures, and can be more sensitive to temperature fluctuations outside their optimum range. Also, ammonia is more toxic in thermophilic digesters due to a higher proportion of free ammonia. Although thermophilic digesters have higher energy requirements, heat losses can be minimized through effective insulation and use of heat exchangers to reduce effluent heat losses. Thermophilic operation is practiced when the reduced reactor size justifies the higher energy requirements and added effort to ensure stable performance, when process wastewater is already hot, or when pathogen removal is of greater concern.

Biomethanogenesis is sensitive to several groups of inhibitors including alternate electron acceptors (oxygen, nitrate, and sulfate), sulfides, heavy metals, halogenated hydrocarbons, volatile organic acids, ammonia, and cations. The intermittent presence of microbial inhibitors in the wastewater stream can lead to serious process upsets and failure. The toxic effect of an inhibitory compound depends on its concentration and the ability of the bacteria to acclimate to its effects. The inhibitory concentration depends on different variables, including pH, HRT, temperature, and the ratio of the toxic substance concentration to the bacterial mass concentration. Antagonistic and synergistic effects are also common. Methanogenic populations are usually influenced by dramatic changes in their environment but can be acclimated to otherwise toxic concentrations of many compounds.

Organic acids, pH, and alkalinity are related parameters that influence digester performance. Under conditions of overloading and the presence of inhibitors, methanogenic activity cannot remove hydrogen and organic acids as fast as they are produced. The result is accumulation of acids, depletion of buffer, and depression of pH. If uncorrected via pH control and reduction in feeding, pH will drop to levels that stop the fermentation. Independent of pH, extremely high volatile acid levels (>10,000 mg/liter) also inhibit performance. The major alkalis contributing to alkalinity are ammonia and bicarbonate. The most common chemicals for pH control are sodium hydroxide, lime, magnesium hydroxide, and sodium bicarbonate. Lime produces calcium bicarbonate up to the point of solubility of 1,000 mg/liter. Sodium bicarbonate adds directly to the bicarbonate alkalinity without reacting with carbon dioxide. However, precautions must be taken not to add this chemical to a level of sodium toxicity (>3,500 mg/liter). Currently, the control of feed rate to an anaerobic digester most often relies on off-line measurements of volatile organic acids to prevent process upset through manual intervention. Several investigators have advocated control schemes based on biogas production rate, alkalinity, liquid-phase hydrogen, pH, and digester substrate concentration.

BIOGAS USE

Biogas is a flexible form of renewable energy that may be used directly for process heat and steam or converted to electricity in reciprocating engines, gas turbines, or fuel cells. Biogas is composed mostly of methane, as is natural gas, but may contain some impurities such as hydrogen sulfide. Biogas can be used readily in all applications designed for natural gas such as direct combustion for absorption heating and cooling, cooking, space and water heating, and drying. Biogas can also be upgraded to natural gas specifications and injected into the existing network of natural gas pipelines. Biogas may also be catalytically transformed into hydrogen, ethanol, or methanol.

If cogeneration is employed in the biogas conversion system, heat normally wasted may be recovered and used for hot water production. In gas turbines, the waste heat may be used to make steam and drive an additional steam turbine, with the final waste heat going to hot water production. This is termed a combined cycle cogeneration system. Combining hot water recovery with electricity generation, biogas can provide an overall conversion efficiency of 65 to 85%.

For smaller biogas installations, shaft horsepower and electrical generation are most effectively achieved by the use of a stationary internal combustion engine. Adequate removal of hydrogen sulfide is important to reduce engine maintenance requirements. If compressed for use as an alternative transportation fuel in light and heavy-duty vehicles, biogas can use the same existing technique for fueling as currently used for compressed-natural-gas vehicles. In many countries, biogas is viewed as an environmentally attractive alternative to diesel and gasoline for operating buses and other local transit vehicles. The exhaust fume emissions from methane-powered engines are lower than the emissions from diesel and gasoline engines. Also, the sound level generated by methane-powered engines is generally lower than that generated by diesel engines.

WASTE RESOURCES

Recently, anaerobic wastewater pretreatment has attained extensive acceptance for a variety of industrial wastewaters associated with food processing, beverages, breweries, distilleries, and most recently pulp and paper production. Batch operation of the production sequence is common in these industries, producing a wastewater of variable strength and quantity, complicating the operation of a continuous biological treatment system. A few examples of agricultural and industrial waste streams are identified in Table 2. Traditionally, treatment of manures and municipal sludge have been the most prominent applications of anaerobic digestion, and there is currently a resurgence in the promotion of on-farm biogas production from animal manure (see the Agstar Program, U.S. Environmental Protection Agency; http://www.epa.gov/agstar/). Anaerobic digestion of municipal sludge is applied at many municipal wastewater treatment plants. However, the pretreat-

Table 2. Examples of agricultural and industrial wastewater strength

Feed source	Wastewater COD (mg/liter)
Beef processing	7,500
Beverage	1,600
Brewery	1,900–2,400
Clam	3,500
Confectionery	9,500
Dairy	1,900–5,260
Distillery	95,000
Ice cream	29,063
Municipal	200
Pharmaceutical	9,985
Pork processing	1,572
Potato	2,000–10,500
Pulp and paper	1,600–16,400
Rendering	8,800
Sauerkraut	10,000
Starch	8,800–11,400
Sugar beet refining	5,000–20,000
Vegetable	2,300–10,000
Whey	8,900
Yeast	30,000

ment of municipal wastewater by high-rate anaerobic treatment offers a new application of biogas production in municipal wastewater treatment works (van Haandel and Lettinga, 1994). Conversion of soluble biochemical oxygen demand in municipal wastewater to biogas avoids much of the costs of aeration and the production of residual sludge requiring disposal.

The organic fraction of municipal solid wastes (MSW) also has a high potential for biogas production. A majority of MSW is disposed of in landfills, many of which are implementing biogas recovery systems. However, nutrients contained in MSW are sequestered in landfills and the land area for these operations is often not suitable for economic development. Separation of the organic fraction of MSW and conversion to biogas can produce compost residuals that are suitable for crop production, which results in a sustainable solid-waste recycling system.

CODIGESTION

Digestion of a given waste can often benefit from codigestion with other waste streams that are locally available. There are many reasons for considering codigestion, including the potential to reach a more favorable economy of scale due to materials handling or optimal production and utilization of biogas. Codigestion may provide increased revenues from tipping fees as well as from enhanced biogas production. Very dry feedstocks may be blended with wastewaters to facilitate handling and digestion. Waste high in protein, which could suffer from ammonia toxicity, can be blended with lignocellulosic materials, which are low in nitrogen, to improve digestion rates. Household or other waste streams can be blended with manure to improve the microbial diversity and contribute essential micronutrients. The organic fraction of MSW is suitable for codigestion with farm and industrial wastes, and many successful examples can be found in Europe (see the European Anaerobic Digestion Network; http://www.adnett.org/). Conversion of agricultural, municipal, and industrial wastes to biogas offers a sustainable means for biofuels production, yet the role of biogas production in the production of other biofuels (e.g., alcohols, biodiesel, hydrogen, and syngas) is also an application worthy of exploitation.

METHANE IN BIOETHANOL PRODUCTION

The production of biomethane at bioethanol production facilities can contribute to the energy requirements of ethanol production or to increasing the energy yields from substrates for sale to local markets as fuel or electricity. Depending on the feedstock and process design, ethanol production results in several by-products (Fig. 2) which may include crop residues, stillage, evaporator condensate, condensed solubles, spent cake and/or distillers' grains, all of which have a high potential for methane production (Table 3). Stillage, a residual of the distillation of ethanol from fermentation liquor, contains a high level of biodegradable COD as well as nutrients and has a high pollution potential (Wilkie et al., 2000). Up to 20 liters of stillage may be generated for each liter of ethanol produced. Conversion of stillage to biogas and application of effluent to croplands results in a more sustainable ethanol production system.

Many ethanol plants minimize effluent discharges by evaporation of the stillage to produce evaporator condensate (used partially for makeup water) and condensed solubles. The evaporator condensate contains volatile fermentation products that can inhibit ethanol fermentation. Anaerobic digestion can remove these fermentation products and provide a liquid more suitable for process recycling. The distillers' grains and condensed solubles are normally blended for use in animal feed as dried distillers' grains and solubles. However, the current rapid expansion of ethanol production could lead to saturation of the feed market with dried distillers' grains and solubles, affecting the sale value of this by-product. Thus, there is an opportunity for biogas production from these by-products to offset facility energy requirements. In cellulosic ethanol production, nonfermentable hydrolysis products can also be converted to methane. Finally, crop residues may also be harnessed for biogas production, which can greatly improve the energy yield from ethanol production.

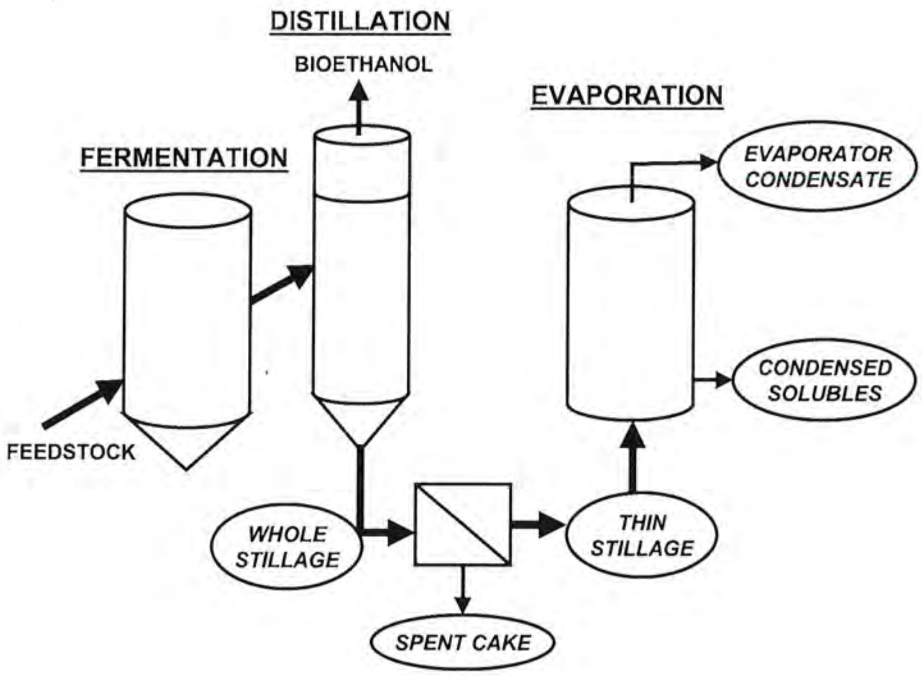

Figure 2. Potential biogas feedstocks from bioethanol production.

METHANE IN BIODIESEL PRODUCTION

Biodiesel is normally produced from either virgin plant oils or waste vegetable oils through a catalytic transesterification process. The typical biodiesel production process uses an alkaline hydrolysis reaction to convert vegetable oil into biodiesel by using methanol, potassium hydroxide, and heat. A transesterification reaction splits the glycerol group from the triglyceride oils, producing methyl esters (biodiesel) and glycerol by-product (Fig. 3). To purify the biodiesel, a washing process is employed to remove soaps, free fatty acids, and excess methanol, producing a washwater by-product. While process yields and inputs depend largely on oil type and quality, for every 100 liters of oil, approximately 25 liters of methanol and 0.8 kg of KOH/NaOH are consumed, yielding around 75 liters of biodiesel and 25 liters of crude glycerol. The washing process produces another 30 liters of biodiesel washwater. Both the crude glycerol and the biodiesel washwater have significant methane production potential. When vegetable oil is pressed from seeds (or algae), there is also a press cake by-product along with crop residues from harvesting that are both amenable to biogas production (Table 3). Conversion of biodiesel by-products to methane offers a sustainable treatment solution, while also providing additional energy. Methane can also be converted to methanol, an ingredient used in biodiesel production. Also, digester effluent could be used to grow oleaginous algae for biodiesel production.

Table 3. COD of some bioenergy by-products

Feedstock	COD (g/kg)
Ethanol thin stillage from corn	56.0–64.5
Ethanol stillage from beet molasses	55.5–116.0
Ethanol stillage from cane juice	22.0–45.0
Ethanol stillage from cane molasses	22.5–118.0
Ethanol stillage from cellulosics	19.1–140.0
Evaporator condensate	2.6–5.7
Condensed solubles	724
Dried distillers' grains	368
Crude glycerol from biodiesel production	1,800–2,600
Washwater from biodiesel	40.1–161.0
Press cake from oil crops	1,570

METHANE IN THE HYDROGEN ECONOMY

Hydrogen is often considered as a long-term solution to dwindling petroleum supplies and the environmental consequences of petroleum use in the transportation sector. However, hydrogen production and storage are still very expensive. Since water is the primary product of H_2 combustion, the fuel is viewed as a means to eliminate CO_2 emissions. Yet, if H_2 production is from fossil sources, it will still result in significant CO_2 emissions. Only the production of H_2 from renewable energy sources can result in reduced greenhouse gas emissions. One means of renewable H_2 production is through fermentation of organic matter.

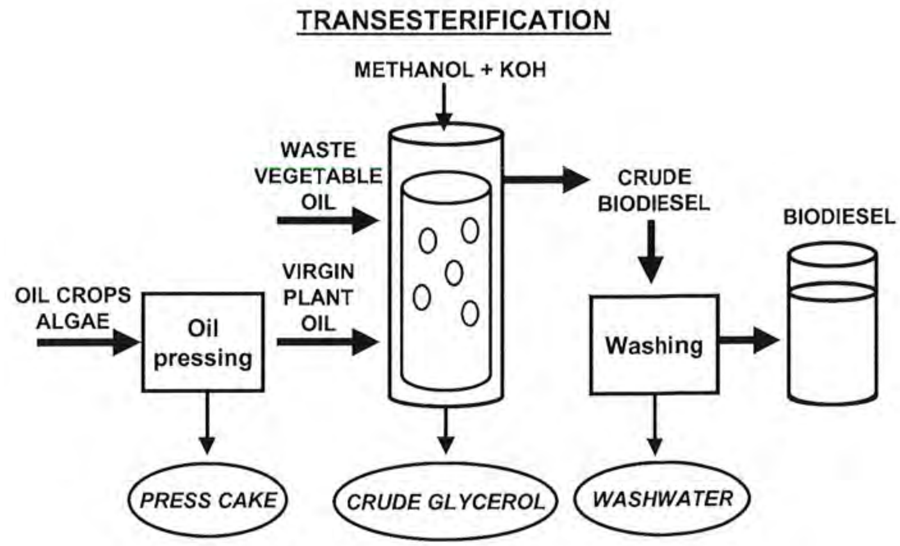

Figure 3. Potential biogas feedstocks from biodiesel production.

However, theoretically, only 33% of the energy in carbohydrates is available for microbial H_2 production due to the requirement to regenerate metabolic reducing potential (Angenent et al., 2004; Hungate, 1974). This means that 66% of the carbohydrate feedstock remains in the fermentation effluent and requires further processing. Anaerobic digestion can easily convert this residual carbon to biomethane, and the methane could then be converted to hydrogen catalytically. Still, the efficiency of conversion for methane production suggests that it is easier to convert all of the carbohydrate directly to methane rather than suffer the low yields of microbial hydrogen production. This methane could be upgraded to natural gas or converted into electricity, both of which are easier to transport than H_2.

There are other means by which methane factors into the hydrogen economy. First, the energy density of H_2 is four times less than that of CH_4 on a molar or volume basis, suggesting that methane could serve as a more efficient storage vector for hydrogen. Secondly, there is an existing infrastructure of pipelines for transporting CH_4 that are not suitable for moving H_2. Capitalizing on this network of pipelines, methane could be transported to regions of demand and converted to H_2 locally as required. Renewable methane, therefore, is an appropriate energy vector even if hydrogen is a desirable replacement fuel.

SYNTHESIS GAS

Another renewable fuel source that could integrate with methane production is the production of synthesis gas (syngas) through thermochemical gasification of biomass. Wastes and biomass crops can be gasified in a reduced atmosphere combustion process to convert the biomass into a mixture of CH_4, CO_2, CO, and H_2. While catalytic conversion of syngas to methanol has historical application for producing "wood alcohol," the H_2, CO_2, and CO in syngas can be used as a feedstock in methane production. Currently, catalysts for conversion of syngas to mixed higher alcohols (ethanol, propanol, and butanol) are in development, but in any of the catalytic processes, H_2S is problematic for catalyst longevity. Anaerobic digestion could serve as a process for syngas cleanup to convert the mixture to CH_4 (Sipma et al., 2006) and allow more-efficient catalytic conversion to further products (H_2, ethanol, or methanol). Pure-culture fermentation of syngas to ethanol is also in development (Younesi et al., 2005), a process which also generates acetate that may in turn be converted to CH_4 via anaerobic digestion.

ENERGY CROPS

Meeting the demand for alternative fuels from seasonal crops grown for bioenergy is potentially tenuous. Storage of crops can result in losses of carbohydrates available for fermentation to ethanol. Direct methane production from energy crops can overcome these losses because of the ability of the anaerobic digestion process to use fermentation intermediates as substrates. Harvested crops can be ensiled to preserve overall energy content, using technology with which farmers are already familiar. Further, any improvement in conversion efficiency that enhances cellulosic ethanol yields is equally applicable for biomass conversion to methane.

Sugarcane, a power crop, has a long growing season in tropical and subtropical climates, and because it is a C4 plant, sugarcane is one of the best plants for collecting and harvesting solar energy. While conversion of the soluble fraction of sugarcane into ethanol has been implemented on a large scale in Brazil, ethanol production facilities are capital intensive, requiring several unit processes and significant energy consumption. However, the soluble fraction of sugarcane can also be converted into biogas. The production of biogas requires much less investment, little energy is consumed in the process, and the potential feedstock is not limited to the sugars but can use the whole sugarcane plant as well as other energy crops. Further, nutrients contained in the cane are conserved in the process and can be returned to the fields to maintain a sustainable production cycle with minimal synthetic fertilizer inputs.

Cane juice can be digested directly to produce methane, without the need for alcohol fermentation, centrifugation and distillation, and the consumption of high-grade energy associated with these processes. Some 47% of the total energy in cane would be present in the biogas produced. The remaining bagasse could still be used for energy production through combustion, as currently implemented in the sugar industry. A further reduction of investment and operational costs and an increase in energy output could be obtained by subjecting not only the juice but the whole cane to anaerobic digestion. Assuming that 70% of the bagasse can be converted into methane, which is a realistic figure for a low-lignin (only 6.3%) plant such as sugarcane, then the energy conversion efficiency would increase to 80% of the energy content of cane (Chynoweth et al., 1993; Pate et al., 1984; van Haandel, 2005). By comparison, only 40% of the energy content of cane is actually converted into alcohol, consuming 24% of the cane energy in the process, while 12% is discharged as wastewater (stillage) and 24% remains in the excess bagasse (van Haandel, 2005).

Corn has also undergone whole-plant conversion to methane. Methane yields for corn at varying harvest times have ranged from 268 to 366 liters/kg of VS (Amon et al., 2007). Table 4 gives ranges of methane yield for various terrestrial and marine energy crops. Methane yields from seaweeds, grasses, and crops all approach theoretical yields, such that as much as 80% of biomass energy content could be recovered in methane.

Table 4. Ranges of biochemical methane potential yield for biomass energy crops[a]

Sample	Methane yield (at STP[b]) (liter/g of VS)
Kelp (*Macrocystis*)	0.39–0.41
Sorghum	0.26–0.39
Sargassum	0.26–0.38
Napiergrass	0.19–0.34
Poplar	0.23–0.32
Water hyacinth	0.19–0.32
Sugarcane	0.23–0.30
Willow	0.13–0.30
Laminaria	0.26–0.28
Municipal solid waste	0.20–0.22
Avicel cellulose	0.37

[a]Modified from Chynoweth et al., 1993.
[b]STP, standard temperature and pressure.

SUMMARY

Biogas production from agricultural, municipal, and industrial wastes is a sustainable means for producing a useful biofuel that can be used for process heating, electrical production, and vehicular fuel. Biogas can be upgraded and injected into natural gas pipelines, leveraging the existing distribution infrastructure. Liquids, slurries, solid wastes, and gaseous waste can all be processed by anaerobic digestion to form biogas. Several digester designs have been developed to optimize processing of different feedstocks. Digester size can be scaled to match the application, and centralized plants, codigesting a mixture of wastes, can be utilized to achieve economies of scale and improved performance. Methane production can be integrated into biorefineries since by-products from production of bioethanol, biodiesel, biohydrogen, and syngas are also suitable for anaerobic digestion, thus increasing net energy yields and recycling valuable nutrients for crop production. Finally, processing of terrestrial and marine energy crops to biomethane can result in higher energy yields than that of other biofuels. Given the diversity of feedstocks and ease of product recovery, methane from organic wastes and energy crops offers a major sustainable energy solution that is renewable, carbon dioxide neutral, and locally based, thereby protecting the environment, creating jobs, and strengthening local economies.

REFERENCES

Amon, T., B. Amon, V. Kryvoruchko, W. Zollitsch, K. Mayer, and L. Gruber. 2007. Biogas production from maize and dairy cattle manure—influence of biomass composition on the methane yield. *Agric. Ecosystems Environ.* **118:**173–182.

Angenent, L. T., K. Karim, M. H. Al-Dahhan, B. A. Wrenn, and R. Domiguez-Espinosa. 2004. Production of bioenergy and biochemicals from industrial and agricultural wastewater. *Trends Biotechnol.* **22:**477–485.

Bryant, M. P., E. A. Wolin, M. J. Wolin, and R. S. Wolfe. 1967. *Methanobacillus omelianskii*, a symbiotic association of two species of bacteria. *Arch. Mikrobiol.* **59:**20.

Buswell, A. M., and F. W. Sollo. 1948. The mechanism of the methane fermentation. *J. Am. Chem. Soc.* **70:**1778–1780.

Chynoweth, D. P., C. E. Turick, J. M. Owens, D. E. Jerger, and M. W. Peck. 1993. Biochemical methane potential of biomass and waste feedstocks. *Biomass Bioenergy* **5:**95–111.

Hungate, R. E. 1974. Potentials and limitations of microbial methanogenesis. *ASM News* **40:**833–838.

Pate, F. M., J. Alvarez, J. D. Phillips, and B. R. Eiland. 1984. Sugarcane as a cattle feed: production and utilization. *In Florida Sugarcane Handbook. Bulletin 884.* Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Sipma, J., A. M. Henstra, S. N. Parshina, P. N. L. Lens, G. Lettinga, and A. J. M. Stams. 2006. Microbial CO conversions with applications in synthesis gas purification and bio-desulfurization. *Crit. Rev. Biotechnol.* **26:**41–65.

Speece, R. E. 1996. *Anaerobic Biotechnology for Industrial Wastewaters.* Archae Press, Nashville, TN.

van Haandel, A. C. 2005. Integrated energy production and reduction of the environmental impact at alcohol distillery plants. *Water Sci. Technol.* **52:**49–57.

van Haandel, A. C., and G. Lettinga. 1994. *Anaerobic Sewage Treatment.* John Wiley & Sons, Ltd., Chichester, United Kingdom.

Wilkie, A. C. 2005. Anaerobic digestion: biology and benefits, p. 63–72. *In Dairy Manure Management: Treatment, Handling, and Community Relations.* NRAES-176. Natural Resource, Agriculture, and Engineering Service, Cornell University, Ithaca, NY.

Wilkie, A., M. Goto, F. M. Bordeaux, and P. H. Smith. 1986. Enhancement of anaerobic methanogenesis from Napiergrass by addition of micronutrients. *Biomass* **11:**135–146.

Wilkie, A. C., K. J. Riedesel, and J. M. Owens. 2000. Stillage characterization and anaerobic treatment of ethanol stillage from conventional and cellulosic feedstocks. *Biomass Bioenergy* **19:**63–102.

Wilkie, A. C., H. F. Castro, K. R. Cubinski, J. M. Owens, and S. C. Yan. 2004. Fixed-film anaerobic digestion of flushed dairy manure after primary treatment: wastewater production and characterisation. *Biosystems Eng.* **89:**457–471.

Younesi, H., G. Najafpour, and A. R. Mohamed. 2005. Ethanol and acetate production from synthesis gas via fermentation processes using anaerobic bacterium, *Clostridium ljungdahlii. Biochem. Eng. J.* **27:**110–119.

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Important Factors for Hay Quality When Buying Hay

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Florida livestock producers grow their own forages. While pasture is the primary source, each year the winter months require differing amounts of hay supplementation. Some producers are large enough to have the labor force to put up their own hay. Others are dependent on finding hay that is both economical and nutritious.

The horse industry differs here in that much of the forage is purchased on the open market. In many cases this is a year-round necessity of “hay buying”.

Traditional Method

Whether it is cattle or horses, farmers and ranchers have historically purchased based on sensory skills. The appearance and smell of the hay are helpful. A skilled buyer will see leafiness, color, dustiness, presence of legumes, absence of weeds, and presence of mold. Purchasing hay in this way is a learned and important skill.

Nutritional Analysis

More important than sensory perception of hay is its nutritional suitability to meet an animal’s daily nutrient requirements. Nutrient needs vary from horse to cow, age of an animal, size, condition, stage of lactation, etc.

To begin to address the needs of an animal or herd of animals, knowing the scientific analysis is crucial. While ranchers would not purchase feed without a guarantee tag, they too often would make a major investment in hay without knowing this vital information.

Important Factors

-Species

Legumes like alfalfa and perennial peanut are higher in protein, energy, and minerals and lower in fiber than grasses like timothy, bermuda, and bahia.

-Maturity

Yield typically increases with maturity while quality decreases. Changes in leaf / steam ratio is the primary reason.

-Climate

Weather can play a role in the best hay crop or destroy its quality if rained on while drying. In Florida, drought and flooding are important factors.

-Pasture Management and Harvesting Practices

Fertilizer, irrigation, and weed control are major factors that depend on the rancher or hay producer. After species, stage of maturity at harvest is the most human controlled factor.

Forage lab Terms

When using forage analysis, understanding terms is essential.

Table 1. Nutrient composition of typical legume and grass hays (DM basis).

Species	CP%	ADF%	NDF%	RFV	TDN%	DE, Mcal/lb	Ca%	P%
Legume	20.9	30.0	38.4	163	59	1.181.20	0.28	
Grass	10.4	39.8	63.8	86	44	0.880.57	0.25	
Bermudagrass	9.5	36.7	69.0	82	45	0.900.49	0.19	

Dairy One Summary Statisitics. 2000

- Dry matter basis – nutrient results for a sample reported with the water removed. Removing the water eliminates the dilution effect of the water and enables direct nutrient comparison of different forages. For example, suppose that you wanted to compare the protein content of hay testing 90% dry matter to a pasture testing 20% dry matter. On an as sampled basis, the hay tests 14% crude protein (CP) and the pasture 4% CP. The hay appears to be higher in CP. However, removing the dilution effect of the water reveals that the hay is 15.5% CP (14/.90) and the pasture is 20% (4/.20) on a dry matter basis. Thus, removing the dilution effect of the water revealed that per pound of dry matter, the pasture is higher in protein. Thus, when comparing figures to one another, it is important to use the results expressed on a dry matter basis. It is also important to realize that most daily nutrient requirements for balancing rations are expressed on a dry matter basis. To fully utilize the information contained in a forage analysis, it is essential to become accustomed to using results on a dry matter basis.

- Crude Protein (CP) – the total protein in the sample including true protein and non-protein nitrogen. Proteins are organic compounds composed of amino acids. They are a major part of vital organs, tissue, muscle, hair, skin, milk, and enzymes. Protein is required on a daily basis for maintenance, growth, reproduction, and lactation.

- Acid Detergent Fiber (ADF) – a measure of cellulose and lignin. Cellulose varies in digestibility and is negatively influenced by lignin content. As lignin increases, digestibility of the cellulose decreases. ADF is negatively correlated with overall digestibility.

- Neutral Detergent Fiber (NDF) – a measure of hemicellulose, cellulose and lignin representing the fibrous bulk of the forage. These three components are classified as cell wall or structural carbohydrates. They provide support for the growing plant. NDF is negatively correlated with intake.

- Digestible Energy (DE) – equals gross feed energy minus fecal energy. For horses, it is predicted from CP and ADF for forages and ADF for grains.

- Total Digestible Nutrients (TDN) – an energy measure denoting the sum of the digestible protein, digestible nitrogen free extract (NFE), digestible crude fiber and 2.25x the digestible fat. TDN is estimated from the digestible energy (DE).

- Relative Feed Value (RFV) – an index for ranking forages based on digestibility and intake potential of cattle. RFV is calculated from ADF and NDF. A RFV of 100 is considered the average score and represents an alfalfa hay containing 41% ADF and 53% NDF on a dry matter basis. The higher the RFV, the better the quality.

Due to the inherent variability of measuring ADF and NDF, absolute RFV values should be used to classify forage. For example, if a RFV of 150 is the target value, any forage testing 145 to 155 should be considered to have an equivalent value. A good rule of thumb is to accept anything within at least +/- 5 points of the target value. A lot of hay is priced on 20 point spreads. This allows for sampling and analytical variations. This represents the best use of RFV as a marketing tool.

How do I use this information to evaluate hay?

Consider the following example: Two hays are available with the following analyses:

	CP%	ADE%	NDF%	DE Mcal/lb	Ca%	P%	RFV
Hay X	17	35	47	1.04	1.19	0.30	122
Hay Y	11	39	61	0.90	0.60	0.25	89

Which is the best hay? Clearly, Hay X is higher in quality. It is higher in protein, DE, minerals, and RFV and lower in fiber than Hay Y. However, *best* is a relative term. Best for what? Consider the daily nutrient requirements for 3 different horses:

	CP%	DE, Mcal/lb	Ca%	P%
Light Work	8.8	1.05	0.27	0.19
Lactating Mare (0-3 mo. Lact.)	12.0	1.10	0.47	0.30
Weanling, 4 mo.	13.1	1.25	0.62	0.34

Now which hay is the best? For the light working horse, Hay Y more closely mirrors its nutrient requirements. The lower DE content can easily be supplemented with the grain portion of the ration.

The DE, protein and mineral requirements of the mare and weanling are greater than the light working horse. Additional nutrients are required to support lactation in the mare and growth in the weanling. In this case, hay X would be a good candidate, though ideally, a combination of Hay X and Y would work best.

Dairy One Forage Lab
Florida Equine Institute and Allied Trade Show Proceedings, 2001

Conclusion

Nutritional analysis of hay is one factor in considering hay buying. It is, however, the best way to calculate meeting nutrient requirements of livestock. Remember, your animal's needs may not be the highest quality and most expensive hay. At the same time, you do not want to pay high quality hay prices for hay the lab shows as poor quality.

Factors Affecting Forage Quality[1]

A. T. Adesogan, L. E. Sollenberger, Y.C. Newman, and J.M.B. Vendramini[2]

Introduction

Forage testing is necessary because forage quality varies considerably due to several factors, including differences in forage genotype, maturity, season, and management. An understanding of factors affecting forage quality will help producers anticipate and plan for changes in forage quality.

When forage quality is low, forages alone may not support desired rates of animal performance. In such cases, it is necessary to provide livestock with supplements for protein and energy.

What is Forage Quality?

Animal performance, whether growth or milk production, depends upon the animal's potential for production, as well as on how much dry matter (DM) the animal eats and the nutritive value of the DM the animal consumes. Therefore, the two forage-related factors that determine animal performance are forage intake and forage nutritive value. Collectively, these factors determine the quality of the forage. When forage is fed without restriction as the sole feed, forage quality can be an excellent predictor of animal performance.

Figure 1. Bahiagrass field in Florida.
Credits: Y.C. Newman

Factors Affecting Forage Intake

Forage intake is affected by a range of factors, including the amount of forage available and characteristics of the forage consumed, as well as the animal's gut capacity, performance level, health, genotype, and social hierarchy. Environmental factors also affect forage intake, including prevailing temperature and humidity. Management factors — such as stocking rate, type and level of supplementation, feeding

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frequency, and availability of water and feed — also affect forage intake.

Additionally, forage intake is affected by forage availability and by many characteristics of forages, such as particle size of stored forages and amounts of fiber, protein, and minerals in the DM. How fast undigested DM passes through the animal also affects an animal's forage intake. Molds and any other substances that make the forage unpalatable also affect livestock intake of hay. Intake of pasture forage is also affected by the nature of the sward. Accumulations of dead forage or manure on pasture will decrease intake, and a dense, leafy canopy will increase forage intake.

"Voluntary forage intake" is used to describe how much forage DM an animal will consume when adequate amounts of palatable forage are available, when no supplements of protein and energy are fed to the animal, and when adequate minerals are available — either in the forage or as supplements. Energy and protein supplements may either increase or decrease livestock forage intake, depending upon the composition of the forage and the composition and amount of supplement being fed to the livestock.

Factors Affecting Forage Nutritive Value

Forage nutritive value is primarily determined by concentrations of crude protein (CP) and "available" energy in the forage. For many years total digestible nutrients (TDN) has been used as an overall measure of available energy in forages. In the past 20 years, however, measurements of digestible forage, metabolizable forage, and net energy of forage have increasingly been used. However, TDN is still an acceptable and easily understood measure of nutritive value, particularly for beef cattle.

Forage quality is affected most by variations in forage genotype, maturity, season, and management. Other "anti-quality" factors may be encountered occasionally; these factors are described below, under heading 5, Anti-Quality Factors Affecting Forage.

1. Genotype

Legumes generally have a higher quality than grasses. Legumes have higher CP concentrations and a higher intake by livestock due to a higher percentage of rapidly digestible leaves. However, TDN concentrations of legumes and cool-season grasses are similar. Generalizations about quality of grasses are risky, but temperate or cool-season grasses, such as rye and ryegrass, often have higher quality than tropical or warm-season grasses, such as bermudagrass and bahiagrass. However, there is much variation in forage quality within and among grass genera.

2. Maturity

The stage of forage regrowth at the time of utilization — whether as hay, haylage, or grazing — has a major influence on forage quality. Forage-regrowth stage is determined by the number of days between harvests for hay or haylage and by the rest period in rotational grazing.

Forage quality begins to decline as soon as forages start to regrow due to the accumulation of stems and deposition of poorly digested lignin in both leaves and stems. Therefore, forage quality generally declines with increasing length of the interval between harvests of stored forages or with longer rest periods in rotational grazing.

Maturity of legumes and cool-season grasses can be assessed by determining the reproductive stage of growth. For warm-season grasses, however, weeks of regrowth are a better indicator of maturity because flowering may begin shortly after regrowth begins.

Table 1 shows a decline in digestibility and crude protein of Coastal bermudagrass after week five (35 days) of regrowth. The information in this table indicates that harvesting Coastal bermudagrass at intervals greater than five weeks will reduce the quality of this forage.

Table 2 provides examples of the effects of forage genotype and maturity on the quality of typical forage grasses in Florida. Each value represents several cuttings made from different cultivars in different years. These values are a general reference point. These data suggest that digitgrass and limpograss tend to have higher quality than bahiagrass, bermudagrass, and stargrass, especially at later stages of maturity. These differences often affect voluntary intake as well.

With respect to maturity effects on perennial grasses, the most dramatic difference is the decrease in voluntary intake between six and eight weeks. These data and others show that after eight weeks regrowth, forage quality will generally be less than needed for livestock maintenance. Exceptions are digitgrass and limpograss, which maintain a somewhat higher TDN when mature than do the other grasses. Consequently, limpograss and digitgrass are excellent forages for fall stockpiling. However, mature limpograss and digitgrass often are low in CP and require protein supplementation for maximum utilization.

3. Season

Seasonal effects on forage quality have been noted in grazing trials in Florida, where forage regrowth intervals were kept constant. A "summer slump" was observed in that gains of grazing cattle were less during the summer than in spring and fall. That this slump in cattle weight gain during the summer is an effect of environment on forages — and not due to the effect of the environment on animals — was suggested by a direct comparison of bahiagrass with dwarf elephantgrass.

The summer slump was dramatic with bahiagrass, but not apparent with elephantgrass even though similar cattle grazed adjacent paddocks of the two grasses. Summer slumps in quality of warm-season grasses have been observed with hay harvested after similar regrowth intervals on different dates throughout the growing season (Table 3). Summer regrowth may have lower quality because high temperature increases lignin deposition, and high rainfall increases growth rates and maturation of the forage.

In the case of hay made in Florida, the negative effects of season and maturity on forage quality may be additive. Spring harvests are made generally after short regrowth periods, while summer harvests are made after long regrowth periods because of heavy summer rainfall that delays harvests. Therefore, the quality of bermudagrass hay is highest when harvested in the spring or early summer.

4. Management

Pre-Harvest Management

Pre-harvest management for maximum quality of hay or silage involves weed control and frequent cutting. (See discussion above under heading 2, Maturity.) Some producers harvest every four or five weeks throughout the season, making either hay or silage, depending on rainfall.

Post-Harvest Management

The quality of hay or silage will never increase during harvesting and storage, but post-harvest decreases in quality can be minimized by careful management. Post-harvest management requires avoiding rain damage, as well as proper curing of hay to less than 15% moisture or wilting of silage to 60%–70% moisture, promptly sealing silos and wrapping haylages, and minimizing losses during storage. Leaching of nutrients from weathering decreases forage nutritive value. Therefore, hay bales should be stored under a barn or a tarp whenever possible.

Growth of molds may also decrease palatability and, therefore, reduce livestock intake of forage. Additionally, molds may lead to production of mycotoxins, which can impair animal health and also affect human health negatively. To avoid mold growth, stored forages should be harvested and conserved at the recommended moisture concentrations. In addition, silage or haylage plastic should be maintained properly; any holes should be promptly sealed with silage tape. Silages should be packed at a density of approximately 15 pounds/ft^3 and fed out at a rate that prevents heating. Application of additives containing propionic acid or *Lactobacillus buchneri* inoculants can also prevent the growth of molds.

Management of Grazed Pastures

For maximum quality, pastures should be managed to maintain a leafy canopy that is free of weeds and dead herbage and is grazed uniformly without many ungrazed patches. There is much controversy about how to achieve such a target. Some grazing experts contend that frequent rotation is desirable. Others feel that if stocking rate is matched carefully to forage availability, then frequent rotation offers little advantage

The management requirements of a particular forage and the objectives of the livestock operation often are the most important factors influencing choice of rotation frequency. In addition, over-grazing should be avoided because lack of available forage will have a major negative impact on animal performance regardless of forage nutritive value and potential quality.

Generally, fertilizer application has little effect on forage quality except that CP will be increased for a period of time following N fertilization. If forage CP is low in unfertilized grass, then N fertilizer application will often increase forage CP and contribute to improved forage intake and animal performance.

5. Anti-Quality Factors

Examples of anti-quality factors in commonly grazed or fed Florida forages are noxious weeds, nitrates, prussic acid, ergot alkaloids, insect infestation, and unusually wet growing areas.

Nitrate or prussic acid accumulation can occur in certain forages after stressful periods, such as drought, frost, hail, and herbicide or fertilizer injury. Nitrate accumulation is common in corn, rye, sorghum, sudangrass, and alfalfa, and prussic acid accumulates in millet, sorghum, and sudangrass. Both of these compounds — nitrate and prussic acid — can limit oxygen transfer in the blood of livestock. Therefore, the accumulation of these compounds in forage is dangerous to livestock. If forages have undergone a stressful period as described above, forage samples should be sent for nitrate or prussic-acid testing before the forage is fed to livestock. Proper ensiling generally reduces concentrations of these compounds to safe levels, but volatile toxic gases are released during the ensiling process. Therefore, workers should be careful when handling ensiled forages.

Ergot alkaloids have also been observed in a few cases on bermudagrass in Florida, as in Mexico, Texas, and Oklahoma. Problems such as 'tremors' associated with ingestion of ergot alkaloids can be avoided by maintaining a four-to-five-week cutting interval for bermudagrass, interseeding with legumes or other grasses, and diluting the toxin with nontoxic forages and supplements.

In some cases, insects can defoliate forages, thus decreasing forage quality. Additionally, cattle grazing improved forages grown under very wet conditions (i.e., standing water) are observed to have low rates of performance, but the reasons for this effect are not well defined.

Implications

Forage quality varies widely due to variations in forage genotype, maturity, season, management, and anti-quality components. Because of all these factors and their interactions, tables of forage quality and nutritive value are unlikely — by themselves — to provide useful information about a particular forage. Therefore, be sure to test forages frequently, using forage samples that are taken carefully to insure that the samples are representative of forage being consumed by livestock.

Additional Information

Newman, Yoana C., Adegbola T. Adesogan, Joao Vendramini, and Lynn Sollenberger. 2009. *Defining Forage Quality*, EDIS Publication SS-AGR-322, http://edis.ifas.ufl.edu/ag332. Department of Agronomy, Institute of Food and Agricultural Sciences, University of Florida.

Vendramini, J.M., M.S. Silveira, J. D. Arthington, and A. R. Blount. 2001 and 2009. *Forage Testing*, EDIS Publication SS-AGR-63, http://edis.ifas.ufl.edu/aa192. Department of Agronomy, Institute of Food and Agricultural Sciences, University of Florida.

Table 1. Nutrient Composition of Coastal Bermudagrass as Affected by Maturity. (Adapted from Mandevbu et al. 1999).

	Digestibility	**Crude Protein**	**ADF**	**Lignin**
Age of Grass (Weeks)	--------------------------%--------------------------			
4	60	18	29	4
5	59	18	30	4
6	56	16	31	5
7	53	13	33	6

Table 2. Effects of Grass and Maturity on Forage Quality.[a]

Grass	**TDN**[b]			**Voluntary Intake**[c]		
	4 weeks	**6 weeks**	**8 weeks**	**4 weeks**	**6 weeks**	**8 weeks**
Bahia	56	55	54	2.3	2.1	1.7
Bermuda	57	52	44	2.3	2.2	1.8
Star	60	53	49	2.4	2.5	2.1
Digit	60	58	57	2.5	2.7	2.2
Limpo	63	63	56	2.5	2.3	2.2

[a] Adapted from Brown and Kalmbacher, p. 79-87, in 47th Annual Florida Beef Cattle Short Course Proceedings, May 1998 (summary of research with sheep by J.E. Moore and W.R. Ocumpaugh).
[b] Total Digestible Nutrients, percentage by dry matter.[c] Intake of dry matter expressed as percentage of body weight. [d] Voluntary TDN intake relative to maintenance requirement, 1.0=maintenance.

Table 3. Quality of Coastal Bermudagrass Hay Harvested at Different Maturities and Seasons.[a]

Item	Weeks of Regrowth	Harvest Date				
		6/14	7/12	8/9	9/6	10/4
TDN %[b]	4 68	55 5252	57 5151	52 4746	53 4947	46 4844
QI[c]	4 68	1.4 1.31.3	1.4 1.41.1	1.3 1.00.9	1.3 1.21.1	1.1 1.20.8
ADG, lb[d]	4 68	0.57 0.340.16	0.78 0.480.07	0.72 -0.04-0.39	0.63 0.420.07	0.28 0.22-0.39

[a] Adapted from Nelson, et al. Louisiana Agr. Exp. Stat. Bull. 730, October, 1980.
[b] Total Digestible Nutrients, percentage of dry matter.[c] Quality index.[d] Average daily gain, in pounds/day; feeding trial conducted with steers from December through February for all hays.

Forage Testing[1]

J.M. Vendramini, M.S. Silveira, J.D. Arthington, and A.R. Blount[2]

Why Test Forage?

Forage testing provides useful information about the nutritive value of forage. This information can be used to adjust the amount and composition of nutritional supplements offered to livestock consuming forage. The correct adjustments can reduce costs of forage production and optimize the amount of nutrients imported to the property.

Where to Send Forage Samples and What Testing Results Will Be Provided

The UF/IFAS Forage Extension Laboratory is located at the Range Cattle Research and Education Center in Ona, Florida. The laboratory provides forage testing for Florida's livestock producers and forage producers. Results of the tests include crude protein (CP) and total digestible nutrients (TDN).

Mail samples to Forage Extension Laboratory, UF/IFAS, Range Cattle REC, 3401 Experiment Station, Ona, FL, 33865.

Beyond understanding the nutrient quality of your forage, it is also valuable to understand how your forage samples compare with other such samples submitted to the laboratory. On an annual basis, the Forage Extension Laboratory publishes the average forage nutritive values by forage species (Table 1).

Nutritive-Value Parameters and Definitions

The nutritive-value parameters reported by the Forage Extension Laboratory are as follows:

1) Dry matter (DM): DM refers to the portion of the forage after water is excluded. All nutritive-value parameters are reported on a "dry matter basis," thus results of samples with different DM concentrations can be compared. Dry matter concentration is important for conserved forage — such as hay, haylage, and silage — because this measure indicates how the conservation process may impact forage nutritive value. Dry matter concentration for hay should be approximately 85%–92%, haylage 40%–60%, and silage 30%–40%.

2) Crude protein (CP): CP is the nitrogen and amino acids in feeds. An estimate of forage total crude protein is obtained by multiplying total nitrogen concentration by a constant of 6.25. Adequate CP concentrations in the forage

1. This document is SS-AGR-63, one of a series of the Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date April 2001. Revised January 2012. This publication is part of the *Florida Forage Handbook*, an electronic publication of the Agronomy Department.

2. J.M. Vendramini, assistant professor, Agronomy Department, Range Cattle Research and Education Center, Ona, FL; M.S. Silveira, assistant professor, Soil and Water Science Department, Range Cattle Research and Education Center, Ona, FL; J.D. Arthington, professor, Agronomy Department, and director, Range Cattle Research and Education Center, Ona, FL; and A.R. Blount, professor, Agronomy Department, North Florida Research and Education Center, Marianna, FL; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

are dependent on forage species and animal requirements. For more information, see EDIS Publication AN190, *Basic Nutrient Requirements of Beef Cows* (http://edis.ifas.ufl.edu/an190).

3) Total digestible nutrients (TDN): TDN represents the energy concentration in the forage, the sum of digestible fiber, starch, sugars, protein, and fat in the forage. Energy is the nutrient required by cattle in the greatest amount and usually accounts for the largest proportion of feed costs.

4) Neutral detergent fiber (NDF): NDF represents plant cell wall components (hemicelluloses, cellulose, lignin), which are more or less degradable, depending on the stage of maturity and degree of lignification of the forage. In general, as NDF increases, voluntary forge intake is reduced.

5) Acid detergent fiber (ADF): The ADF component of forage is determined when either the NDF residue or an intact forage sample is processed in a detergent solution primarily containing sulfuric acid. The remaining fiber residue, mostly cellulose and lignin, is called ADF. In general, as ADF increases, forage digestibility is reduced.

How to Collect a Sample

Properly collecting and identifying a sample is very important. A sampling device or tool is needed for collecting hay samples. Several commercial types are available. These tools usually consist of a tube — with a cutting edge on one end and a shank on the other — that is fastened in the chuck of an electric drill or hand brace. The sampler is driven into the end of a rectangular bale or the rounded side of the round bale. Collect a single core sample from each of 12 bales for a particular lot of hay. To ensure the sample is representative, combine the 12 cores into one sample. The outer layer of weathered round bales should be pulled away before sampling. Each hay cutting, type of hay, etc., should be sampled and analyzed separately. Each hay cutting or lot should be identified and stored separately.

Silage samples can be collected from the face of a bunker silo as it is being fed and from the unloader of an upright silo. Bagged silage can be sampled by cutting small slits along the side of the bag and penetrating the hay sampler to collect the material. Producers must reseal the slit with waterproof tape after collection.

Collect silage from five or six places along the bag, mix well, and extract a single sample to send to the laboratory. Immediately place the sample in a plastic bag and seal it. If the sample is not mailed right away, place the sample in a refrigerator or freezer.

Pasture samples can be collected and analyzed by plucking the forage with your fingers at the height the animals are grazing it. However, keep in mind that, when adequate pasture forage is available, cattle may select forage with a better nutritive value than the forage sampled by hand plucking. One practical example of selection can be found in limpograss pastures with good forage availability. In this example, cattle will typically select leaves that have greater nutritive value than hand-plucked samples collected with leaves and stems. In this case, forage testing results may suggest that cattle would respond to protein supplementation. However, in fact, the animals are already consuming adequate amounts of protein from forage selection and may not respond to supplementation.

Scissors or some other cutting device also can be used. If possible, these samples should be dried before sending to the laboratory. If drying is not possible, mail the sample immediately after it is harvested. Your results are only as good as your sample!

Additional Information and Testing Procedures

Nutritive value results (Table 1) are reported by forage species. Forage species not included in this publication were not received by the laboratory in sufficient numbers to be included in this annual report. Crude protein and TDN were analyzed in all samples. Dry matter (DM), NDF, and ADF were analyzed in selected samples submitted by dairy producers participating in the Southeast Dairy, Inc., Check-Off Program.

The UF/IFAS Forage Extension Laboratory sample processing and analyses are as follows:

• Forage samples are dried at 55°C in a forced-air oven for DM determination.

• Total digestible nutrients (TDN) are estimated using the “in vitro” dry matter digestibility (IVDDM) procedure described by Goering and Van Soest (1970). (USDA-ARS Agric. Handb. 379. U.S. Gov. Print. Office, Washington, DC). modified for the Ankom Daisy II In Vitro Digester (Ankom Technol. Corp., Fairport, NY).

• Crude protein was calculated by multiplying nitrogen concentration by 6.25.

• Nitrogen is determined by combustion using the Flash EA 1112 Series (Thermo Electron Corporation, Waltham, MA).

• Neutral detergent fiber (NDF) and acid detergent fiber (ADF) are analyzed using an Ankom 2000 Fiber Analyzer (Ankom Technology Corp., Fairport, NY).

Many laboratories provide forage testing results based on the NIRS procedure. The NIRS procedure is often valid, depending upon the set of forage samples originally used to establish the procedure's equations. In general, wet chemistry procedures are more accurate.

If you do not know how to interpret the results, contact your County Agricultural Extension Office, or the UF/IFAS Forage Extension Laboratory at jv@ufl.edu.

The authors sincerely thank the Dairy Check-Off Program for sponsoring forage testing for the Southeast Diary, Inc. producer samples.

References

Ankom Technology Corporation. 1998. Method for determining Acid Detergent Fiber, Neutral Detergent Fiber and Crude Fiber, using the Ankom Fiber Analyser. Ankom Technology Corporation, 14 Turk Hill Park, Fairport, New York 14450, USA.

Goering, H.K., and P.J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents, procedures, and some applications). USDA Agric. Handb. 379. U.S. Gov. Print. Office, Washington, DC.

Hersom, Matt. 2007. *Basic Nutrient Requirements of Beef Cows*. Gainesville: University of Florida Insitute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/an190.

Table 1. Dry matter (DM), crude protein (CP), total digestible nutrients (TDN), acid detergent fiber (ADF), and neutral detergent fiber (NDF) of forage samples submitted to the Forage Extension Laboratory at the Range Cattle Research and Education Center – Ona, FL (October 2006 to December 2011)

Forage Species	Number of Samples	CP	TDN	ADF	NDF
Bahiagrass[a]	103	7.7 ± 3.0	51 ± 5	--	--
Bermudagrass	232	9.5 ± 3.6	53 ± 6	44 ± 4	77 ± 3
Stargrass	112	9.4 ± 3.0	52 ± 6	59 ± 2	69 ± 16
Limpograss	170	4.8 ± 2.2	54 ± 6	41 ± 4	70 ± 6
Corn Silage	41	8.7 ± 2.2	73 ± 5	29 ± 1	46 ± 6

[a]ADF and NDF analysis performed only on samples submitted by dairy producers. Bahiagrass was not analyzed for these nutrient constituents.

Identification and Control of Coral Ardisia (*Ardisia crenata*): A Potentially Poisonous Plant.[1]

B. A. Sellers, Sarah Lancaster, K. A. Langeland, J.A. Ferrell, Michael Meisenberg, and J. Walter.[2]

Coral ardisia, also known as coral berry, spice berry, and scratchthroat, was introduced to Florida in the early 1900's for ornamental purposes (Figure 1). Since then, it has escaped cultivation, and it is found in hardwood hammocks and other moist, natural-wooded areas and grazing lands. Documented herbarium specimens, or preserved plants, have been collected from 19 western and south-central Florida counties (Wunderlin and Hansen, 2004). Coral ardisia is considered invasive by the Florida Exotic Pest Plant Council and the UF/IFAS Assessment (Fox et al., 2005).

Identification

Coral ardisia is an evergreen, sub-shrub that reaches heights of 1.5 to 6 feet. It tends to grow in multi-stemmed clumps. The alternate, waxy leaves are about 8 inches long, and they are dark green above. They are also hairless, with scalloped margins and calluses in the margin notches (Figure 2). Flowers are typically pink to white in stalked axillary clusters, usually drooping below the foliage (Figure 3). The fruit is bright red, globular, and one-seeded, measuring about 0.25 inches in diameter (Figure 4). Berries tend to persist on the plant nearly year-round, and white-berried populations also exist.

Figure 1. Coral ardisia in a hardwood hammock.
Credits: Michael Meisenburg

1. This document is SS AGR 276, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date September 2007. Revised November 2013. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. B.A. Sellers, assistant professor, Range Cattle Research and Education Center-Ona, FL; Sarah Lancaster, Extension scientist, Range Cattle Research and Education Center-Ona, FL; K. A. Langeland, professor, Agronomy Department, J. A. Ferrell, associate professor, Agronomy Department; Michael J. Meisenburg, biologist, Center for Aquatic and Invasive Plants; J. Walter, Extension agent, Brevard County Extension Office; UF/IFAS Extension, Gainesville, FL 32611.

Figure 2. Coral ardisia leaves are waxy with a bright, shiny appearance. The leaves may contain substances that are toxic to cattle and other livestock.
Credits: Brent Sellers

Figure 3. Coral ardisia has pink to white flowers in axillary stalks that tend to hang underneath the foliage.
Credits: Michael Meisenburg

Toxicity

Although there is no published literature supporting the theory that coral ardisia is toxic, it is suspected that the berries and/or foliage are poisonous to livestock, pets, and humans. In 2001, 2007, and 2012, the plant was the suspected causal agent for livestock deaths in Florida.

Control

Coral ardisia can be suppressed by using low-volume, foliar applications of 3% v/v (volume to volume) solution of triclopyr ester-containing products (Garlon 4 Ultra, Remedy Ultra, others), 4% triclopyr amine-containing products (Garlon 3A, others), or 1% imazapic-containing products (Impose, Panoramic, Plateau) (Table 1). Basal bark applications with an 18% v/v solution of Garlon 4 or Remedy Ultra in an oil carrier can also suppress the plant. Complete coverage is essential when using foliar application. Do not apply more than 8 quarts of Remedy or Garlon 4 per acre. If applying greater than 2 quarts, then treat no more than 10% of the total grazed area. Since formulations can evaporate when temperatures exceed 90°F, use care when applying high rates of these herbicides. The herbicide Imazapic has been shown to reduce seedling germination within 12 months after application. Regardless of the application method, retreatment will be necessary for complete control. For more information on basal bark applications, visit http://edis.ifas.ufl.edu/AG245 to read the EDIS publication entitled "Herbicide Application Techniques for Woody Plant Control."

Figure 4. Coral ardisia has bright red berries. It is thought that livestock died after consuming the berries in 2001 and 2007 in Florida.
Credits: Michael Meisenburg

References and Further Reading

FLEPPC. 2011. *List of Invasive Plant Species.* Florida Exotic Pest Plant Council. Internet: http://www.fleppc.org/list/11list.htm or Wildland Weeds Vol. 14(3-4):11-14. Summer/Fall 2011.

Fox, A. M., D. R. Gordon, J. A. Dusky, L. Tyson, and R. K. Stocker. 2005. *IFAS Assessment of the Status of Non-native Plants in Florida's Natural Areas*. Cited from the internet (September 25, 2013), http://plants.ifas.ufl.edu/assessment/pdfs/status_assessment.pdf.

Hutchinson, J. T., K. A. Langeland, and M. Miesenberg. 2011. *Field trials for herbicide control of coral ardisia (Ardisia crenata) in natural areas of north-central Florida*. Invasive Plant Sci Mgmt. 4:234-238.

IFAS Assessment. 2011. *Conclusions from the IFAS Assessment of Non-Native Plants in Florida's Natural Areas*. http://plants.ifas.ufl.edu/assessment/pdfs/concl_genus_Feb2011.pdf. UF/IFAS Extension, Gainesville, FL.

Wunderlin, R. P., and B. F. Hansen. 2004. *Atlas of Florida Vascular Plants* http://www.plantatlas.usf.edu/. [S. M. Landry and K. N. Campbell (application development), Florida for Community Design and Research.] Institute for Systematic Botany, University of South Florida, Tampa, FL.

Table 1. Control of mature and seedling coral ardisia with selected herbicides 12 months after treatment. Adapted from Hutchinson et al. 2011.

Active ingredient	Trade names	Rate (% v/v)	Mature plant control (%)	Seedling control (%)
Triclopyr ester	Garlon 4 Ultra, Remedy Ultra, others	3	96	76
Triclopyr amine	Garlon 3A, others	4	90	52
Imazapic	Impose, Panoramic, Plateau, others	1	99	93
Triclopyr amine + imazapic	Garlon 3 A + Plateau	4 + 1	99	96

SS-AGR-17

Brazilian Pepper-tree Control [1]

Ken Gioeli and Ken Langeland[2]

Common Name: **Brazilian Pepper-tree**

Scientific Name: *Schinus terebinthifolius*

Family Name: Anacardiaceae, Sumac Family

Figure 1. The Brazillian pepper-tree is an aggressive non-native invader that needs to be controlled throughout Florida.

Florida's natural ecosystems are being degraded by an invasion of non-native plants. This invasion is partially responsible for the declining numbers and quality of native biotic communities throughout Florida.

Brazilian pepper-tree is one of the most aggressive of these non-native invaders. Where once there were ecologically productive mangrove communities, now there are pure stands of Brazilian pepper-trees. Scrub and pine flatwood communities are also being affected by this invasion. Nearly all terrestrial ecosystems in central and southern Florida are being encroached upon by the Brazilian pepper-tree.

Land managers and home owners now are realizing the need to remove and stop the spread of Brazilian pepper-trees.

History

Brazilian pepper-tree is a native of Argentina, Paraguay, and Brazil. It is thought to have been introduced into Florida around 1842-1849 as a cultivated ornamental plant. *Schinus* is the Greek word for mastic-tree, a plant with resinous sap, which this genus resembles. The species name *terebinthifolius* is a combination of the genus name *Terebinthus* and the Latin word *folia*, leaf. It refers to the leaves of Brazilian pepper-tree that resemble the leaves of species in the genus *Terebinthus*.

Habitat

Brazilian pepper-tree is sensitive to cold temperatures, so it is more abundant in southern Florida and protected areas of central and north Florida. Brazilian pepper-tree successfully colonizes native tree hammocks, pine flatlands, and mangrove forest communities.

1. This document is SS-AGR-17, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date April 1997. Revised February 2009. Reviewed January 2015. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. Ken Gioeli, courtesy Extension agent I, St. Lucie County; and Ken Langeland, professor, Agronomy Department, UF/IFAS Extension, Gainesville, FL 32611.

Identification

Seedlings

The cotyledons are simple with both the apex and the base having an obtuse outline. The margin is generally curved inward on one side. The first true leaves are simple with a toothed margin (Figure 2). The later leaves are compound (Figure 3).

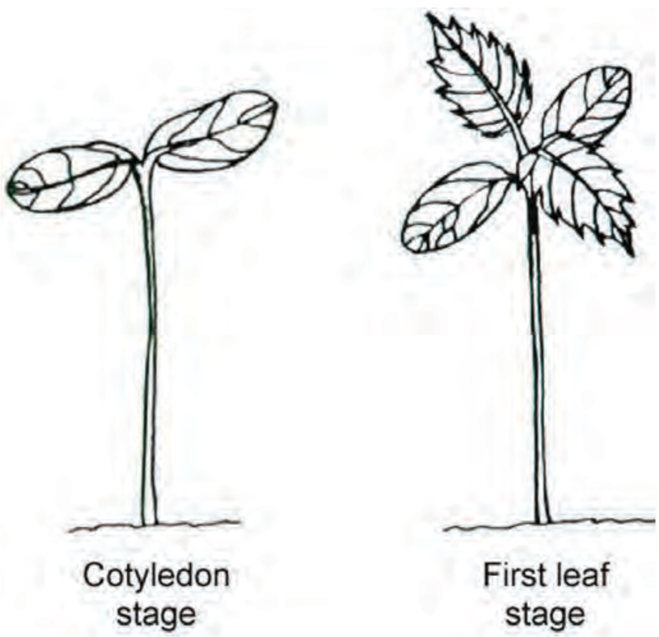

Figure 2. Brazilian pepper seedlings.

Figure 3. Leaves and fruits of mature Brazilian pepper-tree.

Mature Plant

Brazilian pepper-tree is a shrub or small tree to 10 m (33 ft) tall with a short trunk usually hidden in a dense head of contorted, intertwining branches. The leaves have a reddish, sometimes winged midrib, and have 3 to 13 sessile, oblong or elliptic, finely toothed leaflets, 2.5 to 5 cm (1 to 2 in) long (Figure 3). Leaves smell of turpentine when crushed. The plants have separate male or female flowers and each sex occurs in clusters on separate plants. The male and female flowers are both white and are made up of five parts with male flowers having 10 stamens in 2 rows of 5 (Figure 4). Petals are 1.5 mm (0.6 in) long. The male flowers also have a lobed disc within the stamens. The fruits are in clusters, glossy, green and juicy at first, becoming bright red on ripening, and 6 mm (2.4 in) wide. The red skin dries to become a papery shell surrounding the seed. The seed is dark brown and 0.3 mm (0.1 in) in diameter.

Figure 4. Male and female flowers of mature Brazilian pepper-tree.

Biology

Seedlings are flood-tolerant, but rapid change of water level up or down causes some mortality. About 20 percent of seedlings exposed to fire re-sprout. Flowering occurs predominantly from September through November. Male flowers last only 1 day. Female flowers last up to 6 days and are pollinated by insects. Fruits usually are mature by December. Birds and mammals are the chief means of seed dispersal. Seed viability is 30 to 60 percent and can last up to 2 months, but declines to 0.05 percent at 5 months. Many native species have a lower percentage of germination than *Schinus.* The high seed viability combined with animal dispersing agents may explain colonization by Brazilian pepper-tree in our native plant communities.

Seedlings have a high rate of survival and some can be found all year. Any break in the tree canopy can be exploited by seedlings. Reproduction can occur 3 years after germination. Some trees can live for about 35 years.

Control

Using Herbicides

Herbicides are available that aid in the control of Brazilian pepper-trees (Table 1). Only those herbicides that are recommended for Brazilian pepper-tree control should be used. They are safe and effective when used correctly. **It is illegal to use an herbicide in a manner inconsistent with the label's instructions; therefore, read the label carefully and follow the instructions.**

Herbicide Application to Cut-Stump

Brazilian pepper-trees can be controlled by cutting them down and treating the stumps with herbicide. A saw should be used to cut the trunk as close to the ground as possible. Within 5 minutes, an herbicide that contains the active ingredient glyphosate or triclopyr should be applied as carefully as possible to the thin layer of living tissue, called the cambium, which is just inside the bark of the stump (Figure 5).

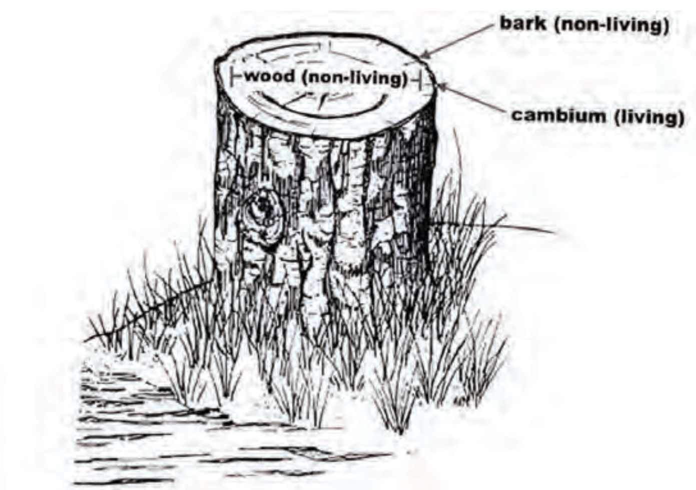

Figure 5. Brazilian pepper-tree stump showing location of the cambium layer.

The best time to cut Brazilian pepper-trees is when they are not fruiting because seeds contained in the fruits have the capability of producing new Brazilian pepper-trees. If Brazilian pepper-trees that have fruits attached are cut, care should be taken not to spread the fruits to locations where they can cause future problems. Fruiting Brazilian pepper-trees can be controlled using a basal bark herbicide application. Information about basal bark herbicide applications is described in the next section.

Caution: Avoid touching the tree's cambium. A rash can result. Some individuals are very sensitive to touching only the leaves. Use proper protective gear when sawing the tree and applying the herbicides.

Basal Bark Herbicide Application

Brazilian pepper-trees can be controlled using basal bark herbicide application. An application of an herbicide product that contains triclopyr ester is applied to the Brazilian pepper-tree's bark between one half and one foot from the ground. Garlon 4® is diluted with a penetrating oil. Pathfinder II® is pre-mixed with a penetrating oil. The herbicide will pass through the bark. Therefore, girdling the tree's trunk is not necessary and, in fact, may reduce the effectiveness. Once the basal bark treatment has been completed, it may take several weeks before there is evidence that the tree has been controlled. Defoliation and the presence of termites are indicators that the treatment has been successful.

Basal bark treatments are most effective in the fall when the Brazilian pepper-trees are flowering. This is due to the high level of translocation occurring within the tree. Fruiting occurs during winter, and Brazilian pepper-trees that have been controlled using a basal bark treatment may retain their fruit. This situation will require that the area be checked for seedlings on a regular basis.

Foliar Herbicide Application

Foliar herbicide application can be used on Brazilian pepper-tree seedlings. An herbicide containing triclopyr or glyphosate is applied directly to the tree's foliage. Results of a foliar application will be wilting of leaves. The herbicide will be translocated to other parts of the tree, thus effectively controlling the Brazilian pepper-tree.

Caution: Foliar applications require considerably more herbicide to control Brazilian pepper-tree. Also, damage to nearby plants resulting from wind drift of the herbicide should be avoided.

Biological Control

Currently, there are no biological controls that have been released in the United States for Brazilian pepper-tree. Over 200 insects have been identified that feed on Brazilian pepper-trees in the tree's native land. However, in order for them to be considered as possible biological control agents, scientists must prove that they are specific to Brazilian pepper-trees. Effective biological control agents must be able to reproduce after introduction into the United States.

University of Florida scientists have identified two insect species that may prove to be effective biological control agents, a sawfly and a thrips. The sawfly causes defoliation and the thrips feeds on new shoots. UF scientists expect authorization to release these insects in the future. However, their effectiveness for controlling Brazilian pepper-trees in Florida is as yet unknown.

For more information, see UF/IFAS EDIS publication ENY-820 Classical Biological Control of Brazilian Peppertree (*Schinus terebinthifolius*) in Florida at http://edis.ifas.ufl.edu/IN114 and EENY-270 Brazilian Peppertree Seed Wasp, *Megastigmus transvaalensis* (Hymenoptera: Torymidae) at http://edis.ifas.ufl.edu/IN453.

Table 1. Herbicides and application methods for Brazilian pepper-tree control.

Active ingredient[1]	Application Methods	Comments
Glyphosate	Cut stump Foliar	Some products available in small containers from retail garden suppliers. Some products may be applied directly to water
Imazapyr (2 lb/gallon)	Cut stump Foliar (low volume) Basal bark	Should only be applied by licensed herbicide applicators.
Triclopyr amine	Cut stump Foliar	Some products available in small containers from retail garden suppliers. Some products may be applied directly to water
Triclopyr ester	Cut stump Foliar Basal bark	Available from agricultural suppliers. May **not** be applied directly to water.

[1] Based on the acid.

Showy Crotalaria (*Crotalaria spectabilis*)

D. Mudge, UF/IFAS Extension Orange County

Showy Crotalaria was introduced as a nematode-trap crop. Unfortunately, this legume is toxic. It draws consumption from farm animals and then poisons them. There are 12 varieties all with pea-shaped seed pods. It is widely distributed from Florida to Texas. Especially abundant along roadsides, fields, and waste land. All parts of the plant are toxic especially the seeds due to the alkaloid monocrotaline. Chickens, horses, cattle, swine, goats, sheep, mules, and dogs are all affected. It is toxic green and dried in hay. There is no effective treatment.

Identification and Control of Johnsongrass, Vaseygrass, and Guinea Grass in Pastures[1]

H. Smith, J. Ferrell, and B. Sellers[2]

Johnsongrass is a common perennial grass that grows throughout the South and Midwest. It is so common and well known as a troublesome weed that any large undesirable grass is often called johnsongrass. This is problematic because it is one of three perennial grasses found in pastures. Vaseygrass and guinea grass are often misidentified as johnsongrass but they have very different herbicide recommendations. Calling a plant johnsongrass when it is really vaseygrass or guinea grass can result in the wrong recommendation and lead to an expensive herbicide failure.

Identification: Johnsongrass, Vaseygrass, Guinea Grass

All three grasses have a prominent white midrib that extends the length of the leaf. But few similarities exist beyond this characteristic.

Growth Habit

All three grasses are perennial, but only johnsongrass has a creeping rhizome system and grows in patches rather than in individual bunches. Vaseygrass and guinea grass are both bunch-type grasses without a significant rhizome system. Additionally, vaseygrass is most commonly found in wet fields or along drainage ditches. Johnsongrass and guinea grass prefer dryer sites.

Seedhead

Johnsongrass and guinea grass have an open panicle seedhead that is angular. Color and size are the key differences between johnsongrass and guinea grass seedheads. Johnsongrass seeds are much larger and have a red/black mottled color, while the guinea grass seeds are smaller and somewhat green. Vaseygrass has a very different seedhead with alternating spikelets forming silky hairs around the seeds. Seeds are produced along the entire length of the seedhead branch, which does not occur in johnsongrass or guinea grass seedheads.

Figure 1. From left to right, guinea grass seedhead (Credits: Hunter Smith); johnsongrass seedhead (Credits: Brent Sellers); vaseygrass seedhead (Credits: Brent Sellers).

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Seeds

Guinea grass has small, oval, light green seeds, which often have wrinkles. Vaseygrass seeds have similar characteristics but are flatter, with the presence of hairs. Johnsongrass has much larger, pointed seeds that develop a reddish/brown tint as they mature.

Figure 2. From left to right, guinea grass seedhead branch (Credits: Brent Sellers); johnsongrass seedhead branch (Credits: Hunter Smith); and vaseygrass spikelet (Credits: Brent Sellers).

Stems

The stems of johnsongrass and guinea grass can look very similar. Inspection of the stems will show scattered but abundant hairs along the stem of guinea grass. Stem hair on guinea grass varies because of the different biotypes. Johnsongrass stems are totally smooth with no hairs. Vaseygrass stems have hairs where the leaf meets the stem or on the stem toward the base of the plant. This is because vaseygrass will generally lose stem hairs as the stems elongate.

Leaves

Johnsongrass leaves have a large white midrib and a smooth, glossy appearance. Guinea grass leaves have a less prominent white midrib, and the undersides are rough with stiff hairs. Vaseygrass leaves are long and narrow with an indented midrib and crinkled leaf margins.

Figure 4. From left to right, guinea grass leaf blade; johnsongrass leaf blade; vaseygrass leaf blade. Credits: Hunter Smith

Figure 5. Vaseygrass leaf margin. Credits: Hunter Smith

Roots

A fifth and final identification method is to pull or dig up the roots. All three of these grasses are perennial, but johnsongrass has large white rhizomes that are easily seen if the plant is well established. Vaseygrass and guinea grass have smaller, more fibrous root structures compared to johnsongrass.

Figure 6. Guinea grass root structure. Credits: Hunter Smith

Figure 7. Vaseygrass root structure. Credits: Brent Sellers

Figure 8. Johnsongrass rhizome. Credits: Brent Sellers

Control

Johnsongrass

Outrider: For best johnsongrass control, apply 1.33 ounces per acre when grass is actively growing and is at least 18–24 inches tall, up to the heading stage.

Impose (bermudagrass only): Use 4–6 ounces per acre on johnsongrass less than 24 inches. Higher rates can be used, but unacceptable injury on bermudagrass will likely occur. Although 4 oz of Impose can control johnsongrass, some regrowth should be expected on older stands that are large at the time of application.

Pastora (bermudagrass only): Use 1 oz/A on seedling johnsongrass (rhizomes < 18”) and 1.5 oz/A on mature stands. Bermudagrass injury will occur with Pastora, but will be less than that observed with Impose. Maximum application rate of Pastora is 2.5 ounces per acre per year.

Vaseygrass

Impose (bermudagrass only): Vaseygrass control can be accomplished by using 6–8 ounces per acre. This rate of Impose will be highly injurious to bermudagrass and one cutting of hay will likely be lost. This injury can be minimized if the application is made immediately after hay removal and before the bermudagrass leaf-out. Additionally, do not apply Impose until after the first hay cutting when rainfall is common.

Glyphosate: Spot spraying with 1% solution (1.2 oz/gal) can be effective. Care should be taken to avoid contact with desirable grasses.

Guinea grass

Glyphosate: Spot spraying with 1% solution (1.2 oz/gal) can be effective. Care should be taken to avoid contact with desirable grasses.

Palmer Amaranth (*Amaranthus palmeri*)

J. Bosques, UF/IFAS Extension Marion County

Palmer amaranth, or pigweed is an aggressive weed, invasive and highly prolific. It is native to the desert regions of southwest United States and northern Mexico. Palmer amaranth has become one of the major invasive weeds in Florida thanks to its ability to produce huge amounts of seed. Recently this weed has become resistant to glyphosate and ALS herbicides. Farm equipment, wildlife and animal manure can spread palmer amaranth seeds into un-infested pastures. Seed viability has been reported for up to 12 years in the soil.

Picture 1. Palmer Amaranth in vegetative stage.

Picture 2: Palmer Amaranth seedhead.

Smutgrass, small (*Sporobolus indicus*) and large (*Sporobolus indicus* var. *pyramidalis*)

C. Kelly-Begazo, UF/IFAS Extension Indian River County

Smutgrass is a warm-season perennial bunch grass that becomes relatively unpalatable as it matures. There are two varieties of smutgrass in Florida, small and large. Although small smutgrass was once more prevalent, large smutgrass is now the dominate species in central and south Florida pastures. Some grazing of juvenile smutgrass does occur when its quality is similar to bahiagrass, but within a few weeks it is no longer palatable to cattle. Control is difficult due to its aggressive nature and the fact that it is a prolific producer of seeds throughout the growing season with up to 45,000 seeds produced per plant. Seed size is relatively small making them easily transported and they cling to feathers and hair due to an outer gelatinous substance that becomes sticky when wet. Seeds can be viable for up 2 years in the soil and only need bare ground and a little moisture to germinate.

Smutgrass bunch.
http://www.commodities.caes.uga.edu/turfgrass

Smutgrass panicle.
http://www.archbold-station.org

Smutgrass top-killed by frost.
http://www.archbold-station.org

Blackberry and Dewberry: Biology and Control[1]

J. A. Ferrell and B. A. Sellers[2]

There are numerous *Rubus* (blackberry and dewberry) species in the southeastern United States, and many of them are found in Florida. Blackberry is commonly found in fence rows, ditch banks, and pastures, and can be overlooked for extended periods of time. However, lack of management can give rise to thickets that are difficult to control.

Blackberry and dewberry are often viewed simply as nuisance weeds that reduce grazing in a portion of the field. This may not seem that detrimental. However, severe financial losses can occur if cattle are injured by these growing thickets. For example, a bull's reproductive organs can be severely damaged by blackberry or dewberry thorns. Lesions or scratches from the thorns may result in infection or complete loss of reproductive performance. Lactating cows and dairy cows are not safe either. Thorns can scratch and cause infections of the udder, which may result in lower milk production. Therefore, blackberry infestations can result in monetary losses from both reduced grazing and potential animal injury.

Identification

It may be difficult to distinguish dewberry and blackberry when looking at a single leaf. However, the overall plant appearance and growth habits of these two species are quite different. Dewberry has a low, vine-like growth habit and rarely reaches heights greater than 2 feet (Figure 1). Blackberry has a very upright growth pattern and commonly reaches 3–6 feet in height (Figure 2). Dewberry commonly has slender thorns with red hairs on the stem (Figure 3), while blackberry has hard, tough thorns and no hairs. Additionally, the seeds in dewberry fruit are much larger and tougher than those in blackberry.

Figure 1. Dewberry has a trailing or vine-like growth pattern.

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Figure 2. Bush-type blackberry has upright growth.

Figure 3. Dewberry stems have slender thorns with red hairs.

Biology

Blackberry is a perennial, thicket-forming shrub common throughout the southeastern United States. Under each plant is a large lateral-growing root system that sprouts and produces additional plants. The rhizomatous root system is perennial, while the aboveground canes are biennial (living for two years). The first year, the canes emerge and grow rapidly; the second year, the canes bud and produce flowers and fruit. The canes subsequently die after fruiting.

Control

Herbicide application timing is important for effective blackberry control. Blackberry is most sensitive to herbicides when blooming in late spring and in the fall prior to frost. Applications made soon after emergence from winter dormancy or during fruiting are generally less effective. It is also important that the plants are not drought-stressed at the time of herbicide application.

Mowing is an effective practice if the goal is to keep blackberry at a manageable size until herbicide treatment is warranted. However, controlling blackberry by mowing alone is difficult and often ineffective. The large underground root structures are difficult to kill with mowing, and resprouting of the cut stems is common. Additionally, blackberry propagates from both seed and rhizomes. Therefore, mowing at bloom reduces seed production, but does little to stop the spread of blackberry rhizomes.

However, mowing can be an effective component when combined with herbicides. Large, dense thickets often have many dead canes with no leaves or two-year-old canes that possess old leaves. Old leaves do not absorb herbicide sprays as effectively as new foliage and are not as susceptible to herbicide applications. Additionally, dead canes can intercept the spray and decrease herbicide contact with susceptible foliage. Therefore, mowing reduces the size of the thicket and makes herbicide application easier.

Herbicides should **not** be applied in the same growing season as mowing. Applying herbicides soon after mowing often leads to ineffective or inconsistent control. The most effective strategy is mowing followed by six months of active blackberry regrowth before herbicide treatment. For example, in North Florida, if mowing takes place in October, it is often best to delay herbicide application until the following August because blackberry does not actively grow from November to February.

Soon after herbicide application it may be necessary to mow the dead blackberry plants to improve grazing in the treated area. However, it is best to allow the herbicide to work for approximately six weeks before the dead canes are mowed and removed. This allows the herbicide sufficient time to act before the treated plants are destroyed.

Herbicides

Currently, several herbicides list blackberry on their label. The most effective herbicides are metsulfuron, triclopyr ester (Remedy Ultra, others), PastureGard HL, and Telar. Velpar, Weedmaster, and 2,4-D are not recommended because individual plants rarely die and thicket density will not be reduced.

PastureGard HL (triclopyr + fluroxypyr) and triclopyr ester (Remedy Ultra, others) can safely be applied to bermudagrass and bahiagrass. Triclopyr ester or Pasturegard HL at 2 pints per acre applied when blooming is effective, but retreatment the following year may be required to achieve 100% control. These herbicides cause rapid blackberry defoliation (relative to metsulfuron and Telar, which are more slow acting) while controlling many other broadleaf species. Triclopyr ester will not control dewberry. Pasturegard HL applied at 2 pints per acre is more effective on dewberry, but only fair control (60% or 70%) should be expected. Pasturegard HL and triclopyr ester can be effective when applied in the spring or fall. However, research has shown that fall applications are generally more effective than spring applications.

Research has shown that metsulfuron products are the most consistent herbicides for control of blackberry. Applications made in spring or fall have proven equally effective. However, activity is slow and may take two or three months to show significant control.

Telar (chlorsulfuron) is closely related to metsulfuron, but can safely be applied to bermudagrass and bahiagrass. Telar at 1.0 oz/A is effective on blackberry, but will not likely control other common pasture weeds.

Summary

Complete blackberry and dewberry eradication is difficult and will likely require multiple applications and/or tactics. When relying solely on herbicides to control these species, it is best to spray when blooming or in the fall prior to frost. If a mowing strategy is employed, at least six months of active regrowth should occur prior to herbicide application, and at least six weeks should pass after herbicide application before removing dead canes.

Weed Management in Pastures and Rangeland—2015[1]

B. A. Sellers and J. A. Ferrell[2]

Weeds in pastures and rangeland cost ranchers in excess of $180 million annually in Florida by reducing forage yield, lowering forage quality, and causing animal injury through toxicity or specialized plant organs (thorns and spines). Effective weed management begins with a healthy pasture. Weeds are seldom a serious problem in a well-managed, vigorously growing pasture. Good pasture management involves the proper choice of the forage species and variety, an adequate fertility program, controlled grazing management, and pest management (weeds, insects, and diseases).

If pasture health declines, weeds will exploit the situation and become established. Bare ground is the perfect environment for establishment of weeds. Once established, weeds must be controlled with mechanical or chemical methods. However, unless the pasture-management problem that caused forage decline is corrected, the grass will not re-establish and weeds will re-infest the area.

Integrated weed management is both an economically and environmentally sound approach to weed management. An integrated approach involves scouting, prevention, and control (biological, cultural, mechanical, and chemical) in a coordinated plan.

Scouting

Scouting pastures is the foundation of a sound weed management program, but is often overlooked. Scouting involves routinely walking or driving through pastures and identifying weeds. This defines the scope of the problem and allows the best management practices to be implemented in a timely fashion. The number of weeds, the species present, and their locations are important. Note the dominant species as well as uncommon or perennial weeds. The management strategies adopted should focus on controlling the dominant species, while preventing the spread of less common species. If not managed proactively, the less common weeds in a pasture may become future dominant weed problems.

Proper identification of weeds is the first step toward weed control. A good example is knowing the difference between tropical soda apple (TSA) and red soda apple (cockroach berry). Of the two, only TSA is a troublesome invasive weed that must be controlled. However, some have occasionally confused the two species and allowed TSA to go uncontrolled. Unfortunately, this costly mistake results in TSA spreading throughout the ranch and potentially onto neighboring ranches. If there are questions concerning weed identification, contact your local county Extension office for assistance.

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Some weeds grow best in wet sites (maidencane ponds, depressional areas, ditches, etc.), while others can be found on dry sites (ditch banks, upland areas, and fence rows). Scout pastures for weeds in conjunction with other activities, such as checking calves, working cattle, and feeding. When a weed is first discovered, remove it or spot treat with an appropriate herbicide. Do not allow that one plant to produce seed and give rise to hundreds of new plants. It is less expensive (in terms of both time and money) to control one plant than to wait and have to control hundreds of plants.

Poisonous plants (e.g., *Crotalaria*, black nightshade, spiny pigweed, lantana, etc.) are commonly found throughout Florida. Animals do not usually choose to graze most poisonous plants when forage is abundant; however, when quality forage is limited because of poor growing conditions or overstocking, they may graze these plants.

Prevention

Prevention is any activity that keeps weeds from infesting a pasture. Most weeds spread by seed. Thus, preventing the movement of weed seeds onto the ranch reduces potential weed pressure. Weed seeds can be transported in hay, harvested grass seed, sod, cattle, mowing equipment, or dispersed by wind, water, and wildlife. Producers should avoid buying hay or grass seed that is contaminated with weed seeds. Refuse to purchase hay from someone who cannot provide a weed-free product. Using certified forage seed reduces weed seed contamination and is highly recommended.

Also, consider TSA. Cattle have been shown to excrete TSA seeds for at least 7 days after consumption. If cattle are grazing in a TSA-infested pasture, it is recommended that the cattle are held in a clean area for 10 days before moving them to a new pasture. This will reduce the likelihood of transporting TSA seeds. Remember, an ounce of prevention is worth a pound of cure.

Control

Cultural Control

Cultural practices improve weed control by increasing the competitiveness of the forage. This involves optimizing forage production through monitoring soil pH, fertility, and, potentially, water management. Generally speaking, a thick sward will prevent weed emergence, will outcompete emerged weeds, and will capture the majority of environmental resources (light, water, nutrients) necessary for growth. The aim of cultural practices is to modify your management program so that the sward is as competitive as possible.

Soil pH is an important factor for forage growth as well as weed establishment. Forage agronomists and soil scientists at the University of Florida have determined the optimum soil pH for most forages grown in Florida. Acidic soils limit plant growth and can result in aluminum and manganese toxicity, and magnesium, calcium, phosphorous, molybdenum, and potassium deficiency. Soil acidity may also result in poor root growth, which can reduce water and nutrient uptake. Weeds that grow under such conditions can be indicators of low soil pH. For example, crowfoot grass germination is optimum at soil pH levels between 4 and 5, which is too low for optimum forage growth. Thus, the presence of crowfoot grass in your pasture may warrant a soil test and corrective action.

Mechanical Control

Mowing is one of the most often used weed control methods in pastures. Mowing improves the appearance of a pasture, temporarily increases forage production, and, if properly timed, prevents weeds from producing seed. Mowing is generally more effective on broadleaf weeds than grass weeds and is more effective on annual weeds than perennial weeds. Carefully consider the cost of mowing and the anticipated effectiveness. As fuel prices increase, it may be more cost-effective to avoid mowing and use other forms of weed control since other weed control methods may be more effective on a given species.

Mechanical weed control does have drawbacks. Large weeds with extensive root systems will not be controlled through mowing alone. Additionally, mowing misses prostrate-growing weeds like crabgrass, spurges, and matchweed. Mowing can also spread vegetative plant stems, allowing the plant (e.g., prickly pear) to root elsewhere. If mowing is performed after seed set, seeds can accumulate on the mowing equipment and worsen the weed problem by spreading seed to other pastures.

Biological Control

Biological control involves the use of biotic agents (e.g., plants, herbivores, insects, nematodes, and phytopathogens) to suppress weeds. Overall, biological control is still in its infancy, but great strides are being made, especially against invasive plants. Two good examples are the tobacco mild green mosaic tobamovirus (TMGMV), and the newly released insect, *Gratiana boliviana*, both used for TSA control. The virus, TMGMV, can be sprayed to control existing TSA plants, while the beetle is used primarily for suppression.

Most biological control agents rarely provide complete weed control, but they usually suppress the weed population to a manageable level. Additionally, biological control agents are rarely fast-acting, so time is needed for the agent to suppress a given weed population. For example, the effect of *Gratiana boliviana* is not often seen until the year following the release of the beetle.

Chemical Control

Chemical weed control includes the use of herbicides. Herbicides kill weeds by inhibiting plant processes that are necessary for growth. Herbicides should be selected based on forage species being grown, weed species present, cost, and ease of application. Application method and environmental impact should also be considered.

Proper herbicide choice and application rate are extremely important. Lower-than-recommended application rates will not provide consistent weed control, while excessive application rates may cause injury to the forage or result in only killing the above-ground portion of perennial weeds. Also, herbicides must be applied at the correct time to be cost-effective.

Preemergence applications are made before weeds germinate and emerge. Understanding the life cycle of the weed is important when using a preemergence herbicide. Some weed seeds germinate in the summer, while others germinate in the winter months. Always refer to the herbicide label for additional information about controlling specific weeds.

Postemergence applications are made after the weeds emerge. The most effective and cost-efficient applications are made when the weeds have recently emerged and are small. For perennial weeds (regrowing from root storage organs), it is advisable to allow them to bloom before spraying, which allows sufficient leaf surface for coverage and ensures that the perennial is transporting photosynthates back to the roots.

Postemergence herbicides may be broadcast over the entire pasture or may be applied as a spot treatment to sparse weed patches. Spot treatment is less costly compared to broadcast spraying. Other application methods include wipers and mowers that dispense herbicide while mowing the weed. In all cases, it is extremely important to carefully read the herbicide label before purchase to determine if that herbicide controls the weeds in your situation.

Precautions When Using Phenoxy or Benzoic Acid Herbicides

1. For information about growth-regulating herbicides not covered below, see IFAS Publication SS-AGR-12, *Florida's Organo-Auxin Herbicide Rule 2012* (http://edis.ifas.ufl.edu/wg051).

2. Application of other pesticides from sprayers previously used for 2,4-D, dicamba, or other phenoxy or benzoic acid herbicides to susceptible crops, may result in injury.

3. Legumes in pastures or rangelands will be injured or killed by these herbicides.

4. Avoid drift to susceptible crops by applying at low pressures and when wind speeds are low and blowing away from susceptible crops. The use of a drift-control additive is advisable.

5. Clean sprayer thoroughly with household ammonia as follows:

a. Flush system with water. Drain.

b. Flush the system with ammonia (1 qt ammonia per 25 gallons water); let it circulate for at least 15 minutes, then flush the system again. Drain again.

c. Remove screens, strainers, and tips and clean in fresh water.

d. Repeat step b.

e. Thoroughly rinse the tank, hoses, booms, and nozzles.

f. Be sure to clean all other associated application equipment.

Forage Tolerance

Not all cultivars of a particular forage species respond similarly to a given herbicide (Table 5). Argentine bahiagrass tolerates most pasture herbicides except Roundup, while Pensacola may be severely injured by metsulfuron-containing products such as Cimarron, Chapparal, and others. All herbicides may be used on stargrass and bermudagrass, with some level of injury from Velpar. *Hemarthria*, also known as limpograss, is the most sensitive to herbicide applications of all forage grasses grown in Florida.

It is important to realize that the response observed from an herbicide application can vary. For example, the chance for forage injury can increase or decrease as the rate of herbicide applied either increases or decreases. Additionally, environmental conditions such as high temperature and high relative humidity may increase the potential for herbicide injury. For example, we have observed little or no injury to limpograss from 8 pt./acre 2,4-D amine when applied under cooler conditions, while 4 pt./acre in warmer weather caused moderate to severe injury.

The response of forages in Table 5 is for established forage cultivars. However, 2,4-D + dicamba (2 pt./acre) can be applied to sprigged forage cultivars, except for limpograss, seven days after planting/sprigging. A forage can be considered established when at least three tillers are present on bahiagrass or at least 6 in. of new stolon growth is present on sprigged forages.

Summary

Maintaining healthy, productive pastures will minimize the risk associated with weedy plants. Good pasture management practices such as adequate fertilization, insect control, and controlled grazing will result in healthy pastures. Unfortunately, weeds are present in pastures and the associated loss in forage production can have serious economic implications. An integrated weed management strategy involving prevention, detection, and control is the most economical and environmentally friendly approach to pasture weed management.

Table 1. Weed control in pastures and rangeland.

Trade Name and Rate of Commercial Product Per Acre	Common Name	Remarks
DURING ESTABLISHMENT		
Preemergence to Weeds		
2,4-D Several Brands[1] 1.0–2.0 qt. of 4 lb./gal. formulation	2,4-D amine or LV ester 1.0–2.0 lb.	**Bermudagrass and stargrass only.** Apply after sprigging and before emergence of sprigged bermudagrass. Will not give complete weed control; however, short residual control of seedling broadleaves, sedges, and certain grasses may be noted for 2–3 weeks, if proper environmental conditions exist.
Diuron 4L 1.5–4.5 pt./ac.c. or Diuron 80 1–3 lb./ac.c.	Diuron 0.8–2.4 lb.	**Bermudagrass only**. Will provide fair to good control of crabgrass, crowfootgrass, and goosegrass. Plant sprigs 2 inches deep. If sprigs have emerged at time of application, bermudagrass injury will occur. Do not graze or cut hay within 70 days. Before application, ensure that your product has proper labeling, since not all Diuron products are labeled for use in pastures.
2,4-D + dicamba[1] (Weedmaster, others) 2 pt.	dicamba + 2,4-D	**Bermudagrass and stargrass only.** Similar to 2,4-D, but often provides greater weed control. Short residual control of seedling broadleaves, sedges, and certain grasses may be noted for 2–3 weeks, if proper environmental conditions exist. **Do not apply to limpograss (*Hemarthria*).**
Postemergence to Weeds		
2,4-D Several Brands[1] (0.5–1.0 qt. of 4 lb./gal. formulation)	2,4-D amine	**Do not apply to bahiagrass until plants are 5″–6″ tall. Do not apply to limpograss (*Hemarthria* sp.).** Bermudagrass can tolerate 2,4-D at any growth stage. Controls most seedling broadleaf weeds. Repeat application may be needed.
2,4-D + dicamba[1] (Weedmaster, others) 2 pt./ac.	dicamba + 2,4-D	Can be used during establishment of hybrid bermudagrass, stargrass, and pangolagrass. Annual sedges and some grasses will be suppressed if less than 1 inch at time of application. Best results are seen if applications are made 7–10 days after planting. **Do not apply to limpograss (*Hemarthria*).**
Banvel, Clarity, Vanquish 1.5–2 pt./ac.	dicamba	Primarily used for establishment of Floralta limpograss (*Hemarthria*). Annual sedges and some grasses will be suppressed if less than 1 inch at time of application. Best results are seen if applications are made 7–10 days after planting.
Outrider 1.0–1.33 oz./ac.	sulfosulfuron	Use for perennial and annual sedge control 30 days after planting of bermudagrass, stargrass, and limpograss. Mix with 2,4-D or 2,4-D + dicamba when broadleaf pressure is also high. Do not apply to bahiagrass or Mulato (*Brachiaria* species) during establishment.
ESTABLISHED STANDS		
Dormant Pastures		
Gramoxone SL 1–2 pt.	paraquat	For **dormant** bermudagrass or bahiagrass. Apply in 20–30 gal.lons of water in late winter or early spring (probably in January or February) before grass begins spring green–up. Add 1 pt. surfactant (non–ionic) per 100 gal. spray mix. Do not mow for hay until 40 days after treatment. Can be mixed with 2,4-D or other herbicides for more broad–spectrum control.
Prowl H_2O 2–4 qt./ac.	pendimethalin	Dormant grass only. Applications of 3 qt./ac. have provided satisfactory weed control, but late–season escapes should be expected. Provides preemergence control of crabgrass, goosegrass, Texas panicum, sandbur, and other summer annual grasses. A 60–day hay restriction and a 45–day grazing restriction must be observed. Must have activating rainfall or irrigation within 2 weeks or control will be minimal at best.
Roundup Weathermax 11 oz.	glyphosate	Apply in mid– to late–winter months to bermudagrass or bahiagrass pastures and hayfields for the control of weedy grasses. Apply before new growth appears in the spring. Bermudagrass that is not dormant at the time of application may show a 2–4 week delay in green–up. No restrictions exist between application and grazing or haying.

Trade Name and Rate of Commercial Product Per Acre	Common Name	Remarks
Non–Dormant Pastures		
2,4-D Several Brands [1] 2.0–4.0 pt. of 4 lb./gal. formulation	2,4-D amine or LV ester 1.0–2.0 lb.	**Broadleaf weeds.** Annual weeds should be treated soon after emergence for best control with lower rates. Perennial weeds should be allowed to obtain a leaf surface large enough to allow sufficient spray coverage (about 12″–18″ tall). Use amine formulations during warm weather and LV esters during cool weather. Avoid drift. Applications of 2,4-D to limpograss (*Hemarthria* sp.) will cause significant injury during periods of high temperatures and humidity; much less injury has been observed during cool and dry conditions.
Banvel[1], Clarity, Vanquish 0.5–2.0 qt.	dicamba	**Broadleaf weeds.** Rate depends on weed species and size. Refer to the label for grazing restrictions. Avoid drift. *Hemarthria* sp. has generally exhibited more tolerance to dicamba than 2,4-D.
Chaparral 2.0–3.3 oz./ac.	metsulfuron + aminopyralid	Use on bermudagrass, pangolagrass, stargrass, and limpograss. Do not use on bahiagrass. Controls tropical soda apple, pigweed, blackberry, and many other problematic weed species. Will not control dogfennel. Add a non–ionic surfactant at 1–2 pt./100 gal. of solution. Avoid applications during spring green–up.
Cimarron Plus 0.125–1.25 oz./ac. or Cimarron Xtra 0.5–2.0 oz./ac.	metsulfuron + chlorsulfuron	Use on bermudagrass, pangolagrass, and stargrass. Controls several cool–season broadleaf weeds, pigweeds, and Pensacola bahiagrass. Bermudagrass should be established no less than 60 days prior to application. Add a non–ionic surfactant at 1–2 pt./100 gal. of solution. Avoid application during spring green–up.
Cimarron Max Part A (0.25–1.0 oz.) Part B (1.0–4.0 pt.)	Part A–metsulfuron Part B–2,4-D + dicamba	Cimarron Max is a two–part product that should be mixed at a ratio of 5 oz. *Part A* to 2.5 gal.lons *Part B*. Depending on the weeds present and the rate range that is selected, this mix will treat between 5 to 20 acres. For specific information on rate selection, consult the product label.
GrazonNext HL[1] 1.6–2.1 pt.	aminopyralid + 2,4-D	Excellent control of TSA, horsenettle, and other members of the nightshade family. Also controls pigweeds and other broadleaf weeds including less than 20″ dogfennel. Do not apply more than 2.1 pt./ac./yr. Do not apply to desirable forage legumes or severe injury and stand loss will occur. Do not apply to limpograss. GrazonNext will pass through animals and remain in the waste. Do not mulch sensitive crops with manure if animals have been grazing on GrazonNext–treated pastures. Avoid applications of this product to limpograss pastures during hot and humid conditions.
MSM 60, others 0.3–1.0 oz./ac.	metsulfuron	Use on bermudagrass, pangolagrass, and stargrass. Controls several cool–season broadleaf weeds, pigweeds, and Pensacola bahiagrass. Bermudagrass should be established no less than 60 days prior to application. Add a non–ionic surfactant at 1–2 pt./100 gal. of solution. Avoid application during spring green–up.
Impose or Panoramic 4–12 fl. oz./ac.	imazapic	DO NOT apply to bahiagrass. DO NOT apply during spring transition or severe bermudagrass or stargrass injury will occur. In summer months, expect 3–4 weeks of bermudagrass stunting after application, followed by quick recovery and rapid growth. This will reduce harvest yields of that cutting by 30%–50%. If this yield reduction is not accept. able, do not use these herbicides. Yield reductions of subsequent cuttings have not been observed. For control of crabgrass, sandspur, nutsedges, and vaseygrass, use 4 oz./ac. For suppression of bahiagrass, use 12 oz./ac.
Milestone 3–7 oz.	aminopyralid	Excellent control of tropical soda apple, horsenettle, and other members of the nightshade family. Controls pigweeds and other broadleaf weeds, but does not control blackberry or dogfennel. Can be safely applied under trees. Do not apply more than 7 oz./ac./yr. Do not apply to desirable forage legumes or loss of stand will occur. The use of a non–ionic surfactant is recommended. Milestone will pass through animals and remain in the waste. Do not mulch sensitive crops with manure if animals have been feeding on Milestone–treated pastures. Safe on limpograss.
Outrider 1.0–1.33 oz.	sulfosulfuron	Safe to apply to established bermudagrass, bahiagrass, stargrass, and limpograss. Provides excellent control of annual and perennial sedges.

Trade Name and Rate of Commercial Product Per Acre	Common Name	Remarks
Pastora 1–1.5 oz.	metsulfuron + nicosulfuron	**Established Bermudagrass Only**. Can be used to effectively control seedling crabgrass, sandbur, vaseygrass and established johnsongrass. Established vaseygrass will require retreatment for long–term control. If sandbur or crabgrass is greater than 4" tall, only seedhead suppression should be expected. Do not apply more than 2.5 oz./ac./yr. Do not apply to limpograss or bahiagrass due to high injury potential.
PastureGard HL[1] 1–2 pt.	triclopyr + fluroxypyr	Provides excellent control of dogfennel, blackberry, teaweed, and other broadleaf weeds. Less effective on tropical soda apple than triclopyr–ester (Remedy Ultra, others) alone. Forage legumes will be severely injured or lost if present at time of application. Applications of 2 pt./ac. may result in less than desirable weed control. Do not apply more than 8 pt./ac. per season. Surfactant should be added to spray mixture at 0.25% v/v.
Remedy Ultra, others 2 pt.	triclopyr ester	Provides excellent control of herbaceous and certain woody plants in pasture and rangeland. For best results, apply in 30 or 40 gal.lons of water per acre. The addition of a non–ionic surfactant at 0.25% v/v will increase control. Applications at air temperatures > 85°F may cause moderate to severe bermudagrass injury for 2–3 weeks.
Roundup Weathermax 8–11 fl. oz./ac.	glyphosate	For control of annual grasses in bermudagrass and stargrass. Apply immediately after hay removal, but prior to regrowth. Applications made after regrowth has occurred will cause stunting. Application rates as low as 6 oz./ac. are often effective for crabgrass and other small annual grass weeds. Do not apply more than 2 qt./ac./year. If Roundup Weathermax is applied to a dormant pasture, it cannot be sprayed again that season.
Telar 0.1–1.0 oz.	chlorsulfuron	For use on established warm–season forage grass species. Telar will control blackberry, pigweeds, wild radish, and selected winter weeds. Not effective on ragweed, tropical soda apple, and other common weeds. Ryegrasses will be severely injured or killed by Telar. Do not apply more than 1.3 oz./ac./yr. There are no grazing restrictions for any animals.
2,4-D + dicamba[1] (Weedmaster, others) 0.5–4.0 pt.	dicamba + 2,4-D amine	See remarks for 2,4-D and dicamba above. This mixture is usually more effective than either herbicide used alone.
Hard–To–Kill Perennial Grasses		
glyphosate 1–4 oz. per gal.	glyphosate 1%–3% solution for hand sprayer	**Spot treatment.** Apply when perennial weeds are actively growing. Surrounding forage will be killed if sprayed.
glyphosate 4–8 qt. to 2 gal. water	glyphosate 33%–50% solution	**Wiper application.** Apply at speeds up to 5 mph. Two passes in opposite directions. No more than 10% of any acre should be treated at one time.
Smutgrass		
Velpar L 2.75–4.5 pt., Velossa 2.29–3.75 pt. or Velpar DF 0.9–1.5 lb.	hexazinone	Apply Velpar to established stands of bermudagrass or bahiagrass when soil conditions are warm and moist and weeds are actively growing. Best control of smutgrass is usually achieved in late spring to early summer when regular rainfall occurs. Some temporary yellowing of the bermuda or bahiagrass will be noted, but plants will soon outgrow this effect. Apply Velpar by ground equipment only, and only **one** application is allowed per year. **KEEP SPRAYS WELL AWAY (AT LEAST 100 FT.) FROM THE BASE OF DESIRABLE TREES, ESPECIALLY OAKS.** Check label instructions for further precautions and safe use suggestions.
Pensacola Bahiagrass		
MSM 60, others 0.3 oz./ac.	metsulfuron	Apply to bermudagrass hay fields early in the season, after bahiagrass green–up but prior to seedhead formation. Early applications are often most effective; fall applications rarely control bahiagrass. Do not apply with liquid fertilizer solutions, as poor control may occur. Prolonged periods of dry weather prior to application will greatly decrease herbicide effectiveness. Always include a non–ionic surfactant at a rate of 0.25% v/v. Common or Argentine bahiagrass will not be effectively controlled. Pasture legumes will be severely injured or killed.

Trade Name and Rate of Commercial Product Per Acre	Common Name	Remarks
Cimarron Plus 0.5 oz./ac. or Cimarron Xtra 1.0 oz./ac.	metsulfuron + chlorsulfuron	Same as metsulfuron.
	Tropical Soda Apple	
Chaparral 2–3 oz.	metsulfuron + aminopyralid	Excellent control of TSA plants. Provides preemergence control of TSA seedlings for approximately 6 months after application. There are no grazing or haying restrictions; however, delaying cutting for 14 days will enhance weed control. Not for use on Pensacola bahiagrass.
GrazonNext HL[1] 1.6–2.1 pt.	aminopyralid + 2,4-D	Excellent control of tropical soda apple. Provides preemergence control of TSA seedlings for approximately 6 months after application. The 1.6 pt./ac. rate is highly effective on emerged TSA plants, but the 2.1 pt./ac. rate will provide the greatest length of residual control. Do not apply more than 2.1 pt./ac./yr. Will severely injure desirable forage legumes. Do not apply to limpograss. There are no grazing restrictions, but do not harvest for silage or hay for 7 days.
Milestone 5–7 oz.	aminopyralid	Excellent control of tropical soda apple. Provides preemergence control of TSA seedlings for approximately 6 months after application. The 5 oz. rate is highly effective on emerged plants, but the 7 oz. rate will provide the greatest length of residual control. Do not apply more than 7 oz./ac./yr. Do not apply to desirable forage legumes or loss of stand will occur. Volatility is low. The use of a non–ionic surfactant at 0.25% v/v is recommended.
Remedy Ultra, others [1] 1.0 qt.	triclopyr ester	Apply in late spring through summer as a broadcast spray for control of this species. Best results will occur when plants are adequately covered with spray solutions. Application of 30–40 gal./ac. of herbicide solution will be more effective than 20 or lower. The addition of a non–ionic surfactant at 0.25% v/v will increase control. Retreatment will be required as new seedlings emerge. Spot spray rate is 0.5%–1.0% v/v.
	Prickly Pear Cactus	
Remedy Ultra, others [1] 20% + basal oil 80%	triclopyr ester 20% diesel fuel or basal oil 80% (Spot treatment)	Apply as a spot treatment directly to prickly pear pads during spring and summer. Grass will be burned in treated spots but will recover. The addition of diesel fuel drastically enhances herbicide upt.ake, which will lead to prickly pear control. Prickly pear will die slowly over a period of 6–8 months with a few plants requiring retreatment.
Trump Card 3 pt./ac.	fluroxypyr + 2,4-D	Apply Trumpcard as a broadcast treatment in water. The use of a surfactant is required. A maximum of 3 pt./acre per growing season is allowed, but 6 pt./ac. is required for effective control. Two applications of 3 pt./ac. over two growing seasons, has been shown to be effective.
Vista XRT 22 oz./ac.	fluroxypyr	Apply Vista XRT at 22 oz./ac. as a broadcast treatment in water. The use of a surfactant is required. For spot treatment, use 0.5 fl oz. (15 ml.) per gal.lon of water. Control is very slow, and it often takes more than 1 year to see satisfactory results.
	Blackberry	
Chaparral 2 oz./ac.	metsulfuron + aminopyralid	Chaparral will provide good-to-excellent control of blackberry. For best results, apply when moisture conditions are sufficient and blackberry plants are not under drought stress. Late bloom and fall applications of Chaparral are the most effective. DO NOT apply in bahiagrass pastures. Do not mow within 1 year prior to application or control will be greatly reduced.

Trade Name and Rate of Commercial Product Per Acre	Common Name	Remarks
Cimarron Plus 0.75 oz./ac. or Cimarron Xtra 2.0 oz./ac.	metsulfuron + chlorsulfuron	Cimarron will provide good to excellent control of blackberry. Results are best when applied at blooming or late in the fall. Do not mow within 1 year prior to application or control will be reduced. **DO NOT** apply to bahiagrass pastures.
MSM 60, others 0.30–0.5 oz.	metsulfuron	Metsulfuron will provide good to excellent control of blackberry. Results are best when applied at blooming or late in the fall. Apply to bahiagrass pastures only as a last resort and expect 6–8 weeks of reduced growth and some stand thinning. Mixing with 1 pt./ac. 2,4-D amine will help reduce bahiagrass injury when applying in bahiagrass.
PastureGard HL[1] 2 pt.	triclopyr + fluroxypyr	Control similar to Remedy.
Remedy Ultra, others [1] 2 pt.	triclopyr	For best control of blackberry, apply 2 pt. when blooming and do not mow within 1 year prior to application. Remedy does not control dewberry. Applications made during prolonged periods of dry weather can greatly decrease control. Fall applications often provide more consistent blackberry control.
Telar 0.75 oz.	chlorsulfuron	Similar to control with Cimarron. Telar can safely be applied to bahiagrass or bermudagrass.
	Dogfennel	
2,4-D + dicamba[1] (Weedmaster, others) 2–3 pt.	dicamba + 2,4-D	Apply when plants reach a height of 12″–18″. Weedmaster is most effective approximately 1 month after dogfennel transition from winter dormancy. Refer to previous comments for dicamba and 2,4-D above.
GrazonNext HL[1] 24 oz.	aminopyralid + 2,4-D	Apply when plants are less than 30″ tall. If plants are larger than 30″, tank–mix GrazonNext with 3 pt./ac. 2,4-D, or 8 oz./ac. PastureGard HL.
PastureGard HL[1] 24 oz.	triclopyr + fluroxypyr	For control of larger dogfennel that has reached 40 inches or more in height.
Trump Card 3 pt.	fluroxypyr + 2,4-D	For control of dogfennel that are 18″–36″.
	Mixed Stands: Grass–Clover/Lespedeza Pastures	
2,4-D amine[1] 0.5–1.0 pt.	2,4-D (0.25 + 0.5 lb.)	Apply only one treatment per year to established perennial clover. Slight to moderate injury may occur. See label for specific use information.
	Thistles	
2,4-D 2 qt.	2,4-D	Highly effective if applied to thistles in the rosette stage. 2,4-D is not effective on thistles that have bolted or flowered. During cool temperatures, the ester formulation of 2,4-D will be most effective.
GrazonNext HL[1] 1.6–2.1 pt.	aminopyralid + 2,4-D	Excellent control of thistles at any stage of growth.
2,4-D + dicamba[1] (Weedmaster, others) 1.0–2.0 qt.	dicamba + 2,4-D	Apply late fall to early spring when daytime temperatures are > 50ºF. Applications are most effective if applied before flower stalks elongate. The addition of crop oil will increase herbicidal activity. Refer to previous comments for dicamba and 2,4-D above. For small rosettes, 1 qt./ac. rate is sufficient. For larger rosettes, 1.5–2 qt./ac. will be required.

[1] For state rules pertaining to application of organo–auxin herbicides in Florida, see EDIS Publication SS–AGR–12, *Florida Organo–Auxin Herbicide Rule 2012* (http://edis.ifas.ufl.edu/wg051).
Herbicide recommendations in this report are contingent upon their registration by the U.S. Environmental Protection Agency. If an herbicide's EPA registration is canceled, the herbicide is no longer recommended.

Table 2. Estimated effectiveness of herbicides on common broadleaf weeds in pastures and hayfields (2,4–D through Impose/Panoramic).[1]

Weed Name	2,4–D	Chaparral	Cimarron Plus or Xtra	Banvel or others	Vista XRT	Diuron	GrazonNext HL	Metsulfuron	Impose/Panoramic
bitter sneezeweed	E	E	E	E	–	G	E	E	–
blackberry	P	G–E	G–E	F–G	F	P	P–F	G–E	P
bracken fern	P	E	E	P–F	P	P	P	E	–
bullrush	G	–	–	G	P	P	P	–	–
chickweed	F	E	E	E	–	P	F	E	–
crotalaria, showy	G	G	–	G	G	–	G	–	–
cudweed	F	G	G	E	–	–	E	G	–
curly dock	F	E	E	E	–	P	E	E	–
dodder	P	–	–	P	–	P	–	–	–
dogfennel	F–G	P	F	F–G	G	P	F–G	F	–
evening primrose	E	G	G	E	–	G	E	G	–
Florida pusley	P	–	–	P–F	P	E	G–E	–	–
gallberry	G	–	–	E	–	P	–	–	–
goatweed	G	G	G	F–G	P–F	–	–	G	P
goldenrod	F	P	P	G	–	P	G	P	–
honeysuckle	–	–	–	E	–	P	–	–	–
horsenettle	P	E	P–F	G	F	P	E	P–F	–
horseweed	F	G	F	E	–	P	E	F	–
kudzu	P–F	G	P–F	G	P	P	G	P–F	P
maypop	P	P	P	P	–	–	–	P	–
palmetto	P	P	P	F	G	P	P	P	P
persimmon	P	–	–	F–G	–	P	P	–	P
pigweed	F	E	E	E	P	F	E	E	G
plantains	E	E	E	E	–	–	–	E	–
pokeberry	G	–	–	E	P	P	P	–	–
prickly pear	P	P	P	F	G	P	P	P	P
ragweed	E	E	G	E	G	G	E	G	F
red sorrel	P	E	E	E	–	F	–	E	–
shepherdspurse	E	–	–	E	–	G	–	–	–
sicklepod	G	G	G	E	G	F	G	G	F–G
stinging nettle/ fireweed	P	E	–	–	G–E	–	E	–	P
thistles	E	E	F	G	G	F	E	F	–
tropical soda apple	P	E	P	F–G	F	P	E	P	P
Virginia pepperweed	G	–	–	E	G	G	–	–	–
wax myrtle	P	P	–	P–F	–	P	P	–	–
wild garlic	G–E	G	G	E	–	P	–	G	–
wild radish	G	G–E	G–E	E	–	P	G	G–E	–

Weed control symbols: E = 90%–100% control; G = 80%–90% control; F = 60%–80% control; P < 60% control.

Table 3. Estimated effectiveness of herbicides on common broadleaf weeds in pastures and hayfields (Milestone through WeedMaster or others).[1]

Weed Name	Milestone	Outrider	PastureGard HL	Remedy	Velpar	WeedMaster, others
bitter sneezeweed	E	–	E	E	–	E
blackberry	P	P	G–E	G–E	F	P–F
bracken fern	P	–	P–F	P–F	F	P
bullrush	P	–	P	G	–	–
chickweed	–	–	F	E	E	E
crotalaria, showy	–	–	E	E	–	G
cudweed	E	–	G	E	–	G
curly dock	E	–	F	E	P	E
dodder	–	–	P	P	–	P–F
dogfennel	P–F	P	E	G–E	G	G
evening primrose	E	–	G	E	E	E
Florida pusley	–	–	G	–	–	F
gallberry	–	–	E	E	P	G
goatweed	–	–	F	F	–	G
goldenrod	G	–	G	G	–	G–E
honeysuckle	–	–	P	P	–	E
horsenettle	E	–	F	F–G	–	F
horseweed	E	–	G	G	–	E
kudzu	G	P	F	F	–	F
maypop	–	P	G	F	–	P–F
palmetto	P	P	G	F	P	P–F
persimmon	P	P	F–G	F–G	F	P–F
pigweed	E	–	F	E	G	E
plantains	P	–	–	–	–	E
pokeberry	F	–	P	P	–	E
prickly pear	P	P	F	G[2]	P	P–F
ragweed	E	–	E	E	F	E
red sorrel	–	–	F	E	–	G
shepherdspurse	–	–	G	E	E	E
sicklepod	–	–	G–E	E	–	E
stinging nettle/fireweed	E	P	E	E	–	F
thistles	E	–	G–E	E	E	E
tropical soda apple	E	P	G	G–E	F–G	F–G
Virginia pepperweed	–	–	G	P	E	E
wax myrtle	P	–	F–G	G	P	P–F
wild garlic	P	–	P	–	–	E
wild radish	P	–	G–E	E	E	E

[1]Estimated effectiveness based on rates recommended in this report. Effectiveness may vary depending on factors such as herbicide rate, size of weeds, time of application, soil type, and weather conditions.
[2]When applied as spot–treatment in basal oil.
Weed control symbols: E = 90%–100% control; G = 80%–90% control; F = 60%–80% control; P < 60% control.

Table 4. Estimated effectiveness of herbicides on common grass and sedges in pastures and hayfields.

Herbicide	bahia-grass	bermuda-grass	broom-sedge	crab-grass	dallis-grass	guinea-grass	johnson-grass	rye-grass	sandbur	smut-grass	vasey-grass	nutsedge
2,4-D	P	P	P	P	P	P	P	P	P	P	P	P
Banvel or others	P	P	P	P	P	P	P	P	P	P	P	P
Chaparral	G	P	P	P	P	P	–	P	P	P	P	P
Cimarron Plus or Xtra	G	P	P	P	P	P	–	P	P	P	P	P
Diuron	P	P	P	F–G	P	P	P	P	G	P	P	P
GrazonNext HL	P	P	P	P	P	P	P	P	P	P	P	P
Metsulfuron	G	P	P	P	P	P	–	P	P	P	P	P
Impose/ Panoramic	P–F	P	P	E	F	–	G	F	G–F	P	P–G	G–E
Milestone	P	P	P	P	P	P	P	P	P	P	P	P
Outrider	P	P	P	P	P	P	E	–	–	P	F–G	E
Pastora	F–G	P	P	F–G	F–G	F–G	G	G	G	P	F–G	P
PastureGard HL	P	P	P	P	P	P	P	P	P	P	P	P
Remedy	P	P	P	P	P	P	P	P	P	P	P	P
Velpar	P	P	P	P	–	–	–	G	–	E	–	P
Vista XRT	P	P	P	P	P	P	P	P	P	P	P	P
Weedmaster or others	P	P	P	P	P	P	P	P	P	P	P	P

[1]Estimated effectiveness based on rates recommended in this report. Effectiveness may vary depending on factors such as herbicide rate, size of weeds, time of application, soil type, and weather conditions.
Weed control symbols: E = 90%–100% control; G = 80%–90% control; F = 60%–80% control; P < 60% control.

Table 5. Tolerance of ***established*** (for at least 6 months) forage cultivars to commonly used herbicides.

Forage Species	Cultivar	2,4-D	Aim	Banvel	Chaparral	Cimarron Plus	Cimarron X-tra	Vista XRT	GrazonNext HL	Impose/Panoramic	Metsulfuron (MSM 60, others)	Milestone	Outrider	Pastora	Pasturegard HL	Remedy Ultra, others	Roundup/others	Telar	Vista	Banvel + 2,4-D (WeedMaster, etc.)	Velpar
Bahiagrass																					
	Argentine	T	T	T	I	I	I	T	T	S	I	T	T	NL	T	T	S	T	T	T	T
	Pensacola	T	T	T	S	S	S	T	T	S	S	T	T	NL	T	T	S	T	T	T	T
Bermudagrass																					
	Coastal	T	T	T	T	T	T	T	T	I	T	T	T	T	T	T	I–S	T	T	T	T–I
	Florakirk	T	T	T	T	T	T	T	T	I	T	T	T	T	T	T	I–S	T	T	T	T–I
	Jiggs	T	T	T	T	T	T	T	T	I–S	T	T	T	T	T	T	I–S	T	T	T	T–I
	Tifton-85	T	T	T	T	T	T	T	T	I	T	T	T	T	T	T	I–S	T	T	T	T–I
Brachiaria																					
	Mulato	T	I	T	N	N	N	T	T	N	N	T	T	NL	T	T	S	N	T	T	N
Stargrass																					
	Florico	T	T	T	T	T	T	T	T	I	T	T	T	NL	T	T	I–S	T	T	T	NL
	Florona	T	T	T	T	T	T	T	T	I	T	T	T	NL	T	T	I–S	T	T	T	NL
	Okeechobee	T	T	T	T	T	T	T	T	I	T	T	T	NL	T	T	I–S	T	T	T	NL
	Ona	T	T	T	T	T	T	T	T	I	T	T	T	NL	T	T	I–S	T	T	T	NL
Hemarthria																					
	Floralta	I–S	T	T	T	T	T	T–I	I–S	T–I	T	I	T	NL	I	I	S	T	I	I–S	NL

T = Tolerant; very little injury if any
I = Intermediate; slight injury, will regrow in approximately 1 month
S = Severe injury; more than 2 months to recover or complete death
N = No current information available
NL = Not Labeled

Table 6. Days between herbicide application to forage or pasture and feeding, grazing, or animal slaughter.

Herbicide	Non-lactating Cattle			Lactating Dairy Cattle		Horses
	Grazing	Hay Cutting	Slaughter	Grazing	Hay Cutting	
Banvel						
Up to 1 pt.	0	0	30	7	37	0
Up to 1 qt.	0	0	30	21	51	0
Up to 2 qt.	0	0	30	40	70	0
Chaparral	0	0	0	0	0	0
Cimarron Plus and Cimarron Xtra	0	0	0	0	0	0
2,4-D	0	30	3	7	30	0
GrazonNext HL	0	7	0	0	7	0
Metsulfuron	0	0	0	0	0	0
Impose or Panoramic	0	7	0	0	7	0
Milestone	0	0	0	0	0	0
Outrider	0	14	0	0	14	0
Pastora	0	0	0	0	0	0
PastureGard HL	0	14	3	1 season	1 season	0
Prowl H_2O	45	60	0	45	60	45
Remedy Ultra, others	0	14	3	1 season	14	0
Vista XRT	0	7	0	0	7	0
Roundup WeatherMax						
Dormant application	0	0	0	0	0	0
Between cuttings	0	0	0	0	0	0
Pasture renovation	56	56	56	56	56	56
Telar	0	0	0	0	0	0
Trump Card	7	14	2	7	14	7
Velpar	0	38	0	0	38	0
2,4-D + dicamba (Weedmaster, others)	0	37	30	7	37	0

Mole Cricket IPM Guide for Florida[1]

C. R. Kerr, N. C. Leppla, E. A. Buss, and J. H. Frank[2]

Mole crickets can become serious pests of turfgrasses, pastures, and vegetable seedlings. The first step in determining if you have a mole cricket problem at a site is to compare the existing damage to pictures of known mole cricket damage. If the damage is likely caused by mole crickets, specimens should be obtained and the pest identified. You then should determine if the number of mole crickets is great enough to cause an unacceptable level of damage and decide what control measures should be used. Eventually, a long-term, sustainable integrated pest management (IPM) program should be established. This guide will help you identify mole cricket infestations and manage them effectively and economically while minimizing environmental impacts.

Section 1: Observe Damage

Plants Affected

Mole crickets are most often thought of as pests of grasses, such as bahiagrass, bermudagrass, centipedegrass, seashore paspalum, St. Augustinegrass, and zoysiagrass. However, other plants that can be damaged by mole crickets include but are not limited to beet, cabbage, cantaloupe, carrot, cauliflower, chrysanthemum, chufa, coleus, collard, eggplant, gypsophila, kale, lettuce, onion, peanut, pepper, potato, rice, spinach, strawberry, sugarcane, sweet potato, tobacco, tomato, and turnip.

Damage Caused

Mole cricket feeding and tunneling can damage or kill the affected plants, especially during warm and moist summer months when the nymphs are rapidly developing. Feeding on the underground plant parts can cause an overall decline, dead patches, and little to no root mass. In pastures, mole-cricket-infested grass may be uprooted by feeding livestock, rendering the grass unavailable for additional grazing. When mole crickets tunnel in the upper ten inches of the soil surface, plants can become dislodged or have limited water uptake. Moreover, tunneling can create raised surface ridges that disrupt ball roll on golf courses (Figure 2). It may be a symptom of mole cricket activity when plants appear drought-stricken even after sufficient irrigation (Figures 3). Vegetables and other plants are also affected through underground feeding on roots or tubers, and above-ground feeding on foliage or stems, along with their tunneling activity. Above-ground feeding often results in girdling around the base of the stem, or at times the entire plant may be chewed off and taken into a tunnel as food and consumed. This girdling is especially common in seedlings. Flying adult mole crickets are attracted to lights at night, and they often burrow into moist soil nearby to mate and lay eggs. An initial adult mole cricket infestation thus may be localized around outdoor light sources and/or sprinkler heads. After egg hatch and as the next-generation nymphs mature and disperse, greater areas become damaged.

1. This document is IPM-206, one of a series of the Entomology and Nematology Department, UF/IFAS Extension. Original publication date May 2014. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. C. R. Kerr, graduate student, Entomology and Nematology; N. C. Leppla, professor, Entomology and Nematology; E. A. Buss, associate professor, Entomology and Nematology; and J. H. Frank, professor emeritus, Entomology and Nematology; UF/IFAS Extension, Gainesville, FL 32611.

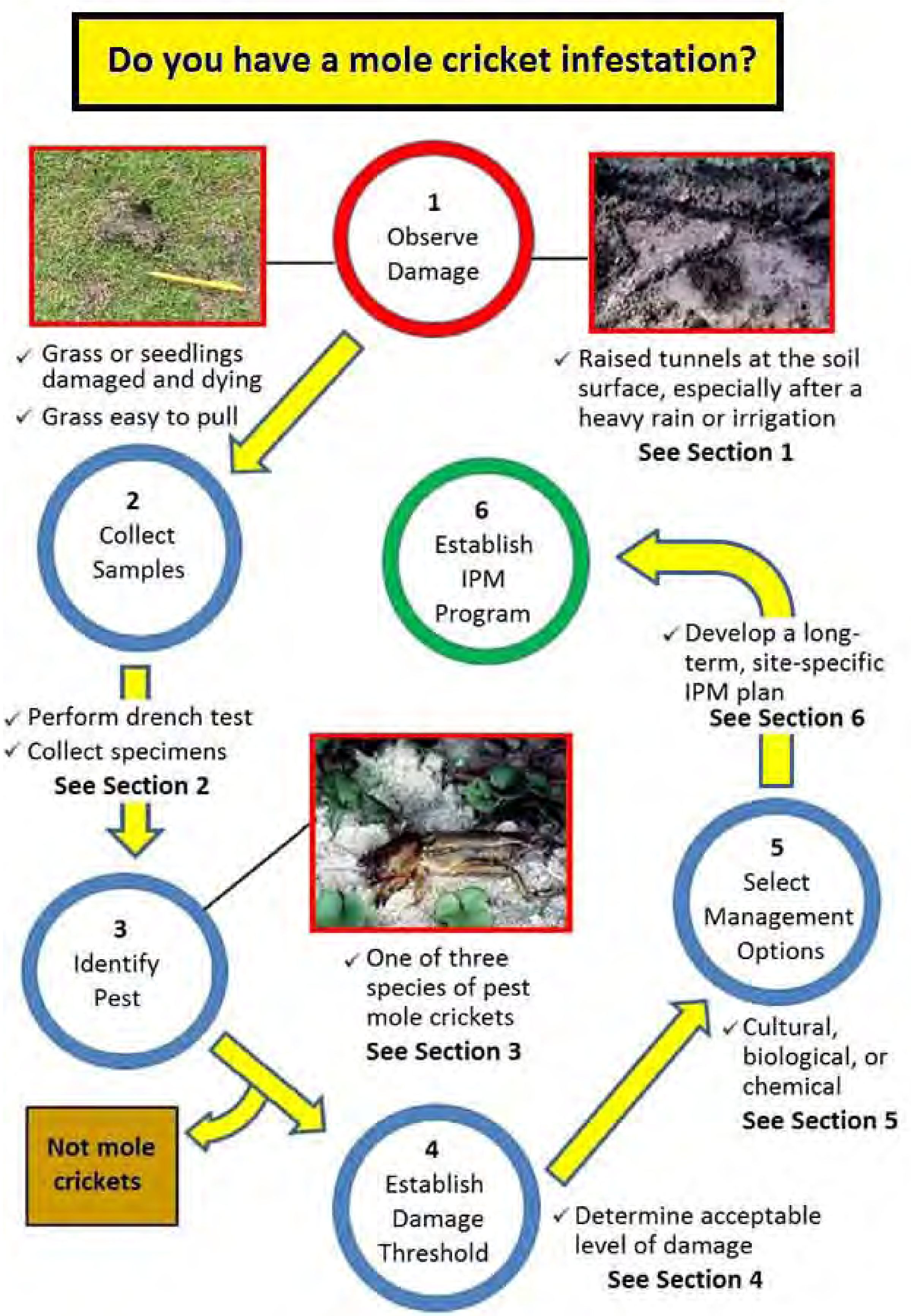

Figure 1. Pest mole cricket management: observe damage, collect samples, identify specimens, establish a damage threshold, select management options, and develop a long-term IPM program.

Figure 2. Characteristic mole cricket tunnels.
Credits: N. Leppla, UF/IFAS

Figure 3. Dead patches caused by mole crickets feeding on turfgrass.
Credits: E. Buss, UF/IFAS

Section 2: Collect Samples

Sampling is a critical part of a well-designed IPM program; it is important to know which pests are present and roughly how many there are. Doing a soap drench can bring mole cricket nymphs and adults to the soil surface, so their species and relative age can be determined. How many insects emerge from the soil may provide an idea of how bad an infestation is, but tunneling severity within a defined area may be more useful for decision-making. Below is a simple drench test for collecting specimens to be identified and for estimating mole cricket population densities. In this procedure, several 4 ft^2 samples are taken from soil that must be moist:

1. Mix ¾ oz. (1.5 tablespoons) of liquid dishwashing soap in a container with 1 gallon of water.
2. Mark out a 2 ft. x 2 ft. area where mole cricket activity is suspected.
3. Evenly pour the soap solution over the marked area.
4. Observe the area for 3 minutes; count and collect the mole crickets that emerge.
5. In many cases, control actions are justified if two or more mole crickets surface during the 3-minute sampling period. See Section 4, "Establishing Damage Threshold," for more information to help you determine whether to treat.

Section 3: Identify Pest

Three non-native pest species of mole crickets occur in Florida: the shortwinged mole cricket, *Scapteriscus abbreviatus* Scudder; the southern mole cricket, *Scapteriscus borellii* Giglio-Tos; and the tawny mole cricket, *Scapteriscus vicinus* Scudder. All three are believed to have been unintentionally transported into the southeastern United States around 1900. It is necessary to distinguish the native, non-pest species of mole cricket, genus *Neocurtilla*, from the invasive mole crickets in the genus *Scapteriscus*. Native mole crickets have four dactyls (claws) on the forelegs and the pest mole crickets have two (Figure 4).

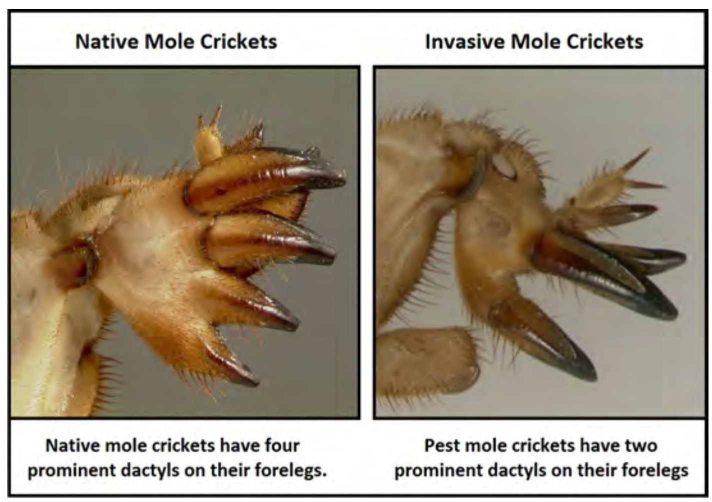

Figure 4. Differences in dactyls between native and invasive mole crickets.
Credits: L. Buss, UF/IFAS

S. abbreviatus (Shortwinged Mole Cricket)	*S. borellii* (Southern Mole Cricket)	*S. vicinus* (Tawny Mole Cricket)
		
The adult shortwinged mole cricket is 22-29 mm long and has wings that are shorter than its pronotum (patterned area just behind the head), generally no longer than the mid-abdomen. The forewings completely cover the hind-wings. Adults cannot fly. The pronotum is brown with several darker spots. The area between the two dactyls appears "U-shaped." The shortwinged mole cricket causes limited damage to plants.	The adult southern mole cricket is 25-32 mm long. Forewings are longer than the pronotum, and the hind-wings extend beyond the tip of the abdomen. The pronotum is mottled dark brown, or dark brown with four lighter spots. The area between the two dactyls appears "U-shaped." The southern mole cricket is mainly predacious and, although it feeds on plants, most of the damage is caused by tunneling.	The adult tawny mole cricket is 24-33 mm long. Forewings are longer than the pronotum, and the hind-wings extend beyond the tip of the abdomen. The pronotum is brown with a darker central region. The area between the two dactyls appears "V-shaped." The tawny mole cricket feeds only on plants, and is usually the most abundant, wide-spread, and damaging of the three invasive species.

Figure 5. Identification of invasive mole cricket species.
Credits: L. Buss, UF/IFAS

Mole Cricket Life Cycle

Eggs (Figure 6): The female builds a circular egg chamber in the soil near one of the tunnels. The 3- to 4-cm-diameter chambers are placed 5-30 cm below the soil surface. Eggs are deposited in a cluster within the egg chamber, each mass containing 25-60 eggs. Eggs are gray to brownish and roughly oval, measuring about 3 mm long and 1.7 mm wide when fresh. Through the absorption of water, the eggs reach a final size of about 3.9 mm long and 2.8 mm wide. Egg development requires 10-40 days, depending on the soil temperature. A female produces 2-5 egg masses in a lifetime.

Figure 6. Shortwinged mole cricket eggs close to hatching.
Credits: L. Buss, UF/IFAS

Nymphs (Figure 7): Recently hatched nymphs, called first instars, are whitish but darken to their mature color during the first 24 hours. First instars may consume the egg shell or cannibalize siblings; however, they soon leave the egg chamber and burrow to the soil surface. Nymphs and adults are similar in appearance, except nymphs have underdeveloped external wings called wing-pads. Development time of nymphs varies, requiring 23-38 weeks during which they go through 8-10 instars before becoming adults.

Figure 7. Shortwinged mole cricket nymphs (note the lack of wings).
Credits: J. Castner, UF/IFAS

Adults (Figure 8): Adult mole crickets are light yellowish to dark brownish and measure 22-33 mm in length, depending on the species. They have enlarged forelegs with dactyls, blade-like projections used for digging. Their antennae are shorter than the body, and they have two long sensory appendages called "cerci" at the tip of the abdomen. Tawny and southern mole crickets become active at dusk when each male emits a "song" from its burrow that attracts a female of the same species. They mate within the burrow, after which the female may eject the male and occupy the burrow. Unlike the other two species, the shortwinged mole cricket male produces only a weak pulsing chirp that attracts a female.

Figure 8. Tawny mole cricket adult.
Credits: L. Buss, UF/IFAS

Mole Cricket Seasonal and Geographic Distribution

THE SHORTWINGED MOLE CRICKET

The shortwinged mole cricket occurs mainly in coastal regions, with sandy soils (Figure 9). Since it is flightless, the species has not spread as extensively as the other two pest mole crickets. It currently has a limited geographical range in Florida, but all life-stages can occur year-round.

THE SOUTHERN MOLE CRICKET

The southern mole cricket occurs across much of the southeastern United States from southern North Carolina to central Texas (Figure 10). It also has been reported recently in Yuma, Arizona, and Los Angeles County, California. It is distributed throughout Florida, occurring primarily in moist, sandy areas. This mole cricket usually has one generation per year, but it has two in southern Florida. Peak flights generally occur from April to June, with an additional minor flight around November. However, in south Florida, a second major flight usually occurs in July.

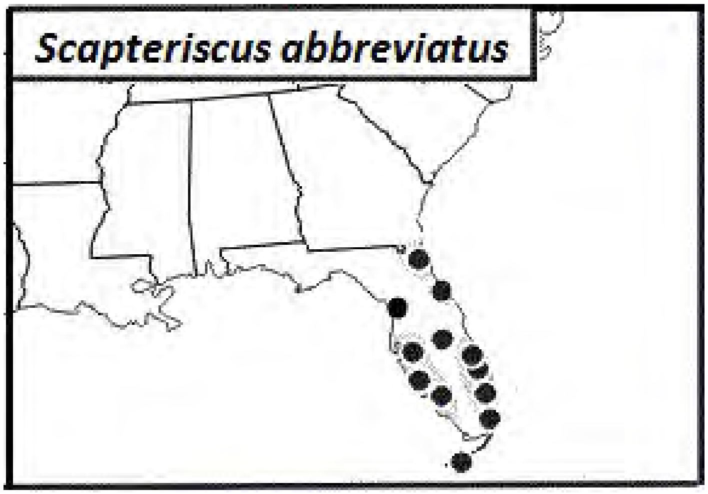

Figure 9. Distribution of the shortwinged mole cricket.
Credit: T. Walker, UF

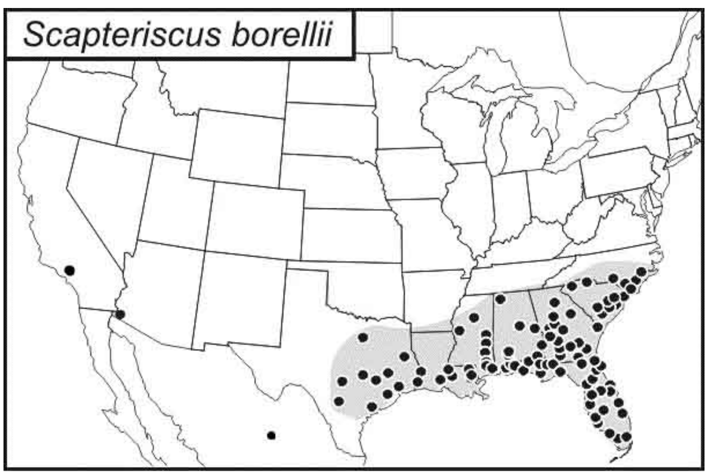

Figure 10. Distribution of the southern mole cricket.
Credit: T. Walker, UF

THE TAWNY MOLE CRICKET

The tawny mole cricket occurs within several miles of the Atlantic and Gulf coasts from North Carolina to eastern Texas (Figure 11). However, it is distributed throughout Florida and primarily inhabits well-drained, moist, sandy areas. This mole cricket has one full generation per year with peak flights generally occurring in March-May, with an additional minor flight in the fall. After December, nearly all mole crickets in flight are the tawny mole cricket. Egg hatch occurs in April-June, after which nymphs develop for five months and become adults as early as September.

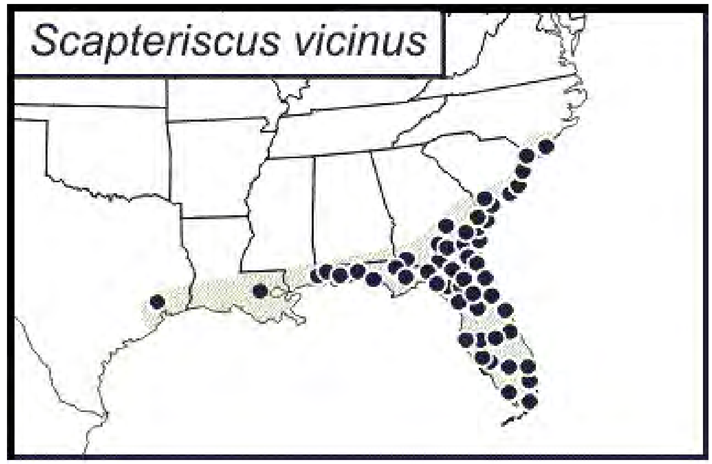

Figure 11. Distribution of the tawny mole cricket.
Credit: T. Walker, UF

Section 4: Establish Damage Threshold

The amount of plant damage a homeowner or site manager determines is tolerable is called the "damage threshold." It varies with the site and expectations for plant quality. On athletic fields and golf courses, the more intensive management practices, lower cutting heights, and esthetic standards may dictate lower thresholds. In vegetable production, on the other hand, acceptable levels of damage may be low during the seedling stage but higher as the plants mature. Thresholds are highly subjective and vary with the condition of the plants.

The damage mole crickets cause is related to the species, stage, and number of mole crickets that infest the site. Tawny mole crickets, for instance, cause a relatively high degree of destruction, and a range of 2-4 adult mole crickets per 4 ft^2 is a general upper limit warranting management action for turf, though most managers set the damage threshold somewhat higher for pastures. The plant damage nymphs cause increases as they grow and disperse. Continue sampling and re-evaluating thresholds throughout the mole crickets' life cycle to watch for increases both in the number of mole crickets and the damage they are causing. Ultimately, the severity of a mole cricket infestation and the associated damage threshold will dictate which control options will be most effective and economical.

Section 5: Select Management Options

Options for managing mole crickets in turfgrass include cultural control, biological control, and chemical control. Properly integrating several options will provide the greatest level of long-term control. After verifying the species, stage, and relative abundance of mole crickets, and deciding on a reasonable action threshold, select management practices from the following options:

Cultural Control

Cultural controls are steps taken in the management of a site that can make it less attractive or supportive for mole crickets. Steps may include selecting tolerant plant cultivars, altering soil moisture, reducing attractive lighting, and changing various growing practices. Cultural controls, such as lighting, may be implemented individually or used in conjunction with other methods.

TOLERANT CULTIVARS

No turfgrass species or cultivar is completely resistant to mole cricket damage, although centipedegrass, St. Augustinegrass, and zoysiagrass are considered the least frequently injured. Bahiagrass, bermudagrass, and seashore paspalum tend to be the most susceptible to damage caused by mole crickets. Table 1 describes some susceptible and tolerant turfgrass cultivars.

Table 1. Some tolerant and susceptible cultivars of turfgrass species.

Turfgrass	Generally Susceptible Cultivars	Generally Tolerant Cultivars
Bahiagrass	Pensacola, Tifton 9, and Sand Mountain	Argentine and Paraguay 22 (tolerance can be low)
Bermudagrass	Tifdwarf, Tifgreen, Sunturf, Texturf-10 and Texturf-1F	Ormond, Tifsport,Tifeagle, Tifway, Tifton-44
Centipedegrass	Most cultivars generally tolerant	
Seashore Paspalum	Most cultivars generally susceptible	
St. Augustinegrass	Bitterblue	Most cultivars generally tolerant
Zoysiagrass	Royal and Meyer	Diamond, Palisades, Emerald, Cavalier

SOIL MOISTURE

Soil moisture can affect mole crickets, significantly increasing plant damage at irrigated sites. Mole crickets remain closer to the soil surface when the soil is moist but tunnel deeper when the soil is dry. Rain after a long dry period causes an increase in the number of mole crickets in flight and may increase the number attracted to lights. During periods of egg-laying, females prefer to lay more eggs in irrigated areas than in non-irrigated ones. Egg survival decreases under drought conditions. Long-term control of soil moisture generally is not an option because it would disrupt plant growth, but the response of mole crickets to soil moisture can be used to time pest management practices. For example, insecticides could be more effective if applied after irrigation that brings mole crickets closer to the soil surface. Alternatively, flooding can drown the mole crickets or force them to move to higher ground where insecticides can be applied as spot treatments.

LIGHTING

Mole crickets fly at dusk for 1-2 hours during which they are attracted to light, especially ultraviolet and mercury-vapor lamps. To limit the incidence of mole crickets in turfgrass, lights should be turned off at a site during times of peak flight. Conversely, lights can be used to attract mole crickets for spot treatment with insecticides. If lights are necessary, yellow bulbs or filters can be used to minimize attraction of mole crickets.

TILLAGE

The objective of tilling is to expose mole crickets to predation or desiccation and kill them mechanically. Feeding by birds may be promoted by tilling, for example. In addition to exposing or damaging the insects, tilling can destroy their burrows and cause them to relocate. Tilling generally is not used on turfgrasses but can be effective on agricultural sites. Till when eggs and young nymphs are present because these life stages are more palatable to birds and less able to resist desiccation, so they are more likely to be killed than adults.

PLANT HEALTH

The plant's health can affect its tolerance to damage by mole crickets. Maintaining proper fertilization, irrigation, and soil conditions is important. For turfgrasses, leaving sufficient shoot growth after mowing is important because cutting too close increases stress on the grass. Mowing height recommendations are given in table 2. For pastures, overgrazing should be avoided as this can cause significant stress to the grass.

Table 2. Turfgrass mowing height recommendations.

Turgrass	Recommended mowing height
Bahiagrass	3-4″
Bermudagrass	Cultivar and utility dependent
Centipedegrass	1-1.5″
St. Augustine Dwarfs	2-2.5″
St. Augustine Standards	3.5-4″
Zoysiagrass	2-2.5″
Source: Dr. Trenholm, UF/IFAS	

RECORD KEEPING

Areas that historically have been infested by mole crickets are likely to be re-infested. It therefore is important to document and map these preferred mole cricket habitats. Monitor these areas intensively so that you can implement control measures quickly before damage thresholds are exceeded.

Biological Control

Biological control is the use of living natural enemies to control pests. Natural enemies can be predators, parasites, pathogens, or competitors. Populations of some natural enemies may be augmented by habitat manipulation. In some cases, natural enemies can be produced in large quantities and released at sites that have too few established natural enemies to effectively limit pest populations, keeping it below the damage threshold. For pest mole crickets in Florida, widespread applications have been made of the entomopathogenic mole cricket nematode, *Steinernema scapterisci*, in addition to releases of the Larra wasp, *Larra bicolor*, and Brazilian red-eyed fly, *Ormia depleta*. These non-native natural enemies were imported, tested for safety and released by the UF/IFAS Mole Cricket Research Program. All are currently present in Florida, but none are available commercially. Specifics on the importation and introduction of these three introduced natural enemies are given by Frank and Walker (2006).

MOLE CRICKET NEMATODE

This nematode (Figure 12) was introduced from South America and widely applied across Florida as a biopesticide until 2012. It infects large nymphs and adults, reproducing inside them to yield additional generations of nematodes. These parasites are not normally observed outside the host; they are spread throughout an area by the infected mole crickets.

Figure 12. *Steinernema scapterisci* nematodes emerging from an adult mole cricket in the laboratory.
Credits: L. Buss, UF/IFAS

LARRA WASP

This wasp (Figures 13 and 14) was introduced from South America into south Florida in 1981, and again into north Florida in 1988, to control pest mole crickets. It parasitizes only *Scapteriscus* spp. and does not sting people, so it was safe to release. The adult wasp is black with a red abdomen, and its wings are clear to smoky blue. A female usually lays one egg on each mole cricket it finds. The egg hatches in 6-7 days, the larva feeds on the mole cricket for 10-11 days and kills it, then pupates in a cocoon in the soil. A new adult emerges roughly 6 weeks later during the warmer months, but those that pupate in the fall may become adults by the following April. Larra wasps lay eggs only on mole cricket adults and medium to large nymphs.

Figure 13. Larra wasp laying an egg onto a tawny mole cricket adult.
Credits: L. Buss, UF/IFAS

Figure 14. Larra wasp larva feeding on a tawny mole cricket adult.
Credits: L. Buss, UF/IFAS

Larra wasps require a nectar source for their survival. The shrubby false button weed, *Spermacoce verticillata* (a.k.a. larraflower), is the preferred nectar source (Figure 15). White flowered pentas, *Pentas lanceolata,* and partridge pea, *Chamaechrista fasciculata,* are good alternative nectar sources. If either of these plants or other nectar sources are available, larra wasps will appear and forage at least 200 yards from them to locate mole crickets. Larraflower can be invasive, so it should be contained. Partridge pea may be toxic if consumed by livestock.

Distribution

By the end of 2008, the larra wasp had spread into much of north and central Florida and had penetrated into parts of south Florida (Figure 16). It also expanded its range into southern and eastern Georgia and coastal areas of Alabama and Mississippi. More recently it has been reported from eastern South Carolina and southeastern North Carolina. In northern Florida, larra wasp adults are active from late April until the first hard frost; in southern Florida, activity may persist year-round, offering even greater mole cricket suppression.

Figure 15. Larra wasp feeding on *S. verticillata* nectar.
Credits: L. Buss, UF/IFAS

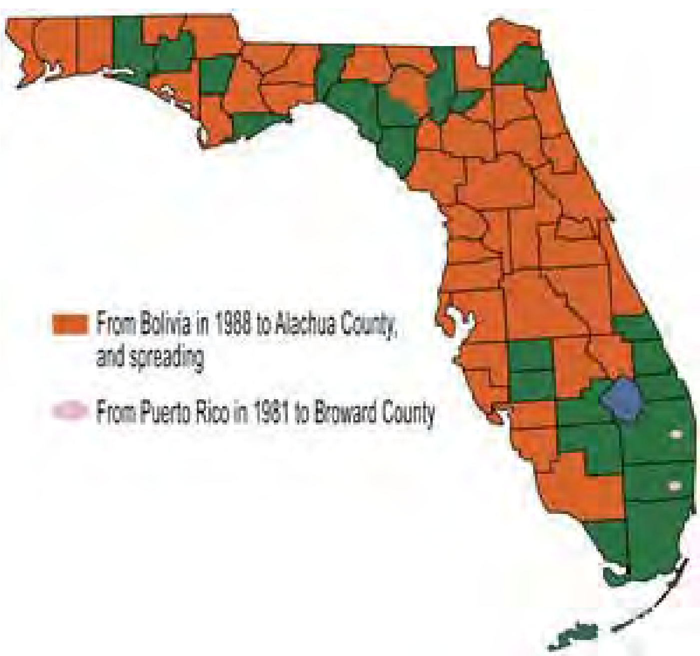

Figure 16. Distribution of larra wasp in Florida.
Credits: J. H. Frank, UF/IFAS

BRAZILIAN RED-EYED FLY

This tachinid fly was introduced from South America to suppress invasive mole crickets. The Brazilian red-eyed fly is distributed in the southern and central parts of Florida with the northern boundary reaching Alachua County (Figure 17). The fly parasitizes a pest mole cricket adult by depositing a larva nearby, the larva finds the adult, develops inside it, and kills it. Golf courses inhabited by the Brazilian red-eyed fly have considerably less damage than those without the fly.

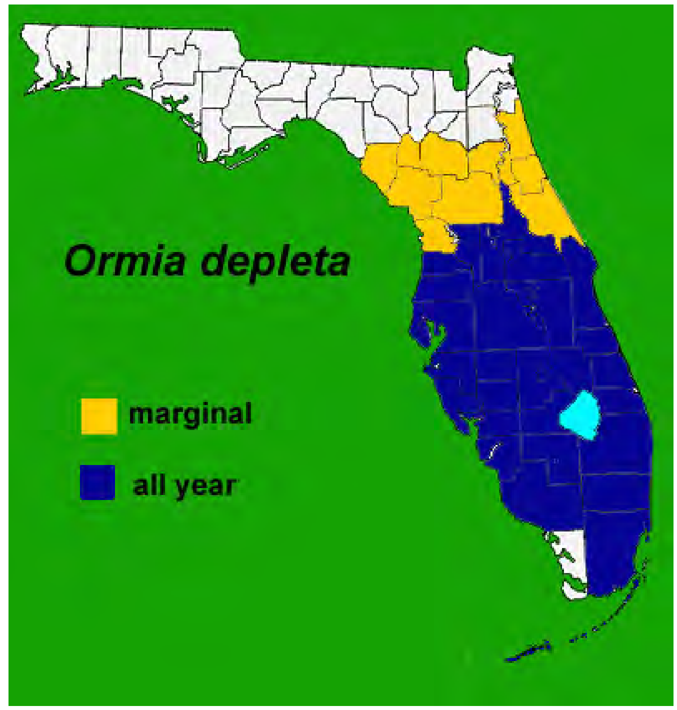

Figure 17. Distribution of Brazilian red-eyed fly in Florida.
Credit: J. H. Frank, Univ. Fla

Figure 18. Brazilian red-eyed fly pupa next to mole cricket.
Credit: L. Buss, UF

MOLE CRICKET PREDATORS

Naturally occurring predators of mole crickets include raccoons, opossums, armadillos, birds, spiders, tiger beetles, and many other insectivorous animals. Unfortunately, foraging by some of these predators, especially armadillos, can cause considerable damage to turfgrass.

Figure 19. Brazilian red-eyed fly adult.
Credit: L. Buss, UF

Chemical Control

Mole cricket IPM includes the use of insecticides when necessary; however, applications can be expensive and disruptive to biological control. Apply an insecticide only when the plant damage threshold is met or exceeded, and follow the instructions on the label. Time applications and target them to infested areas, thus reducing costs and environmental risks. On golf courses, for example, it's frequently most effective to apply insecticides only to fairways, greens, and tees, leaving roughs and driving ranges untreated to maintain populations of beneficial organisms. Small nymphs feeding and growing during the summer months are more susceptible to insecticides than large nymphs present in late summer and fall.

The tables below list the insecticide active ingredients for products in the National Pesticide Information Retrieval System (http://npirspublic.ceris.purdue.edu/) that are currently registered for use in Florida on pest mole crickets in residential lawns, golf courses and athletic fields, pastures, and on vegetables. Registrations for Florida specified 2014 as the year of last registration. Listed are biologically active ingredients that kill pest mole crickets. To minimize resistance to insecticides, products should be rotated based on the Insecticide Resistance Action Committee (IRAC) group numbers. The tables and associated appendix in this publication serve as guides only: keep in mind that the information in them is likely to be outdated because both regulations and registrations are constantly changing.

The appendix includes registered insecticide products formulated with the active ingredients listed in the tables. Restricted-use insecticides must be applied by a licensed applicator. You must read and understand the current product label before applying any insecticide. The label lists all specific sites and pests for which an insecticide may be applied legally. It also displays a signal word indicating the relative toxicity of the product to mammals: slightly toxic (CAUTION), moderately toxic (WARNING), or highly toxic (DANGER).

Residential Lawns[1]

Active Ingredient	IRAC Number	Active Ingredient	IRAC Number
Azadirachtin	29	Esfenvalerate	3A
Beauveria bassiana	Biopesticide	Fipronil	2B
Beta-cyfluthrin	3A	Gamma-cyhalothrin	3A
Beta-cyfluthrin & imidacloprid	3A 4A	Imidacloprid	4A
Bifenthrin	3A	Imidacloprid & lambda-cyhalothrin	4A 3A
Bifenthrin & imidacloprid	3A 4A	Indoxacarb	22A
Bifenthrin & zeta-cypermethrin	3A 3A	Lambda-cyhalothrin	3A
Bifenthrin imidacloprid & zeta-cypermethrin	3A 4A 3A	Permethrin	3A
Carbaryl	1A	Piperonyl butoxide, esfenvalerate & prallethrin	27A 3A 3A
Carbaryl & bifenthrin	1A 3A	Thiamethoxam	4A
Clothianidin	4A	Thiamethoxam & azoxystrobin (fungicide)	4A
Clothianidin & bifenthrin	4A 3A	Thiamethoxam & lambda-cyhalothrin	4A 3A
Cyfluthrin	3A	Trichlorfon	1B
Cypermethrin	3A	Zeta-cypermethrin	3A
Deltamethrin	3A		

[1] Insecticide applications on residential lawns may require a period of time before use is permitted. Be sure to read the entire label before applying any insecticide.

Golf Courses and Athletic Fields[1]

Active Ingredient	IRAC Number	Active Ingredient	IRAC Number
Acephate	1B	Fipronil	2B
Allyl isothiocyanate & capsaicin	--	Imidacloprid	4A
Beauveria bassiana	Biopesticide	Indoxacarb	22A
Beta-cyfluthrin	3A	Lambda-cyhalothrin	3A
Bifenthrin	3A	Permethrin	3A
Bifenthrin & imidacloprid	3A 4A	Piperonyl butoxide & permthrin	27A 3A
Bifenthrin & zeta-cypermethrin	3A 3A	Piperonyl butoxide & pyrethrins	27A 3A
Bifenthrin imidacloprid & zeta-cypermethrin	3A 4A 3A	Pyrethrins	3A
Carbaryl & bifenthrin	1A 3A	Thiamethoxam	4A
Chlorpyrifos	1B	Thiamethoxam & azoxystrobin (fungicide)	4A --
Cyfluthrin	3A	Trichlorfon	1B

[1] Insecticide applications on golf courses and athletic fields may require a period of time before use is permitted. Be sure to read the entire label before applying any insecticide.

Pastures[1]

Active Ingredient	IRAC Number
Beauveria bassiana	Biopesticide
Carbaryl	1A
Piperonyl butoxide & pyrethrins	27A 3A
Pyrethrins	3A

[1] Insecticide applications on pastures may require a period of time before grazing or cutting are permitted. Be sure to read the entire label before applying any insecticide.

Vegetables[1]

Active Ingredient	IRAC Number
Beauveria bassiana	Biopesticide
Bifenthrin	3A
Carbaryl	1A
Piperonyl butoxide & pyrethrins	27A 3A

[1] Insecticide applications on vegetables may require a period of time before harvesting and consumption are permitted. Be sure to read the entire label before applying any insecticide.

Section 6: Establish IPM Program

Develop a long-term, site-specific IPM program by combining cultural, biological, and chemical control measures to suppress pest mole crickets to levels that assure plant damage thresholds are not exceeded and that minimize costs and risks to humans and the environment. The program is based on plant selection and growing practices and mole cricket biology and management options.

The following are guidelines to consider in developing an IPM program for turfgrass:

1. Use a tolerant grass cultivar or species, such as centipedegrass or zoysiagrass.
2. Maintain healthy grass with proper irrigation and cutting.
3. Perform routine soil testing and add fertilizer or lime as needed.
4. Reduce watering during winter months; mole crickets require moist soil.
5. Plant a nectar source such as larraflower or partridge pea to attract and support Larra wasp populations.
6. Eliminate lights from sunset to well past dark during months of peak mole cricket flight.
7. Sample regularly for mole crickets; 2-4 per 4 ft^2 may require management.
8. Apply insecticides if plant damage thresholds are exceeded; evaluate their effectiveness.
9. Target and map areas that become infested.
10. Rotate insecticide chemical classes to delay pesticide resistance.

Acknowledgments

We thank Dennis Howard, Chief, Bureau of Pesticides and Bob Moore, Environmental Specialist in the Pesticide Registration Section, Bureau of Pesticides, Division of Agricultural Environmental Services, Florida Department of Agriculture and Consumer Services, for guidance and assistance with searching the National Pesticide Information Retrieval System. Fred Fishel, Director, UF/IFAS Pesticide Information Office, provided access to the system. He and John Capinera, Chair, UF/IFAS Entomology and Nematology Department, contributed helpful reviews of the manuscript. The work was supported by the USDA, NIFA, EIPM-CS program, and the Southern Region IPM Center.

Selected References

Abraham C. M., Held D. W., and Wheeler C. 2010. Seasonal and diurnal activity of *Larra bicolor* (Hymenoptera: Crabronidae) and potential ornamental plants as nectar sources. Applied Turfgrass Science Accessed Online: 17 January 2014. (http://www.plantmanagementnetwork.org/pub/ats/research/2010/nectar/)

Braman S. K., Duncan R. R., Hanna W. W., and Hudson W.G. 2000. Evaluation of turfgrasses for resistance to mole crickets (Orthoptera: Gryllotalpidae). HortScience 35:665-668.

Braman S. K., Pendley A. F., Carrow R. N., and Engelke M. C. 1994. Potential resistance in zoysiagrasses to tawny mole crickets (Orthoptera: Gryllotalpidae). Florida Entomologist 77:301-305.

Capinera J. L. and Leppla N. C. 2007. Shortwinged mole cricket, *Scapteriscus abbreviatus* Scudder; southern mole cricket, *Scapteriscus borellii* Giglio-Tos; and tawny mole cricket, *Scapteriscus vicinus* Scudder (Insecta: Orthoptera: Gryllotalpidae). UF/IFAS Extension, Electronic Data Information Source, IN-391.

Capinera J. L. and Leppla N. C. 2001. *Scapteriscus abbreviatus* Scudder (Insecta: Orthoptera: Gryllotalpidae). Featured Creatures, UF/IFAS Entomology and Nematology Department. (http://entnemdept.ufl.edu/creatures/orn/turf/pest_mole_crickets.htm).

Chong J. 2009. Comparative efficacy of neonicotinoids and selected insecticides in suppressing tunneling activity of mole crickets (Orthoptera: Gryllotalpidae) in turfgrass. Journal of Agricultrual and Urban Entomology 26:135-146.

Frank J. H., Fasulo T. R., Short D. E., and Weed A. S. 2013. Alternative methods of mole cricket control. (http://entnem.ifas.ufl.edu/fasulo/molecrickets/index.htm)

Frank J. H. and Parkman J. P. 1999. Integrated pest management of pest mole crickets with emphasis on the southeastern USA. Integrated Pest Management Review 4:39-52.

Frank J. H. and Walker T. J. 2006. Permanent control of pest mole crickets (Orthoptera: Gryllotalpidae: *Scapteriscus*) in Florida. American Entomologist 52:138-144.

Frank J. H., Walker T. J., and Parkman J. P. 1996. The introduction, establishment and spread of *Ormia depleta* in Florida. Biological Control 6: 368-377.

Hanna W., Braman S. K., and Hudson W. 2001. Bermudagrass hybrids just say 'no' to mole crickets. Golf Course Management 69:49-51.

Hertl P. T. and Brandenburg R. L. 2002. Effect of soil moisture and time of year on mole cricket (Orthoptera: Gryllotalpidae) surface tunneling. Environmental Entomology 31:476-481.

Hertl P. T. and Brandenburg R. L. 2013. First record of *Larra bicolor* (Hymenoptera: Crabronidae) in North Carolina. Florida Entomologist 96:1175-1176.

Kostromytska O. S., Buss E. A., and Scharf M. E. 2011. Toxicity and neurophysiological effects of selected insecticides on the mole cricket, *Scapteriscus vicinus* (Orthoptera: Gryllotalpidae). Pesticide Biochemistry and Physiology 100:27-34.

Mole Cricket Control- For Ranchers. UF/IFAS Entomology and Nematology Department. (http://entomology.ifas.ufl.edu/fasulo/molecrickets/mcricket_for_ranchers.htm)

Parkman J. P., Frank J. H., Walker T. J., and Schuster D. J. 1996. Classical biological control of *Scapteriscus* spp. (Orthoptera: Gryllotalpidae) in Florida. Environmental Entomology 25:1415-1420.

Portman S. L., Frank J. H., McSorley R., and Leppla, N. C. 2010. Nectar-seeking and host-seeking by *Larra bicolor* (Hymenoptera: Crabronidae), a parasitoid of *Scapteriscus* mole crickets (Orthoptera: Gryllotalpidae). Environmental Entomology 39:939-943.

Reinert J. A. and Busey P. 2001. Host resistance to tawny mole cricket, *Scapteriscus vicinus*, in Bermudagrass, *Cynodon* spp. International Turfgrass Society Research Journal 9:793-797.

Reinert J. A. and Drees B. M. 2007. Mole Crickets Damaging to Turfgrass in Texas. Texas Cooperative Extension. (https://insects.tamu.edu/extension/publications/epubs/eee_00039.cfm)

Ulagaraj S. M. 1975. Mole crickets: ecology, behavior, and dispersal flight (Orthoptera: Gryllotalpidae: *Scapteriscus*). Environmental Entomology 4:265-273.

Walker T. J. and Moore T. E. 2013. Singing insects of North America. (http://entnemdept.ifas.ufl.edu/walker/Buzz/)

Walker T. J., Reinert J. A., and Schuster D. J. 1983. Geographical variation in flights of mole crickets, *Scapteriscus* spp. (Orthoptera: Gryllotalpidae). Annals of the Entomological Society of America 76: 507-517.

Appendix

The National Pesticide Information Retrieval System (http://npirspublic.ceris.purdue.edu/) was used to compile the list of registered insecticide products in this appendix. This retrieval system is available by subscription. The first search criterion was "pest to be controlled," so we used the keyword "mole cricket" and selected all four resulting variations—mole crickets, mole crickets (larvae), mole crickets (nymphs), and mole crickets (adults). Most of the products have not been tested for efficacy by the University of Florida. The application sites and respective site-specific keywords or categories were as follows:

- **Residential Lawns:** For the specific keyword we used "lawn." For sites, we selected all ornamental lawns and turf, including bahiagrass, bermudagrass, centipedegrass, ryegrass, and St. Augustinegrass.
- **Golf Courses and Athletic Fields:** For the specific keywords we used "golf or athletic." For sites, we selected all ornamental turf, athletic fields, golf course turf, annual ryegrass, bahiagrass, bermudagrass, centipedegrass, St. Augustinegrass, and zoysiagrass options except those signaling golf course sand traps, water treatment, grown for sod, stump treatment, soil fumigation, or seed treatment.
- **Pastures:** Within the list generated by the agriculture site category, "forage, fodder, hay and silage grasses," we selected forage-fodder grasses, pastures, bermudagrass, bahiagrass, and rangeland.
- **Vegetables:** Within the agriculture site category, we selected cucurbits, fruiting vegetables, leafy vegetables, root crop vegetables, seed and pod vegetables, and miscellaneous vegetables, and within those categories we included all crops that might be infested by mole crickets.

The insecticide lists given below serve as a guide only; keep in mind that the information given will likely become outdated because both regulations and registrations are constantly changing. **The applicator holds full responsibility in verifying the legal usage and assumes all associated liability when applying any pesticide.** Before applying an insecticide listed, verify your target pest and specific site of application are permitted by consulting the product's label and always wear proper personal protective equipment.

Partial Mole Cricket IPM Program for North Central Florida.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Event												
Adult flights			■	■	■	■			■	■	■	
Egg hatch				■	■	■	■	■				
Nymph development	■	■	■			■	■	■	■	■	■	■
Action												
Sample	■	■	■	■	■	■	■	■	■	■	■	■
Reduce watering	■										■	■
Reduce lighting			■	■	■	■			■	■	■	

Insecticide Products Registered for Residential Lawns.

Azadirachtin

SAFER BRAND BIONEEM MULTI-PURPOSE INSECTICIDE & REPELLENT CONCENTRATE
SAFER BRAND GRUB KILLER READY-TO-SPRAY
NEEMIX 4.5

Beauveria bassiana

BOTANIGARD ES
MYCOTROL O

beta-Cyfluthrin

BAYER ADVANCED TRIPLE ACTION INSECT KILLER FOR LAWNS
BAYER ADVANCED POWER FORCE MULTI-INSECT KILLER
TEMPO ULTRA GC INSECTICIDE (RESTRICTED USE)

beta-Cyfluthrin & Imidacloprid

BAYER ADVANCED COMPLETE BRAND INSECT KILLER FOR SOIL & TURF
BAYER ADVANCED COMPLETE INSECT KILLER FOR SOIL & TURF
BAYER ADVANCED LAWN COMPLETE INSECT KILLER FOR SOIL & TURF

Bifenthrin

ACTISHIELD LIQUID INSECTICIDE
BASELINE FLORIDA INSECTICIDE
BASELINE INSECTICIDE
BASIC SOLUTIONS LAWN & GARDEN INSECT KILLER GRANULES
BIFEN I/T INSECTICIDE/TERMITICIDE
BIFEN L/P INSECTICIDE GRANULES
BIFEN XTS
BIFENTHRIN GC GRANULES (RESTRICTED USE)
BISECT G (RESTRICTED USE)
BISECT L
BONIDE EIGHT INSECT CONTROL FLOWER & VEGETABLE ABOVE & BELOW SOIL INSECT GRANULES
BONIDE INSECT & FEED
BROADCIDE FLOWABLE INSECTICIDE GC (RESTRICTED USE)
BROADCIDE GRANULAR INSECTICIDE GC (RESTRICTED USE)
CARPETMAKER X-X-X WITH 0.069 TALSTAR GRANULAR INSECTICIDE
COMPARE-N-SAVE CONCENTRATED INDOOR/OUTDOOR INSECT CONTROL
COMPARE-N-SAVE LAWN INSECT CONTROL GRANULES
FERTILIZER W/TALSTAR 0.069%
FERTILIZER W/TALSTAR 0.096%
FERTILIZER W/TALSTAR 0.2%
FERTI-LOME BROAD SPECTRUM INSECTICIDE
FORTIFY INSECT CONTROL
FORTIFY PHOSPHORUS FREE INSECT CONTROL PLUS LAWN FOOD 18-0-5
GREEN THUMB PREMIUM FERTILIZER + INSECT CONTROL 30-3-4
GREEN THUMB PREMIUM INSECT CONTROL GRANULES
GREEN THUMB SUMMER INSECT CONTROL + LAWN FERTILIZER (25-0-5)
GROWERS FERTILIZER WITH 0.083% BIFENTHRIN
HEAVY WEIGHT MULTI-INSECT & FIRE ANT KILLER GRANULES
HI-YIELD BUG BLASTER BIFENTHRIN 2.4
HI-YIELD BUG BLASTER II TURF INSECT CONTROL GRANULES
HI-YIELD VEGETABLE & ORNAMENTAL INSECT CONTROL GRANULES
HJE BIFENTHRIN PL GRANULAR
HY-END BIFEN S
KGRO READY TO USE HOME PEST INSECT CONTROL
LAWNSTAR GRANULAR INSECTICIDE
LESCO CROSSCHECK 0.069% PLUS FERTILIZER
LESCO CROSSCHECK EZ GRANULAR INSECTICIDE
LESCO CROSSCHECK PL GRANULAR INSECTICIDE
LESCO CROSSCHECK PLUS MULTI-INSECTICIDE
LESCO TALSTAR 0.069% PLUS FERTILIZER
LESCO TALSTAR 0.096% PLUS FERTILIZER
MASTERLINE BIFENTHRIN 7.9 TERMITICIDE/INSECTICIDE
MAXXTHOR SC
MAXXTHOR SG
MENACE 7.9% FLOWABLE (RESTRICTED USE)
MOLE CRICKET - CHINCH BUG LAWN SPRAY RTS
MONTEREY TURF & ORNAMENTAL INSECT SPRAY

Bifenthrin Cont.

ONYX INSECTICIDE
ONYXPRO INSECTICIDE (RESTRICTED USE)
ORTHO ANT, FLEA & TICK KILLER FOR LAWNS READY TO USE GRANULES
ORTHO BUG B GON MAX INSECT KILLER FOR LAWNS
ORTHO BUG BGON MAX LAWN & GARDEN INSECT KILLER 1
ORTHO MAX PRO
PRO-MATE BIFENTHRIN
PRO-MATE TALSTAR GC 0.069% WITH FERTILIZER (RESTRICTED USE)
PRO-MATE TALSTAR LG 0.069% WITH FERTILIZER
QUALI-PRO BIFENTHRIN I/T 7.9 F
SCOTTS PROFESSIONAL FERTILIZER X-X-X WITH ORTHO MAX PRO
SENTRYHOME YARD AND PREMISE SPRAY CONCENTRATE
SERGEANT'S YARD & PREMISE SPRAY CONCENTRATE

Bifenthrin & Imidacloprid

ALLECTUS G INSECTICIDE
PRO-MATE ALLECTUS 0.225% PLUS TURF FERTILIZER
THE ANDERSONS TURF PRODUCTS FERTILIZER WITH ALLECTUS INSECTICIDE
LESCO ALLECTUS 0.225 INSECTICIDE PLUS FERTILIZER
SIGNATURE ALLECTUS 0.225 G PLUS TURF FERTILIZER
TURFPRIDE ACCUBLEND FERTILIZER WITH 0.225G ALLECTUS INSECTICIDE
TCS GROWSTAR ALLECTUS 0.225 G PLUS TURF FERTILIZER INSECTICIDE
LESCO ALLECTUS 0.18 G PLUS FERTILIZER
TCS GROWSTAR ALLECTUS 0.18 G PLUS TURF FERTILIZER INSECTICIDE
PRO-MATE ALLECTUS 0.15% PLUS TURF FERTILIZER
TURFPRIDE ACCUBLEND FERTILIZER WITH 0.15G ALLECTUS INSECTICIDE

Bifenthrin & Zeta-Cypermethrin

ORTHO BUG B GON INSECT KILLER FOR LAWNS (2)
TALSTAR XTRA GRANULAR INSECTICIDE
ORTHO BUG B GON INSECT KILLER FOR LAWNS & GARDENS
TALSTAR XTRA GC GRANULAR INSECTICIDE (RESTRICTED USE)
TALSTAR XTRA GRANULAR INSECTICIDE

Bifenthrin, Imidacloprid & Zeta-Cypermethrin

TRIPLE CROWN T&O INSECTICIDE

Carbaryl

CARBAIT 5
SA-50 MOLE CRICKET BAIT

CARBARYL & BIFENTHRIN

FORTIFY ABOVE & BELOW INSECT & GRUB CONTROL
THE ANDERSONS TURF PRODUCTS DUOCIDE INSECT CONTROL

Clothianidin

CHINCH BUG KILLER WITH ARENA
GREEN LIGHT CHINCH BUG KILLER1 WITH ARENA
GREEN LIGHT GRUB CONTROL WITH ARENA

Clothianidin & Bifenthrin

ALOFT GC G (RESTRICTED USE – NOT LABELED FOR USE IN FLORIDA)

Cyfluthrin

BAYER ADVANCED POWER FORCE MULTI-INSECT KILLER
BAYER ADVANCED VEGETABLE & GARDEN INSECT SPRAY
BAYER ADVANCED TRIPLE ACTION INSECT KILLER FOR LAWNS & GARDENS
TEMPO 20 WP GOLF COURSE INSECTICIDE (RESTRICTED USE)

Cypermethrin

CYPER TC INSECTICIDE
CYPER-LO EC
DEMON MAX
UP-CYDE PRO 2.0 EC TERMITICIDE/INSECTICIDE (RESTRICTED USE)

Deltamethrin

DELTAGARD G INSECTICIDE GRANULE
DELTAGARD T&O GRANULAR INSECTICIDE
HI-YIELD IMPORTED FIRE ANT CONTROL GRANULES CONTAINING DELTAMETHRIN
HI-YIELD TURF RANGER INSECT CONTROL GRANULES CONTAINING DELTAMETHRIN
SUSPEND SC INSECTICIDE
TERRO HOME INSECT KILLER

Esfenvalerate

FENVASTAR ECOCAP
ONSLAUGHT MICROENCAPSULATED INSECTICIDE

Fipronil

CHIPCO CHOICE INSECTICIDE (RESTRICTED USE)
QUALI-PRO FIPRONIL 0.1G (RESTRICTED USE)

gamma-Cyhalothrin

OPTIMATE CS
SPECTRACIDE ACRE PLUS TRIAZICIDE INSECT KILLER FOR LAWNS & LANDSCAPES
SPECTRACIDE BUG STOP HOME BARRIER REFILL
SPECTRACIDE TRIAZICIDE INSECT KILLER FOR LAWNS
SPECTRACIDE TRIAZICIDE INSECT KILLER ONCE & DONE!

Imidacloprid

AGRISEL IMIDAPRO 2SC INSECTICIDE
ANDERSONS GOLF PRODUCTS TURF FERTILIZER 14-0-14 WITH MERIT
ARMOR TECH IMD 2SC
BAYER ADVANCED LAWN SEASON-LONG GRUB CONTROL
BAYER ADVANCED SEASON LONG GRUB CONTROL
BONIDE SYSTEMIC INSECT SPRAY WITH SYSTEMAXX
CRITERION 0.5 G INSECTICIDE
CRITERION 2F INSECTICIDE
CRITERION 75 WSP INSECTICIDE
DELPHI INSECTICIDE
DOMINION 2L TERMITIICIDE/INSECTICIDE
ENFORCE 0.5G TURF AND ORNAMENTAL INSECTICIDE
ENFORCE 75WSP TURF AND ORNAMENTAL INSECTICIDE
EQUIL ADONIS 2F INSECTICIDE
EQUIL ADONIS 75 WSP INSECTICIDE
FERTILIZER W/MERIT 0.15%
FERTILIZER W/MERIT 0.2%
FERTI-LOME SYSTEMIC INSECT SPRAY
FORTIFY SEASON LONG GRUB CONTROL
GARANT T&O 2F INSECTICIDE
GARANT T&O 75 WSP INSECTICIDE
GORDON'S GRUB NO-MORE GRANULES
GORDON'S PROFESSIONAL TURF & ORNAMENTAL PRODUCTS IMIDIPRO
GRUBEX
GRUBEX II
HI-YIELD GRUB FREE ZONE II
HI-YIELD GRUB FREE ZONE III
HI-YIELD SYSTEMIC INSECT SPRAY
IMIDASTAR 2L T&O
IMIGOLD 0.5 G
IMIGOLD 2 F
IMIGOLD 70 DF TURF, ORNAMENTAL AND GREENHOUSE INSECTICIDE
INVICT BLITZ ANT GRANULES
INVICT XPRESS GRANULAR BAIT
KNOCKOUT READY TO USE GRUB KILLER GRANULES
LADA 2F INSECTICIDE
LESCO BANDIT 0.5 G INSECTICIDE
LESCO BANDIT 2F INSECTICIDE
LESCO BANDIT 75 WSP INSECTICIDE
LESCO MERIT 0.2 PLUS TURF FERTILIZER
LESCO MERIT 0.2 PLUS TURF FERTILIZER
LESCO SYSTEMIC INSECTICIDE CONTAINS MERIT
MALICE 0.5G
MALICE 75 WSP
MALLET 7.1% PF INSECTICIDE

Imidacloprid Cont.

MARTIN'S DOMINION TREE & SHRUB
MERIT 0.5 G INSECTICIDE
MERIT 2F INSECTICIDE
MERIT 75 WP INSECTICIDE
MERIT 75 WSP INSECTICIDE
MIDASH 2SC T&O
PHOENIX HAWK-I 75WSP
PHOENIX HAWK-I 2L
PRIMERAONE IMIDACLOPRID 2F INSECTICIDE
PROFESSIONAL TURF SOLUTIONS WITH MERIT FERTILIZER
PROKOZ ZENITH 0.5 G INSECTICIDE
PROKOZ ZENITH 2F INSECTICIDE
PROKOZ ZENITH 75 WSP INSECTICIDE
PRO-MATE MERIT 0.2% PLUS TURF FERTILIZER
PROTHOR SC 2
QUALI-PRO IMIDACLOPRID 0.5G INSECTICIDE
QUALI-PRO IMIDACLOPRID 75 WSB
REGAL MERIT 0.2 PLUS
SCOTTS FERTILIZER X-X-X WITH GRUBEX PRO
SCOTTS PROFESSIONAL FERTILIZER X-X-X WITH GRUBEX
SIGNATURE FERTILIZER WITH 0.2% MERIT
SPECTRACIDE GRUB KILLER CONCENTRATE
SPECTRACIDE TREE & SHRUB INSECT CONTROL
TCS GROWSTAR MERIT 0.2 PLUS TURF FERTILIZER
THE ANDERSONS GRUBOUT DG 0.2% INSECTICIDE
THE ANDERSONS TURF PRODUCTS FERTILIZER WITH 0.2% MERIT INSECTICIDE
TURF PRIDE ACCUBLEND FERTILIZER WITH 0.2% MERIT
TURFTHOR WP
TURFTHOR WSP
XYTECT 2F INSECTICIDE
XYTECT 75WSP INSECTICIDE

Imidacloprid & lambda-Cyhalothrin

LESCO INSECTUS PLUS FERTILIZER
BONIDE DURATURF INSECT & GRUB CONTROL

Indoxacarb

ADVION INSECT GRANULE
PROVAUNT

lambda-Cyhalothrin

BORDER INSECTICIDE
CUTTER BACKYARD BUG CONTROL CONCENTRATE
CYZMIC CS
DEMAND CS INSECTICIDE
DEMAND EZ INSECTICIDE
DEMAND G INSECTICIDE
EQUIL LAMBDA 9.7 CS INSECTICIDE
GRENADE ER
LAMBDA-CY EC INSECTICIDE
LAMBDASTAR 9.7% CS
MARTIN'S CYONARA LAWN & GARDEN INSECT CONTROL
MARTIN'S CYONARA LAWN & GARDEN INSECT CONTROL READY TO SPRAY
PATROL
SCIMITAR CS INSECTICIDE
SENTRY HOMEGUARD YARD SPRAY
SPECTRACIDE BUG STOP INDOOR PLUS OUTDOOR INSECT KILLER CONCENTRATE
SPECTRACIDE FIRE ANT KILLER YARD PROTECTION GRANULES
SUNNILAND CHINCH BUG GRANULES
SURRENDER BRAND PESTABS INSECTICIDE
TERRO ANT KILLER PLUS MULTI-PURPOSE INSECT CONTROL 2

Permethrin

ADAMS PLUS YARD SPRAY
ASTRO INSECTICIDE
BIO SPOT YARD & GARDEN SPRAY
BONIDE EIGHT INSECT CONTROL YARD & GARDEN READY TO SPRAY
DRAGNET SFR TERMITICIDE/INSECTICIDE
ENFORCER OUTDOOR INSECT KILLER CONCENTRATE

Permethrin Cont.

GORDON'S BUG NO-MORE MULTI-PURPOSE
GROUNDWORK CONCENTRATE MULTI-INSECT KILLER2
HI-YIELD 38 PLUS TURF, TERMITE & ORNAMENTAL INSECT CONTROL
HI-YIELD INDOOR/OUTDOOR BROAD USE INSECTICIDE
MARTIN'S PERMETHRIN SFR TERMITICIDE/ INSECTICIDE
OPTI-GRO GROUND ASSAULT (RESTRICTED USE)
P-37 II INSECTICIDE CONCENTRATE
PERMASTAR PRO PERMETHRIN TERMITICIDE/INSECTICIDE
PERMETHRIN 10% RAPID KILL INSECTICIDE CONCENTRATE
PERMETHRIN 3.2 AG (RESTRICTED USE)
PERMETHRIN 3.2 EC (RESTRICTED USE)
PERMETHRIN E PRO TERMITICIDE/INSECTICIDE
PERM-UP 3.2 EC INSECTICIDE (RESTRICTED USE)
PRE STRIKE YARD & GARDEN SPRAY
PRELUDE TERMITICIDE/INSECTICIDE
PRENTOX PERM-X 1-E
PROZAP INSECTRIN X CONCENTRATE
REALITY TERMITICIDE/INSECTICIDE
SA-50 SOUTHERN AG PERMETROL 10% PERMETHRIN EC
SUNNILAND CHINCH BUG SPRAY
TENGARD SFR ONE SHOT TERMITICIDE/INSECTICIDE
TENKOZ PERMETHRIN 3.2 EC INSECTICIDE (RESTRICTED USE)
VET KEM YARD SPRAY SIPHOTROL
ZODIAC YARD & GARDEN SPRAY

Piperonyl butoxide, Esfenvalerate & Prallethrin

ONSLAUGHT FAST CAP SPIDER & SCORPION INSECTICIDE

Thiamethoxam

MAXIDE PROFESSIONAL GRADE DUAL ACTION GRUB KILLER
MERIDIAN 0.33G
MERIDIAN 25WG

Thiamethoxam & Azoxystrobin

CARAVAN G

Thiamethoxam & lambda-Cyhalothrin

AMDRO QUICK KILL LAWN & LANDSCAPE INSECT KILLER GRANULES
MAXIDE DUAL ACTION INSECT KILLER
MAXIDE PROFESSIONAL GRADE DUAL ACTION INSECT KILLER
TANDEM

Trichlorfon

BAYER ADVANCED 24 HOUR GRUB KILLER PLUS I READY-TO-SPREAD GRANULES
DYLOX 420 SL TURF AND ORNAMENTAL INSECTICIDE
DYLOX 6.2 GRANULAR INSECTICIDE
DYLOX 80 TURF AND ORNAMENTAL INSECTICIDE

Zeta-Cypermethrin

AMDRO PEST BLOCK HOME PERIMETER READY-TO-SPRAY
AMDRO POWERFLEX YARD & PERIMETER OUTDOOR INSECT KILLER
AMDRO QUICK KILL LAWN & LANDSCAPE INSECT KILLER CONCENTRATE

Insecticide Products Registered for Golf Courses and Athletic Fields.

Acephate

ACEPHATE 90 PRILL
ACEPHATE 90 SP SOLUBLE POWDER
ACEPHATE 90 WDG
ACEPHATE 90 WSP INSECTICIDE
ACEPHATE 97 DF
ACEPHATE 97% PRILLS
ACEPHATE 97UP INSECTICIDE
BRACKET 90 WDG
BRACKET 97
BRACKET 97
CHEMINOVA ACEPHATE 75SP
CHEMINOVA ACEPHATE 90SP
ORTHENE 97
ORTHENE TURF, TREE & ORNAMENTAL 97 SPRAY
ORTHENE TURF, TREE & ORNAMENTAL WSP
TENKOZ ACEPHATE 97 INSECTICIDE
TIDE ACEPHATE 90 WDG

beta-Cyfluthrin

TEMPO ULTRA GC INSECTICIDE (Restricted Use)

Bifenthrin

BIFEN 2 AG GOLD (Restricted Use)
BIFENTHRIN GC GRANULES (Restricted Use)
BISECT G (Restricted Use)
BROADCIDE FLOWABLE INSECTICIDE GC (Restricted Use)
BROADCIDE GRANULAR INSECTICIDE GC (Restricted Use)
FIREBIRD PRO (Restricted Use)
GROWERS FERTILIZER WITH 0.083% BIFENTHRIN
LESCO TALSTAR 0.073% PLUS FERTILIZER (Restricted Use)
MENACE GC 7.9% FLOWABLE (Restricted Use)
ONYXPRO INSECTICIDE (Restricted Use)
PHOENIX FIREBIRD PRO (Restricted Use)
PRO-MATE TALSTAR GC 0.069% WITH FERTILIZER (Restricted Use)
QUALI-PRO BIFENTHRIN GOLF & NURSERY 7.9F (Restricted Use)
TALSTAR GC GRANULAR INSECTICIDE (Restricted Use)
TALSTAR SELECT INSECTICIDE (Restricted Use)
TURF PRIDE ACCUBLEND FERTILIZER WITH 0.069% BIFENTHRIN INSECTICIDE PROFUSION PROCESS
TURF PRIDE ACCUBLEND FERTILIZER WITH 0.096% BIFENTHRIN INSECTICIDE PROFUSION PROCESS
UP-STAR GC GRANULAR INSECTICIDE (Restricted Use)
UP-STAR SC LAWN AND NURSERY INSECTICIDE/MITICIDE (Restricted Use)

Bifenthrin & Imidacloprid

ALLECTUS GC GRANULAR INSECTICIDE (Restricted Use)
ATERA GC 2+1 SC INSECTICIDE (Restricted Use)
LESCO ALLECTUS 0.18 GC PLUS FERTILIZER (Restricted Use)
TCS GROWSTAR ALLECTUS 0.225 GC PLUS TURF FERTILIZER (Restricted Use)
TURFPRIDE ACCUBLEND FERTILIZER WITH 0.15GC ALLECTUS (Restricted Use)
TURFPRIDE ACCUBLEND FERTILIZER WITH 0.225GC ALLECTUS (Restricted Use)

Bifenthrin & zeta-Cypermethrin

TALSTAR XTRA GC GRANULAR INSECTICIDE (Restricted Use)

Bifenthrin, Imidacloprid & zeta-Cypermethrin

TRIPLE CROWN GOLF INSECTICIDE (Restricted Use)

Carbaryl & Bifenthrin

ANDERSONS GOLF PRODUCTS DUOCIDE INSECT CONTROL (Restricted Use)

Chlorpyrifos

CHLORPYRIFOS 4E AG (Restricted Use)
DREXEL CHLORPYRIFOS 4E-AG (Restricted Use)
NUFARM CHLORPYRIFOS SPC 1.0% MCB INSECTICIDE
NUFARM CHLORPYRIFOS SPC 2 INSECTICIDE (Restricted Use)
NUFARM CHLORPYRIFOS SPC 2.32% G INSECTICIDE
NUFARM CHLORPYRIFOS SPC 4 INSECTICIDE (Restricted Use)
QUALI-PRO CHLORPYRIFOS 4E (Restricted Use)
SA-50 CHLORPYRIFOS 1% MOLE CRICKET BAIT
VULCAN (Restricted Use)

Cyfluthrin

TEMPO 20 WP GOLF COURSE INSECTICIDE (Restricted Use)

Fipronil

CHIPCO CHOICE INSECTICIDE (Restricted Use)
QUALI-PRO FIPRONIL 0.1G (Restricted Use)

Imidacloprid

AGRISEL IMIDAPRO 2SC INSECTICIDE
ANDERSONS GOLF PRODUCTS TURF FERTILIZER 14-0-14 WITH MERIT INSECTICIDE
ARMOR TECH IMD 2SC
ARMORTECH IMD75
CRITERION 0.5 G INSECTICIDE
CRITERION 2F INSECTICIDE
CRITERION 75 WSP INSECTICIDE
ENFORCE 0.5G TURF AND ORNAMENTAL INSECTICIDE
ENFORCE 75WSP TURF AND ORNAMENTAL INSECTICIDE
EQUIL ADONIS 2F INSECTICIDE
EQUIL ADONIS 75 WSP INSECTICIDE
FERTILIZER W/MERIT 0.15%
FERTILIZER W/MERIT 0.2%
GARANT T&O 2F INSECTICIDE
GARANT T&O 75 WSP INSECTICIDE
GORDON'S PROFESSIONAL TURF & ORNAMENTAL PRODUCTS IMIDIPRO SYSTEMIC INSECTICIDE
GRUBEX PRO
HAWK-I 2L
HAWK-I 75WSP
HI-YIELD GRUB FREE ZONE
HI-YIELD GRUB FREE ZONE III
IMIDASTAR 2L T&O
IMIGOLD 0.5 G
IMIGOLD 2 F
IMIGOLD 70 DF TURF, ORNAMENTAL AND GREENHOUSE INSECTICIDE
INVICT BLITZ ANT GRANULES
INVICT XPRESS GRANULAR BAIT
LADA 2F INSECTICIDE
LESCO BANDIT 0.5 G INSECTICIDE
LESCO BANDIT 2F INSECTICIDE
LESCO BANDIT 75 WSP INSECTICIDE
LESCO MERIT 0.2 PLUS TURF FERTILIZER
LESCO MERIT 0.2 PLUS TURF FERTILIZER
LESCO SYSTEMIC INSECTICIDE CONTAINS MERIT
MALICE 0.5G
MALICE 75 WSP
MALLET 2F INSECTICIDE

Imidacloprid Cont.

MALLET 75 WSP INSECTICIDE
MERIT 0.5 G INSECTICIDE
MERIT 2F INSECTICIDE
MERIT 75 WP INSECTICIDE
MERIT 75 WSP INSECTICIDE
MIDASH 2SC T&O
PHOENIX HAWK-I 75WSP
PHOENIX HAWK-I 2L
PRIMERAONE IMIDACLOPRID 2F INSECTICIDE
PROFESSIONAL TURF SOLUTIONS WITH MERIT FERTILIZER
PROKOZ ZENITH 0.5 G INSECTICIDE
PROKOZ ZENITH 2F INSECTICIDE
PROKOZ ZENITH 75 WSP INSECTICIDE
PRO-MATE MERIT 0.2% PLUS TURF FERTILIZER
PROTHOR SC 2
QUALI-PRO IMIDACLOPRID 0.5G INSECTICIDE
QUALI-PRO IMIDACLOPRID 75 WSB
REGAL MERIT 0.2 PLUS
SCOTTS FERTILIZER 0-0-7 WITH GRUBEX PRO
SCOTTS FERTILIZER 22-0-8 WITH GRUBEX PRO
SCOTTS PROFESSIONAL FERTILIZER 0-0-7 WITH GRUBEX
SCOTTS PROFESSIONAL FERTILIZER 22-0-8 WITH GRUBEX
SIGNATURE FERTILIZER WITH 0.2% MERIT
TCS GROWSTAR MERIT 0.2 PLUS TURF FERTILIZER
THE ANDERSONS GRUBOUT DG 0.2% INSECTICIDE
THE ANDERSONS TURF PRODUCTS FERTILIZER WITH 0.2% MERIT INSECTICIDE 24-0-12
THE ANDERSONS TURF PRODUCTS FERTILIZER WITH 0.2% MERIT INSECTICIDE 22-3-8
TURF PRIDE ACCUBLEND FERTILIZER WITH 0.2% MERIT
TURFTHOR O.5G
TURFTHOR WP
TURFTHOR WSP
XYTECT 2F INSECTICIDE
XYTECT 75WSP INSECTICIDE

Indoxacarb

ADVION INSECT GRANULE
DUPONT ADVION INSECT GRANULE
DUPONT PROVAUNT INSECTICIDE
PROVAUNT

lambda-Cyhalothrin

LAMBDA SELECT (Restricted Use)
LAMBDA-CY EC INSECTICIDE-RUP (Restricted Use)
NUFARM LAMBDA-CYHALOTHRIN 1 EC INSECTICIDE (Restricted Use)
QUALI-PRO LAMBDA GC-O (Restricted Use)

Permethrin

PERMETHRIN 10% RAPID KILL INSECTICIDE CONCENTRATE
PROZAP INSECTRIN X CONCENTRATE

Piperonyl butoxide & Permethrin

FLEX 10-10 INSECTICIDE
KICKER
PYNAMITE SYNERGIZED 10/10 CONCENTRATE
PYRANHA 1-10 PX CONCENTRATE
VECTOR-BAN PLUS MULTI PURPOSE INSECTICIDE

Pyrethrins

MGK EVERGREEN PYRETHRUM CONCENTRATE

Thiamethoxam

MERIDIAN 25WG
MERIDIAN 0.33G

Thiamethoxam & Azoxystrobin

CARAVAN G

Trichlorfon

DYLOX 420 SL TURF AND ORNAMENTAL INSECTICIDE
DYLOX 6.2 GRANULAR INSECTICIDE
DYLOX 80 TURF AND ORNAMENTAL INSECTICIDE

Insecticide Products Registered for Pastures

Beauveria bassiana

BOTANIGARD ES
MYCOTROL O

Carbaryl

DREXEL CARBARYL 5% BAIT

Piperonyl butoxide & Pyrethrins

PYRENONE CROP SPRAY

Pyrethrins

PYGANIC CROP PROTECTION EC 5.0II

Insecticide Products Registered for Vegetables

Beauveria bassiana

BOTANIGARD ES
MYCOTROL O

Bifenthrin

SURRENDER G
BONIDE HOUSE GUARD
BONIDE EIGHT INSECT CONTROL FLOWER & VEGETABLE
VEGETABLE GARDEN SOIL INSECTICIDE

Carbaryl

DREXEL CARBARYL 5% BAIT

Piperonyl butoxide & Pyrethrins

PYRENONE CROP SPRAY

Pyrethrins

PYGANIC CROP PROTECTION EC 5.0II

NOTES

Spring Ranchers Forum
Held at Yarborough Ranch
Central Florida Livestock Agents Group
March 19, 2015

Individual Topic Evaluation:	**Useful**	**Somewhat Useful**	**Not Applicable**	**No Answer**
Live Animal Demonstration: "Effective Body Condition Scoring of Florida Horses" Megan Brew, Livestock Extension Agent, UF/IFAS Extension Lake County Ashley Fluke, Livestock Extension Agent, UF/IFAS Extension Osceola County				
Manure Biodigester Demonstration Dr. Ann Wilkie, Soil & Water Science Professor, University of Florida Marco Pazmino, PhD Candidate, Ag + Bio Engineering, University of Florida Eleanor Foreste, Natural Resources Extension Agent, UF/IFAS Extension Osceola Co.				
Hay Selection: Test your hay buying skills Sharon Gamble, Livestock Agent, UF/IFAS Extension Volusia County Dennis Mudge, Livestock Agent, UF/IFAS Extension Multi-County				
CFLAG Agent Panel: Troublesome Weeds Jonael Bosques-Mendez, Megan Brew, Ashley Fluke, Sharon Gamble, Christine Kelly-Begazo, Dennis Mudge, Mark Shuffitt, Joe Walter, Mark Warren				
Pasture Weed Herbicide Update & Dealing with the Troublesome Weeds Dr. Brent Sellers, Associate Professor of Agronomy, ONA Cattle Research Center, University of Florida IFAS				
University Mole Cricket Update Chris Kerr, PhD Candidate, Plant Medicine, University of Florida				
Was this the first time you attended an Extension Program?	☐ **Yes**		☐ **No**	

How many Spring Ranchers Forums have you attended? (circle one)	1 2 3 4 5 10 17	
Overall Program Evaluation. Answer below ONLY if you attended the Spring Ranchers Forum Last Year.	**YES**	**NO**
Did you share last year's information with anyone?	**YES**	**NO**
Did you improve your animal science skills because of last year's program?	**YES**	**NO**
Did you experience an improved economic return because of last year's program?	**YES**	**NO**
If yes, how much would you estimate is the value? (circle one)	$1,000 $5,000 $10,000 $25,000 or $_______ (fill in)	
Poisonous plant education saves farm animals lives. Have you experienced saving an animal from toxic plants education received at Spring Ranchers Forum?	**YES**	**NO**
If yes, please estimate number of animals you have saved. (circle one)	1 5 10 25 50 100 or _____ (fill in)	
Which livestock do you raise?		
How did you hear about this year's Spring Ranchers Forum?		