Spring Ranchers Forum Proceedings

a program by the

Central Florida Livestock Agents Group

Thursday, March 21, 2019

Yarborough Ranch

1355 Snow Hill Rd.

Geneva, Florida 32732

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CENTRAL FLORIDA LIVESTOCK AGENTS GROUP

Spring Ranchers Forum
March 21, 2019
Proceedings

Central Florida Livestock Agents Group

Agents

Caitlin Bainum (Marion County)
Laura Bennett (Multi-County)
Jonael Bosques-Mendez (Hardee County)
Clay Cooper (Citrus County)
Sharon Fox Gamble (Volusia County)
Ed Jennings (Levi County)
Brittany Justesen (Osceola County)
Megan Mann (Lake County)
Dennis Mudge (Volusia County)
Wendy Mussoline (Multi-County)
Francisco Rivera-Melendez (Hillsborough County)
Stacy Strickland (Osceola County)
Joe Walter (Brevard County)
Tim Wilson (St. Johns County)
JK Yarborough (Multi-County)

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SPRING RANCHERS FORUM

a program by the
Central Florida Livestock Agents Group
THURSDAY, MARCH 21, 2019
YARBOROUGH RANCH
1355 Snow Hill Road, Geneva, FL 32732

AGENDA

8:00 am - Arrival / Registration

8:15 am - Ranch Horse Demonstration– Joel McQuagge & UF Ranch Horse Class

9:00 am - Trade Show Break

10:00 am - Cattle Minerals– Juliana Ranches– UF PhD candidate UF Animal Science

10:45 am - Cattle Economics– Chris Prevatt– State Specialized Extension Agent– UF Range Cattle Research and Education Center

11:30 am - Forage Budgeting, Caitlin Banium and Brittany Justesen – CFLAG Agents

12:15 pm - Official Welcome Steak Lunch - Trade Show

1:30 pm - "The Silage Process"-Joe Walter, Wendy Mussoline and Tim Wilson -CFLAG Agents

2:15 pm - Pasture Weeds– Clay Cooper and Laura Bennett– CFLAG Agents

3:00 pm - Cattlemen's Panel

3:45 pm - Evaluations & Final Giveaways

NOTES

Mineral Nutrition of Grazing Beef Cattle

The importance of trace minerals

Juliana Ranches
Range Cattle Research and Education Center
Animal Sciences Department
University of Florida
March 21, 2019

Overview

- Introduction
  - Cow requirements
  - Forage analysis
- Overview of micro-minerals
- Mineral Analysis
- Mineral Supplementation

Mineral Requirements of Beef Cattle

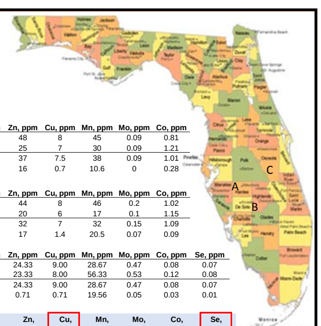
Macro-minerals, %	Gestation	Lactation	Micro-minerals, ppm	
Potassium	0.60	0.70	Copper	10.00
Magnesium	0.12	0.20	Iron	50.00
Sodium	0.06	0.10	Manganese	40.00
Sulfur	0.15	0.15	Zinc	30.00
Calcium	29 – 33 g/d		Cobalt	0.15
Phosphorus	18 – 22 g/d		Iodine	0.50
			Selenium	0.10

[1]Data taken from Nutrient Requirements of Beef Cattle, National Research Council, 1996. Dietary requirements vary by stage of production, with the highest requirement during the first 3 months post-calving.

Typical Forage Contributions

Mineral	Cow Requirement	Warm Season Grass *Florida*
Copper, ppm	10	--
Iron, ppm	50	++
Manganese, ppm	40	++
Zinc, ppm	30	-
Cobalt, ppm	0.15	--
Selenium, ppm	0.10	---

Mineral Summary



Location A	Ca, %	P, %	Mg, %	K, %	Na, %	S, %	Cl, %	Fe, ppm	Zn, ppm	Cu, ppm	Mn, ppm	Mo, ppm	Co, ppm
Bahiagrass 1	0.44	0.25	0.42	1.38	0.009	0.36	0.39	85	48	8	45	0.09	0.81
Bahiagrass 2	0.47	0.19	0.49	1.37	0.011	0.3	0.43	97	25	7	30	0.09	1.21
Ave	0.46	0.22	0.46	1.38	0.01	0.33	0.41	91	37	7.5	38	0.09	1.01
Stnd. Dev.	0.02	0.04	0.05	0.01	0.001	0.04	0.03	8	16	0.7	10.6	0	0.28

Location B	Ca, %	P, %	Mg, %	K, %	Na, %	S, %	Cl, %	Fe, ppm	Zn, ppm	Cu, ppm	Mn, ppm	Mo, ppm	Co, ppm
Bahiagrass 1	0.38	0.32	0.29	1.87	0.006	0.27	0.37	104	44	8	46	0.2	1.02
Bahiagrass 2	0.45	0.27	0.28	1.57	0.005	0.2	0.32	84	20	6	17	0.1	1.15
Ave	0.42	0.3	0.29	1.72	0.006	0.24	0.35	94	32	7	32	0.15	1.09
Stnd. Dev.	0.05	0.04	0.01	0.21	0.001	0.05	0.04	14	17	1.4	20.5	0.07	0.09

Location C	Ca, %	P, %	Mg, %	K, %	Na, %	S, %	Cl, %	Fe, ppm	Zn, ppm	Cu, ppm	Mn, ppm	Mo, ppm	Co, ppm	Se, ppm
Bahiagrass 1	0.69	0.27	0.35	1.09	0.06	0.32	0.45	207.33	24.33	9.00	28.67	0.47	0.08	0.07
Bahiagrass 2	0.57	0.22	0.37	1.22	0.02	0.21	0.36	152.33	23.33	8.00	56.33	0.53	0.12	0.08
Ave	0.69	0.27	0.35	1.09	0.06	0.32	0.45	207.33	24.33	9.00	28.67	0.47	0.08	0.07
Stnd. Dev.	0.09	0.04	0.01	0.09	0.03	0.08	0.06	38.89	0.71	0.71	19.56	0.05	0.03	0.01

	Ca, %	P, %	Mg, %	K, %	Na, %	S, %	Cl, %	Fe, ppm	Zn, ppm	Cu, ppm	Mn, ppm	Mo, ppm	Co, ppm	Se, ppm
Grand Average	0.58	0.25	0.41	1.24	0.04	0.32	0.43	149.17	30.67	8.25	33.33	0.28	0.54	0.07

Salt (NaCl)

- In grazing beef production systems, many cattle can sustain themselves without supplemental macro- and micro-minerals, BUT they must always have a source of Salt.
- **Managing salt availability is one of the most simple and effective practices that can assist producers.**

Salt (NaCl)

- Cattle have a requirement for both sodium (Na) and chlorine (Cl). However, the Cl requirement is minor, poorly understood, and always 2nd to Na, but Cl is the primary major anion in the body and constitutes over 60% of the total anion equivalents in plasma.
- Cattle have evolved an elaborate mechanism for the efficient utilization of Na, but have very little ability to store Na.
- Deficiency will cause reduced appetite and voluntary forage intake resulting in lessened body weight gain or weight loss.

Salt (NaCl)

- Salt (or Na) is the only mineral that cattle have the nutritional wisdom to consume at levels which meet or exceed their requirement.
- Generally, salt intake increases when forages have high moisture. Silage-fed cattle typically consume more salt than dry hay-fed cattle.
- Salt intake often decreases when energy/protein supplements are offered.
- Salt intake is limited by Na content of water.

Salt (NaCl)

- Salt is included in free-choice supplements to both encourage and limit intake. This can be problematic.
- When cattle are not seeking sources of salt, it is important to deliver limiting minerals using another method.
  - Energy/protein supplements
  - Control-fed minerals
  - Injections and drenches

Sulfur

- Sulfur is an essential element for formation of the essential amino acids methionine and cysteine.
- Sulfur is also a component of the vitamins thiamin and biotin and "chondroitin" a key component of cartilage, bone, and tendon.
- Under most all conditions a deficiency of S is unlikely to occur in grazing beef cattle.

Sulfur

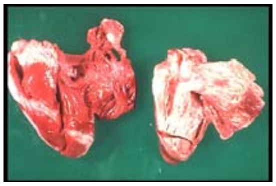
- Most forages and supplements tend to be moderate or high in S.
- Excess S can eventually lead to:
  - Polioencephalomalacia (PEM)
  - Antagonist for copper and selenium
- Sources of dietary S for grazing cattle include;
  - Supplements
  - Fertilizers
  - Atmospheric deposition

Selenium

- Selenium works with vitamin E to as a powerful antioxidant protective mechanism.
- Selenium deficiency is most recognized by the occurrence of White Muscle Disease, and;
  - low fertility
  - retained placentas
  - immune competence

Selenium

White Muscle Disease
or Weak Calf Syndrome



Antioxidant capacity

Selenium

- Selenium deficiency is common in grazing cattle throughout the world and is the most deficient trace mineral in Florida forages.
- In some cases, toxicity can also be a concern.

Selenium

Check the soil selenium content of you county at:
http://mrdata.usgs.gov/geochem/doc/averages/se/usa.html

Florida Survey

Item	Se	Cu	Mn	Mo	Zn
Average	0.67	158	10.8	3.4	140
Deficient	< 0.50	< 75	< 8	------	< 125
Prevalence	5 of 11	3 of 14	0 of 14	-----	0 of 14

Survey of 14 commercial cowherds in Florida (2014)

18% of surveyed cow/calf operations (n = 253) in the US were Se deficient; Dargatz and Ross, 1996

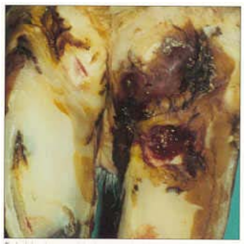
Copper

- Next to selenium, copper is typically the most limiting trace mineral nutrient.
- Estimated to be essential to over 30 enzymes.
- Essential for maintenance of reproduction, immunity, and growth
- Avoid copper oxide. Should be included at a 1:3 ratio with zinc.

Copper

- Copper Deficiency: Loss of hair pigmentation

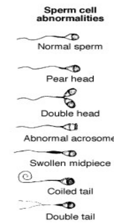
Zinc



- Co-factor for multiple enzymes
- Zinc is an important for the maintenance of hoof integrity.
- Essential for support of physiological processes involving rapidly dividing cells.

Zinc

Essential for normal spermatogenesis

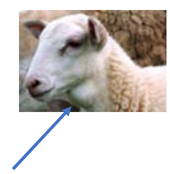


Cobalt

- Cobalt is required by rumen microorganisms for the synthesis of vitamin B12 (cobalamin).
- Cattle are not dependent on diet for B12, however proper Co supplementation is required.
- Vitamin B12 is an essential part of several enzyme systems which carry out a number of basic metabolic functions.

Iodine

- Iodine functions as an essential component of the thyroid hormones thyroxine (T4) and triiodothyronine (T3) which regulates rate of energy metabolism in the body.
- Iodine deficiency as endemic goiter is one of the most prevalent deficiency diseases and occurs in almost every country in the world



Mineral Analysis

- Main sources of mineral:
  - Forages
  - Feed
  - Mineral supplements

- Samples can be sent to a comercial laboratory for mineral analysis.
- When sampling forage, feed and mineral supplements always begin with forage, followed by feed and lastly mineral supplements to avoid contamination.

Mineral Supplementation

The most common form of mineral supplementation

Free - Choice Systems

- The most important component to a free-choice mineral supplementation system is . . . .

Managing Intake

Tubs and Blocks

- All blocks are not created equal. The term "block" results in confusion in the beef industry
  - Hard, salt-based mineral blocks cannot physically deliver mineral in amounts to satisfy requirements. But – better than nothing!
  - Cooked or chemical-formed, molasses-based blocks – formulated properly can be sufficient delivery mechanisms for minerals. But – must manage intake and cost!

"Cafeteria Style" Free-Choice Supplementation

- Based on a premise that cattle will consume different mineral straights or premixes in proper amounts to meet requirements.
- No scientific basis for the system. In fact, published studies have shown that with the exception of Na, cattle do not have the nutritional wisdom to consume minerals at required amounts.
- Dangerous approach (i.e. Mg).

Free - Choice Systems

Complications associated with free-choice loose mineral supplementation

- Uniform Intake
  - animal variation
  - intake variability
- Mineral Wastage
  - moisture
  - wildlife
  - spillage
- Management
  - Provide mineral to the herds
  - They eat more so the must need it?

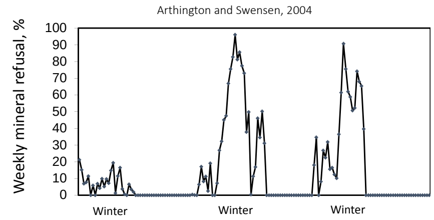
Free - Choice Systems

- What drives variation in intake?
  1. Sodium content of water, forage, and supplement resources
  2. Precipitation and forage dry matter
  3. Palatability
     1. Enhancers
     2. Mineral sources
     3. Specialty blends

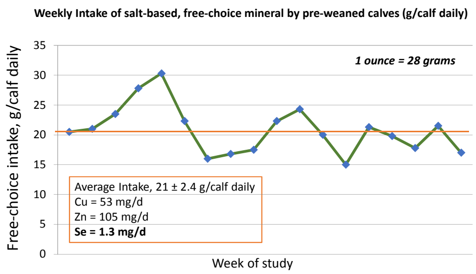
Free - Choice Systems

Refusal of Free-Choice, Salt-Based Mineral

Arthington and Swensen, 2004



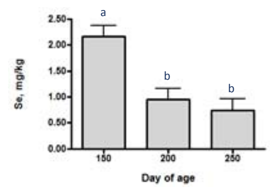
Free - Choice Systems



Free - Choice Systems

- Decline in pre-weaned calf selenium status

1 mg of selenium daily is insufficient for pre-weaned calves in Florida



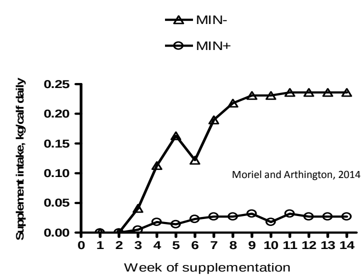
Arthington and Havenga, 2014

Limit Creep Feeding

Increase calf mineral status prior to weaning

- Limit-fed, trace mineral-fortified creep feed (< 0.5 lb/d) for the last 100 days prior to weaning.
  - Exposes calves to
    - concentrated feed
    - human x feed interaction
- A logical idea, but our success was limited due to lack of intake among calves offered mineral-concentrated supplements

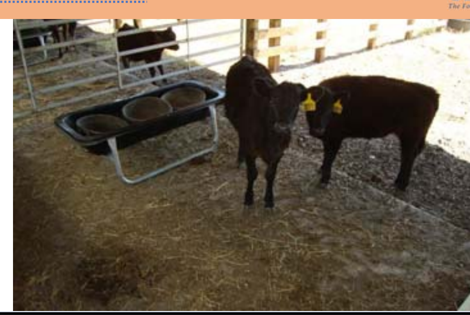
Effect of trace mineral fortification (Min+ vs. Min-) of limit-fed creep feed on voluntary intake



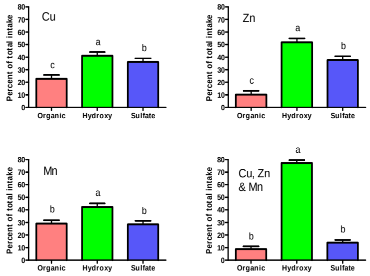
Preference Studies (Cu, Zn, and Mn)

- Studies were completed evaluating the influence of Cu, Zn, and Mn source on voluntary intake of grain-based supplement formulations
- Three trace mineral sources were evaluated
  - Sulfate
  - Hydroxychloride
  - Organic

Preference Studies (Cu, Zn, and Mn)



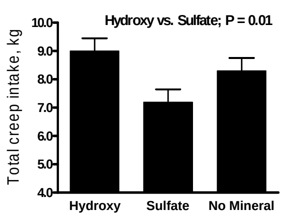
Preference Studies (Cu, Zn, and Mn)



Limit Creep Feeding

- Replacing soluble sources of Cu, Zn, and Mn (i.e. sulfate and organic) solved the intake problem.
- Two studies (2 years each) were conducted to examine the effect of limit-fed creep feeding on calf performance and mineral status:
  - Study 1. Loose mix feed offered 3 X week
  - Study 2. Free-choice, low moisture molasses tubs

Voluntary Intake of mineral-fortified limit fed creep feed



Hydroxy vs. Sulfate
26% increase in intake

Source	lb/d
Hydroxy	0.24
Sulfate	0.19
No Min.	0.22

Caramalac et al. JAS. 2017

Limit Creep Feeding – Calf Mineral Status

Liver mineral concentration, mg/kg DM basis

Element	Mineral	No Mineral	SEM	P =
Co	0.23	0.09	0.032	0.003
Cu	186	129	35.7	0.07
Se	0.57	0.25	0.075	0.003

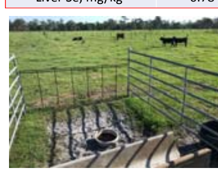
Low Moisture Molasses Blocks

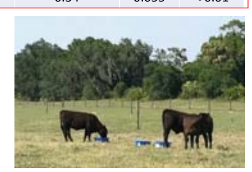
Collaboration with Dr. Jim Drouillard
Kansas State University

- Eliminates daily feedings
- Resistent to rain/weather
- Self limits intake to < 1.0 lb/d
- Delivers functional nutrients

Low Moisture Molasses Blocks

Item	Fortified	Non-Fortified	SEM	P =
Molasses Tubs				
Intake, lb/d	0.48	0.77	0.070	0.01
ADG, lb/d	1.81	1.76	0.079	0.80
Liver Se, mg/kg	0.78	0.34	0.055	< 0.01





Take Home Message

No matter what strategy you choose to supplement your herd, in order to make sure it is being effective you have to manage intake.

Mineral Nutrition of Grazing Beef Cattle

The importance of trace minerals

Sprayer Calibration Formula Sheet

Clay Cooper, UF/IFAS Agriculture/Natural Resource Agent

Conversions:

1 Gallon:

- 4 quarts
- 128 oz.
- 3,785 ml

1 Quart:

- 2 pints (32 oz.)

1 Pint:

- 2 cups (16 oz.)

1 Acre:

- 43,560 sq. ft.

1 MPH:

- 88 ft/min
- 1.47 ft/sec

5940 Method:

$$GPM = \frac{GPA \times MPH \times W}{5940}$$

- **GPA** – Gallons per acre
- **GPM** – Gallons per minute
- **MPH** – Miles per hour
- **W** – Nozzle width
- **5940** – Constant

1/128th Acre Method:

- Based on 128 oz. per gallon
- 1/128th of an acre equals 340 sq. ft.
- Determine how long (seconds) it takes 1 nozzle to cover 1/128th of an acre.
- The number of ounces collected in that time frame is equaled to GPA.

Backpack Sprayer:

- Measure an 18.5 x 18.5 ft. area
- Record how many seconds it takes to cover the area.
- Measure the amount of water collected in that time frame.
- Number of ounces collected equals GPA.

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Single-Nozzle Backpack or ATV Sprayer Calibration[1]

B. A. Sellers, J. A. Ferrell, G. E. MacDonald, and Dennis C. Odero[2]

Many growers have isolated patches of weeds that should be controlled to prevent their spread. In this case, spot spraying with a herbicide would be the most economically feasible approach. Some herbicide labels allow for spot-treatments. However, the recommended amount is often given in % volume of herbicide per volume of water, or a certain amount of herbicide per 1,000 square feet.

Before adding any herbicide to the spray tank, it is extremely important that the output of the sprayer is known. That is, it must be properly calibrated. This allows for reduced herbicide costs and optimum weed control. A simple calibration test for a single-nozzle backpack or ATV sprayer is shown in Table 1. No math is required for this calibration, and the end result is a known output volume for your sprayer in gallons per acre (GPA).

Hints for calibration:

- Keep speed constant. This will ensure that you are walking the same speed at all times.
- Keep the nozzle at the same height at all times—a height that is comfortable.
- Modify the wand by adding a pressure gauge. Try to keep the pressure as constant as possible. Do not let the pressure fall below 10 psi.

Next the amount of herbicide to be added to the spray tank needs to be calculated. To do this multiply the amount of herbicide needed for 1 gallon by the number of gallons in the spray tank.

Example: A sprayer is calibrated with an output of 40 GPA and the tank holds 10 gallons. If the desired herbicide rate is 1 quart per acre, from Table 2, the amount of herbicide for 1 gallon of water is 4.75 tsp. Since the spray tank holds 10 gallons, 40.75 (41) tsp are needed, which is approximately equal to 7 fl oz.

Useful Conversions:

1 teaspoon = 0.17 fl oz

1 tablespoon = 0.5 fl oz

3 teaspoons = 1 tablespoon

1 pint = 16 fl oz = 32 tablespoons = 2 cups

1. This document is SS-AGR-108, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date January 2006. Revised April 2016. Reviewed February 2019. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

2. B. A. Sellers, assistant professor, Range Cattle Research and Education Center; J. A. Ferrell, assistant professor, Agronomy Department; G. E. MacDonald, associate professor, Agronomy Department; and Dennis C. Odero, Extension weed specialist and assistant professor, Agronomy Department, Everglades Research and Education Center; UF/IFAS Extension, Gainesville, FL 32611.

Use herbicides safely. Read and follow directions on the manufacturer's label.

Table 1. A no-math method for calibrating single-nozzle backpack or ATV wand sprayers for spot spraying herbicides.

Step 1	Measure a calibration plot that is exactly 18.5 feet by 18.5 feet.			
Step 2	Spray the calibration plot uniformly with water. Repeat 3 times and record the average number of seconds needed to spray the entire plot.	Time Required	____	Seconds
Step 3	Spray into a clean bucket for the amount of time recorded in Step 2.			
Step 4	Measure the number of ounces of water in the bucket.	Volume Sprayed	____	Ounces
Step 5	The number of ounces collected from the bucket is equal to the number of gallons per acre the sprayer is delivering.	Output Volume	____	Gallons/Acre
Step 6	Determine the volume of the spray tank.	Tank Volume	____	Gallons
Step 7	Determine the number of acres covered in one tank. Divide tank volume (gallons; Step 6) by output volume (gallons/acre; step 5).	Area covered per tank	____	Acres
Step 8	Determine the amount of herbicide to add to the tank from Table 2.	Herbicide/Acre	____	tsp, tbsp, mL, oz, cups

Table 2. Amount liquid herbicide to add to 1 gallon of water. Abbreviations: tsp=teaspoon, fl oz=fluid ounces.

Volume (GPA)	**Recommended Herbicide Rate per Acre**				
	1 pint	**1 quart**	**2 quarts**	**3 quarts**	**4 quarts**
20	5 tsp	10 tsp	3.25 fl oz	4.75 fl oz	6.33 fl oz
30	3 tsp	6 tsp	2 fl oz	3.25 fl oz	4.25 fl oz
40	2.33 tsp	4.75 tsp	1.66 fl oz	2.33 fl oz	3.25 fl oz
50	2 tsp	3.75 tsp	1.25 fl oz	2 fl oz	2.5 fl oz
60	1.66 tsp	3.25 tsp	6.33 tsp	1.66 fl oz	2 fl oz
70	1.33 tsp	2.75 tsp	5.5 tsp	1.33 fl oz	1.75 fl oz
80	1.25 tsp	2.33 tsp	4.75 tsp	7.25 tsp	9.5 tsp
90	1 tsp	2 tsp	2.25 tsp	6.33 tsp	8.5 tsp
100	1 tsp	2 tsp	3.75 tsp	5.75 tsp	7.66 tsp

Boom Sprayer Nozzle Performance Test[1]

Frederick M. Fishel[2]

Introduction

Calibration is adjusting equipment to determine the amount of material being applied to the target area. The main reason for calibration of liquid spray equipment is to determine how much pesticide to put into the sprayer's tank, so you can apply the recommended volume to the target site at a determined speed. Making sure all nozzle tips on the spray boom function uniformly is the fundamental first step of sprayer calibration. The nozzle tips can be affected by several things. Age, lack of maintenance, or type and amount of spray can cause nozzle tips to wear or clog. Worn or clogged nozzle tips make a boom sprayer unable to deliver a uniform spray pattern. The use of a boom sprayer that has a non-uniform nozzle tip output will very likely result in a misapplication.

Why You Need to Calibrate Equipment

Applicators are legally liable for injuries or damage caused by improper pesticide application. Several problems are associated with applying a pesticide at the incorrect volume.

- *Illegal residues.* Applying higher than legal volumes of a pesticide may result in residues on crop plants that exceed the legal tolerance level. If over-application results in illegal residues on plant surfaces, regulators have the authority to confiscate and destroy an entire crop to protect consumers.
- *Impact on effective pest control.* Pesticide registrants and/or manufacturers of pesticides spend millions of dollars researching ways to use their products correctly and effectively. This research includes determining the right amount of pesticide to apply to control target pests. Using less than the labeled rate is legal in most cases but may result in inadequate control, wasting time and money. Application volumes that are too low also may lead to problems such as pest resistance and resurgence. Using higher than the labeled rates is illegal and wastes pesticides and using too much pesticide may adversely affect natural enemies of the pest being controlled.
- *Human health concerns.* Pesticides applied at higher than label rates could endanger the health of pesticide handlers, field workers, yourself, and other people working in or around an area where you applied them.
- *Environmental concerns*. Pesticide concentrations higher than label directions may cause serious environmental problems. Calibrating equipment to maintain application volumes within label requirements reduces the potential for contaminating surface water, groundwater, and the air.
- *Impact on treated plant surfaces*. Certain pesticides are phytotoxic (injurious to plants) and damage treated plant surfaces when used at higher than label-prescribed rates. Manufacturers evaluate these potential problems while testing their products, so they can determine safe concentrations.
- *Soil contamination*. Using too much pesticide increases the chance of building up excessive residues in the soil. A buildup of certain pesticides sometimes seriously limits

1. This document is PI-23, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date April 1998. Revised March 2005, March 2008, and February 2011. Reviewed March 2017. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. Frederick M. Fishel, professor, Agronomy Department and director, Pesticide Information Office; UF/IFAS Extension, Gainesville, FL 32611.

the types of future crops that can safely be grown in the treated area.

- *Wasting resources.* Using the improper amount of pesticide wastes time and adds unnecessary costs to the application.

Conducting the Test

Begin by making certain the boom sprayer has clean water in its tank, is mechanically sound, and has clean screens and intact plumbing. Make sure that all of the nozzle tips on the boom are the same type and size (for example, all tips are AI8002).

Commercial tip testers that measure nozzle flow rate are available but not necessary (Figure 1). Only a few simple items are needed for conducting the test (Figure 2), including the following: a clipboard, a nozzle performance data form (Table 1 located on the last page), a pencil, a wristwatch with a second hand or stopwatch, and a hand-held graduated container marked in milliliters and/or ounces.

Figure 1. Commercially-available flow meter for testing tip output.
Credits: UF/IFAS Pesticide Information Office

Steps to Perform the Test

1. Using the graduated container, catch the output from each nozzle for a predetermined time; either 30 seconds or 1 minute is usually adequate (Figure 3). Write down the nozzle outputs by nozzle on the data form.

2. Sum total amounts from each nozzle. Divide by the number of nozzles to get the average nozzle output. Write down the average output on the data form.

3. Determine the tolerance value by multiplying the average nozzle output by 0.10. In other words, you will replace any nozzle that is applying more or less than 10% of the average nozzle output.

4. Determine the upper limit by adding the tolerance value to the average nozzle output, and determine the lower limit by subtracting the tolerance value from the average nozzle output.

5. If output from any nozzle is greater than the upper limit, the nozzle tip is probably worn out, and a new tip is needed. If output from any nozzle is less than the lower limit, cleaning may bring it into the correct range. If not, replace the nozzle, and repeat the test.

6. If tips are replaced after the initial test, repeat steps 1–5.

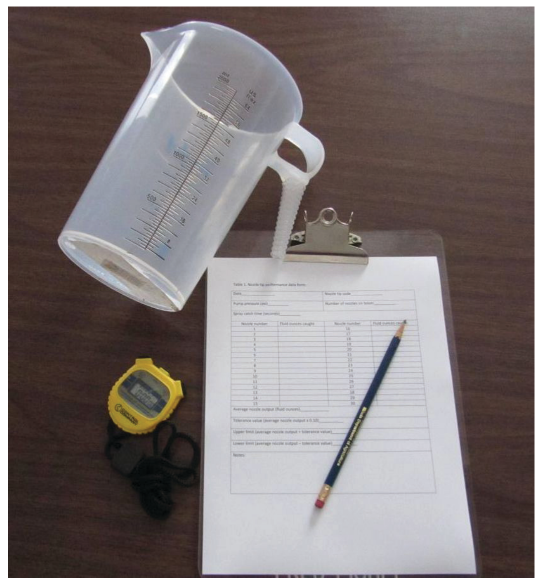

Figure 2. Simple items needed for performing a nozzle performance test.
Credits: UF/IFAS Pesticide Information Office

Figure 3. Performing a nozzle output check.
Credits: UF/IFAS Pesticide Information Office

Example Calculation

1. You have a boom with 8 nozzles and catch the following outputs in 30 seconds per nozzle:

- Nozzle 1: 16 ounces
- Nozzle 2: 12 ounces
- Nozzle 3: 15 ounces
- Nozzle 4: 16 ounces
- Nozzle 5: 16 ounces
- Nozzle 6: 15 ounces
- Nozzle 7: 14 ounces
- Nozzle 8: 19 ounces

2. The average nozzle output is 15.4 ounces (123 ÷ 8).

3. The tolerance value is 1.5 (15.4 x 0.10).

4. The upper limit is 16.9 (15.4 + 1.5), and the lower limit is 13.9 (15.4 – 1.5).

5. Nozzles 2 and 8 should be replaced and the test repeated.

Additional Information

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Table 1. Nozzle tip performance data form

Date		Nozzle tip code	
Pump pressure (psi)		Number of nozzles on boom	
Spray catch time (seconds)			
Nozzle number	Fluid ounces caught	Nozzle number	Fluid ounces caught
1		16	
2		17	
3		18	
4		19	
5		20	
6		21	
7		22	
8		23	
9		24	
10		25	
11		26	
12		27	
13		28	
14		29	
15		30	
Average nozzle output (fluid ounces)			
Tolerance value (average nozzle output x 0.10)			
Upper limit (average nozzle output + tolerance value)			
Lower limit (average nozzle output – tolerance value)			
Notes:			

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Agronomy Facts 37

Adjuvants for Enhancing Herbicide Performance

OVERVIEW

- An adjuvant is any substance in a herbicide formulation or added to the spray tank to improve herbicidal activity or application characteristics.
- Spray adjuvants are generally grouped into two broad categories—activator adjuvants and special purpose adjuvants.

Special purpose adjuvants:

- Widen the range of conditions under which a given herbicide formulation is useful
- May alter the physical characteristics of the spray solution
- Include compatibility agents, buffering agents, antifoam agents, and drift control agents

Activator adjuvants:

- Commonly used to enhance postemergence herbicide performance
- Can increase herbicide activity, herbicide absorption into plant tissue, and rainfastness; can also decrease photodegradation of the herbicide
- Can alter the physical characteristics of the spray solution
- Include surfactants, crop oil concentrates, nitrogen fertilizers, spreader-stickers, wetting agents, and penetrants

Surfactant:

- Primarily reduces the surface tension between the spray droplet and the leaf surface
- Includes nonionic, anionic, cationic, and organosilicones
- Required with many postherbicides
- Applied at ½ to 2 pt/acre or 0.25 percent volume/volume

Crop oil concentrate:

- Contains petroleum-based oils plus some nonionic surfactant
- Increases herbicide penetration and reduces surface tension
- Commonly used with postgrass herbicides and atrazine
- Applied at 1 to 3 pt/acre or 1 percent volume/volume

Vegetable oil concentrates:

- Serve the same function as crop oil concentrates but are derived from vegetable-based oil
- Generally seed oils such as soybean, sunflower, cotton, canola, and linseed that are modified (e.g., methylated seed oil, MSO) to improve performance and adjuvant qualities
- Applied at 1 to 3 pt/acre or 1 percent volume/volume

Nitrogen fertilizer:

- Can increase herbicide activity on certain weed species such as velvetleaf and certain grasses
- Improves the effectiveness of weak acid-type herbicides (e.g., Classic, Harmony, Option, Pursuit, Basagran)
- Ammonium sulfate can reduce problems with hard water
- Generally used in combination with surfactants or crop oil concentrates
- Application rate varies depending on product

Blended adjuvants:

- Contain various combinations of special purpose adjuvants and/or activator adjuvants (e.g., NIS + AMS; AMS + drift inhibitor + defoamer)
- Serve multiple functions; functioning agents serve primary and secondary purposes
- Are becoming more popular because multiple ingredients are included in one jug

Adjuvant selection:

- Should be primarily based on herbicide label
- Should consider percent active ingredient as well as cost

For a detailed listing of many adjuvants and types, see the *Compendium of Herbicide Adjuvants* at **www.herbicide-adjuvants.com**.

Adjuvants are commonly used in agriculture to improve the performance of pesticides. Broadly defined, "an adjuvant is an ingredient that aids or modifies the action of the principal active ingredient." The use of adjuvants with agricultural chemicals generally falls into two categories: (1) formulation adjuvants are present in the container when purchased by the dealer or grower; and (2) spray adjuvants are added along with the formulated product to a carrier such as water. The liquid that is sprayed over the top of a crop, weeds, or insect pest often will contain both formulation and spray adjuvants.

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Formulation adjuvants are added to the active ingredient for a number of reasons, including better mixing and handling, increased effectiveness and safety, better distribution, and drift reduction. These traits are accomplished by altering the solubility, volatility, specific gravity, corrosiveness, shelf-life, compatibility, or spreading and penetration characteristics. With the large number of formulation options available (solutions, emulsions, wettable powders, flowables, granules, and encapsulated materials), adjuvants become even more important in ensuring consistent performance.

Spray adjuvants are added to the tank to improve pesticide performance. Literally hundreds of chemical additives are now available that fall into this category. Spray additives can be grouped into two broad categories: activator adjuvants, such as surfactants, wetting agents, stickers-spreaders, and penetrants; and special purpose or utility modifiers, such as emulsifiers, dispersants, stabilizing agents, coupling agents, co-solvents, compatibility agents, buffering agents, antifoam agents, drift control agents, and nutritionals.

Blended adjuvants are becoming more popular because multiple ingredients are included in one jug and thus serve various functions. Using blended adjuvants is easier for applicators since they need to use only one product compared to properly selecting and mixing numerous spray additives. Generally, a blended adjuvant contains various combinations of special purpose adjuvants and/or activator adjuvants (e.g., nonionic surfactant + ammonium sulfate, ammonium sulfate + drift inhibitor + defoamer, ammonium sulfate + water conditioning agent + drift inhibitor + defoamer). Because of the multiple ingredients included, these adjuvant mixes serve primary and secondary purposes.

Descriptions of the more common types of special purpose adjuvants follow. Table 1 lists some common products sold for these purposes.

SPECIAL PURPOSE ADJUVANTS

Compatibility agents allow simultaneous application of two or more ingredients. They are most often used when herbicides are applied in liquid fertilizer solutions. Unless the pesticide label states that it can be mixed with liquid fertilizers, a compatibility agent should be included.

Buffering agents usually contain a phosphate salt or, more recently, citric acid, which maintains a slightly acid pH when added to alkaline waters. These are added to higher pH solutions to prevent alkaline hydrolysis (a chemical reaction) of some organophosphate (OP) and carbamate insecticides. Some acidifying agents are also sold to enhance herbicide uptake and performance. However, there is little evidence to support the need for these acidifying agents for this purpose with most herbicides. Some buffering agents are also "water softening" agents that are used to reduce problems with hard water. In particular, calcium and magnesium salts may interfere with the performance of certain pesticides. Ammonium sulfate (AMS) is sometimes added to reduce hard water problems. Examine the specific pesticide and water source to determine the need for a buffering agent.

Antifoam agents usually are added to suppress surface foam and minimize air entrapment, which can cause pump and spray problems. Defoamers often contain silicone.

Drift control agents (thickeners) modify spray characteristics to reduce spray drift, usually by minimizing small droplet formation. Drift inhibitors are generally polyacrylamide or polyvinyl polymers to increase droplet size.

ACTIVATOR ADJUVANTS

Activator adjuvants are by far the most common type of additives used to enhance herbicide performance. Although some products are sold to alter pesticide-soil interactions, the emphasis of this discussion will be on foliar-applied materials. The primary use of activator adjuvants is with postemergence herbicide applications.

Before any foliar-applied herbicide can perform the desired biological function, it must be transferred from the leaf surface into the plant tissue. The aboveground portions of plants are covered by a continuous noncellular, nonliving membrane called cuticle (Figure 1). Cuticle is the first barrier that any herbicide must overcome to be effective. The plant cuticle is composed of water-repellent waxes and less water-repellent cutin and pectins that can provide pathways for more water-soluble pesticides. The structure of plant cuticle can be likened to a sponge where the matrix of the sponge corresponds to the cutin and the holes correspond to the embedded wax. The surface of the sponge is also covered with wax (epicuticular wax). Cuticle is extremely diverse and varies greatly between different species of plants.

Table 1. Selected trade names and manufacturers of special purpose adjuvants.

TRADE NAME	MANUFACTURER
Compatibility agents	
Blendex VHC	Helena
Complete Compatibility	Winfield Solutions
E-Z Mix	Loveland Products
FS Tankmix	Growmark
Drift inhibitors ± retention agent ± AMS ± defoamer	
Accuquest	Helena
Chem-Trol	Loveland Products
FS Max Supreme	Growmark
Interlock	Winfield Solutions
Spray-Start	Kalo, Inc.
Sta-Put Plus	Helena
Strike Zone	Helena
Windcheck	Loveland Products
Antifoaming agents (defoamers)	
FastBreak	Winfield Solutions
FoamBuster	Helena
FS Eliminator	Growmark
Buffers	
Ballast	Winfield Solutions
Buffer P.S.	Helena
BS-500	Drexel

Waxes are the principal barrier restricting herbicide movement into plant foliage. The chemical or physical properties of the wax appear to be more important than thickness in restricting penetration. Surface wax high in hydrocarbons and other repellent molecules is less permeable to water and most herbicide sprays than cuticle membranes with lower amounts of water-restrictive waxes. For example, lambsquarters cuticle wax is known to be a strong barrier to the penetration of many herbicides. Lambsquarters cuticle is high in chemical substances called aldehydes, which may help prevent the passage of more water-soluble herbicides. Not only does cuticle composition vary between species, but also the age of the plant has been associated with differences in leaf wax chemistry over time.

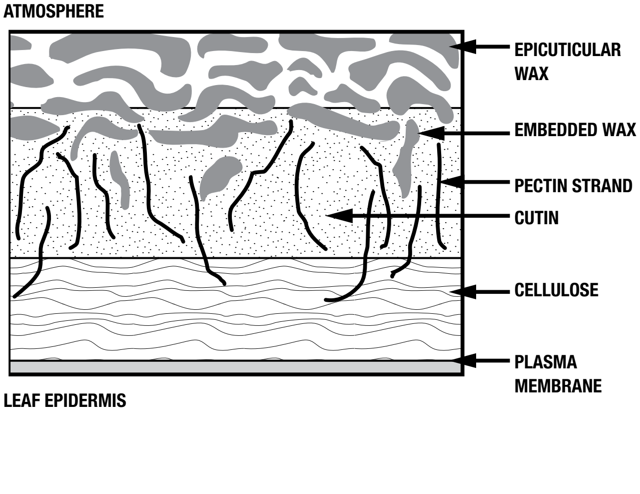
The most common types of activator adjuvants employed are surfactants, oils, and salts. Activator adjuvants influence the physical and chemical properties of the spray solution, including surface tension, density, volatility, and solubility. These properties will in turn modify the spreading, wetting, retention, and penetration of the spray solution. It is important that the appropriate adjuvant is selected for a particular pesticide product. The type of adjuvant added to the spray tank can enhance or reduce the performance of the pesticide.

The first step in choosing the correct additive for a specific product is to read the pesticide label. The wrong adjuvant may increase the risk of poor performance and/or crop injury.

Surfactants

The primary purpose of a surfactant, or "surface active agent," is to reduce the surface tension of the spray solution to allow more intimate contact between the spray droplet and the plant surface. This helps overcome the barriers that impede movement of the herbicide from the leaf surface to the cell interior. Any substance that brings a pesticide into closer contact with the leaf surface has the potential to aid absorption (Figure 2). Surface tension is a measure of the surface energy in terms of force measured in dynes per centimeter. Water has a surface tension of 73 dynes/cm. Surfactants lower the surface tension of water to that of an oil or solvent, which spreads more readily than water on plant surfaces. Surfactants typically lower the surface tension of a solution to between 30 and 50 dynes/cm.

Figure 1. Simplified plant cuticle (taken from F. D. Hess, Sandoz Crop Protection).



The interaction among surfactant, herbicide, and plant surface is far more complex than simply lowering the surface tension of the pesticide solution. Surfactant molecules may also alter the permeability of the cuticle. Surfactants form a bridge between unlike chemicals such as oil and water or water and the wax on a leaf surface. Although there are many different types of surfactants, in general, they are constructed of a long-chain hydrocarbon group on one end that is considered lipophilic (fat loving) and a more hydrophilic (water loving) group of atoms on the other end. The structure of surfactants is often represented by a tadpole or polliwog type of arrangement such as seen in Figure 3. The zigzag tail represents the long-chain hydrocarbon group that gives the molecule its lipophilic characteristics. The head of the polliwog contains more water-soluble (polar) groups that give the molecule its hydrophilic characteristics.

The influence of the surfactant on herbicide performance can be species specific because leaf wax composition varies. For some herbicides, surfactant preference is also herbicide dependent. For example, glyphosate (e.g., Roundup, Touchdown, Credit) is a more water-soluble herbicide that requires a more polar type of surfactant (such as the ethoxylated fatty amines) to improve activity. Highly lipophilic surfactants can actually decrease the performance of glyphosate in comparison to no surfactant at all.

Surfactant molecules can be synthesized to achieve specific solubility characteristics often referred to as the hydrophilic-lipophilic balance (HLB). The capability of a surfactant to modify herbicide penetration is partially attributable to the HLB, with each herbicide-species interaction having an optimum HLB requirement for the surfactant employed.

Figure 2. Effect of a surfactant on the spread and penetration of spray solution across and through the leaf surface.

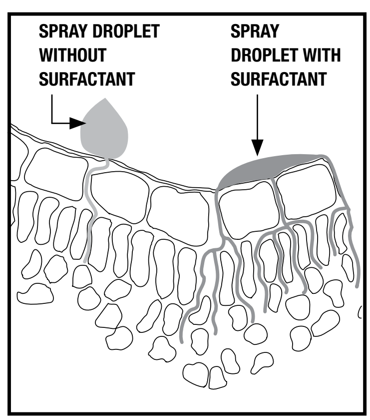


Figure 3. Polliwog representationn of a surfactant molecule.

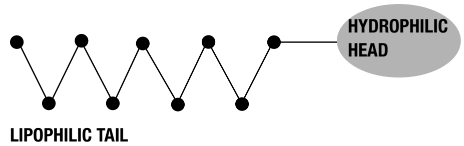


Table 2. Selected trade names and manufacturers of nonionic surfactants (NIS).

TRADE NAME	MANUFACTURER
Activate Plus	Winfield Solutions
Activator 90	Loveland Products
Adspray 80	Helena
Class Act NG (crop-based NIS + AMS + defoamer)	Winfield Solutions
Dyne-Amic (organosilicone)	Helena
Induce	Helena
Kinetic (organosilicone)	Helena
LI-700	Loveland Products
Preference	Winfield Solutions
Silkin (organosilicone)	Winfield Solutions
Silwet L-77 (organosilicone)	Loveland Products
Surf-Ac 820	Drexel Chemical
Surf-Ac 910	Drexel Chemical
Sylgard 309 (organosilicone)	Wilbur-Ellis

Table 3. Selected trade names and manufacturers of oil-based additives.

TRADE NAME	MANUFACTURER
Crop oils	
Dormant Plus	Loveland Products
Crop oil concentrates	
Agri-Dex	Helena
Crop Oil Concentrate (COC)	various
Drop Zone	Helena
FS COC Supreme (high conc.)	Growmark
Herbimax	Loveland Products
Peptoil	Drexel Chemical
Prime Oil	Winfield Solutions
Superb HC (high conc.)	Winfield Solutions
Vegetable oil concentrates	
Destiny (methyl soybean)	Winfield Solutions
Dyne-Amic (silicone methyl vegetable)	Helena
FS MSO Ultra	Growmark
Meth Oil (methyl soybean)	Loveland Products
MSO/MVO	various
Prime Oil EV	Winfield Solutions
Rivet (MSO + organosilicone)	Winfield Solutions
Soy Dex Plus	Helena
Vegetable Oil Concentrate (vegetable)	Helena
Vegetoil	Drexel Chemical

HLB numbers for surfactants are often given on technical information sheets for specific products. They range from 0 to 40 with most of them between 1 and 20. Low HLBs are very oil soluble, while higher HLBs prefer water.

Although there are hundreds of different surfactants, only a few are used in the pesticide adjuvant business. More than half the products used as stickers or wetter-spreaders use the same general surfactant type, alkyl-aryl-poly-oxy-ethylenate, or AAPOE. The next most common type (about 25 percent) is very similar to AAPOE and is an alcohol ethoxylate or alcohol-poly-oxyethylene (APOE). Some surfactants may also contain free fatty acids or fatty acid esters or linear alkyl sulfonates (anionic) in the formulation that also contribute to the principal functioning agent. All surfactants contain inert ingredients that are considered nonfunctioning agents or formulation aids and can include isopropyl alcohol (IPA), propylene glycol (PG), and a poly siloxane foam retardant (Si). Although surfactants can vary considerably within these groups depending on molecular structure (i.e., number of carbon and hydrogen groups) and within a group whose principal function is the same, such as wetters-spreaders, it is not likely that differences between the same type of surfactant are great.

Surfactants are classified as nonionic, anionic, or cationic. Nonionic surfactants have no electrical charge and are generally compatible with most pesticides. Nonionic surfactants are most commonly used because of their universal fit. An anionic surfactant possesses a negatively charged functional group and is most often used with acids or salts. Anionic surfactants are more specialized and sometimes used as dispersants or compatibility agents. Cationic surfactants are used less frequently, but one group (ethoxylated fatty amines) has been sometimes used with glyphosate.

The organosilicone-based materials are another group of surfactants more recently introduced. These surfactants are used in place of or in addition to more traditional nonionic surfactants. Proponents of these surfactants stress low surface tension, greater rainfastness, and possible stomatal penetration characteristics. Several silicone-based products are currently available for use with postemergence herbicides (Tables 2 and 3). Surfactants and other adjuvants are either added to the spray tank on a per-acre basis or a percent volume per volume (percent v/v) concentration. For example, surfactants are usually applied at ½ to 2 pints per acre or at 0.25 percent v/v (i.e., 2 pt/100 gal) unless otherwise directed.

Oils

Adjuvants that are primarily oil based are very popular with pesticide applicators. Crop oils are probably the oldest group within this category.

Crop oil is a misnomer because the material actually is from petroleum (paraffin or naphtha base, not vegetable derivative), a phytobland (nonphytotoxic), nonaromatic oil of 70 to 110 second viscosity (water = 1 and 30 w motor oil = 300). Crop oils are 95 to 98 percent oil with 1 to 2 percent surfactant/emulsifier. Crop oils are believed to promote the penetration of pesticide spray through waxy cuticle or the tough chitinous shell of insects. Traditional crop oils are more commonly used in insect and disease control than with herbicides. Crop oils are typically used at 1 to 2 gallons per acre.

Crop oil concentrate contains 80 to 85 percent phytobland emulsifiable crop oil (petroleum based) plus 15 to 20 percent nonionic surfactant. The purpose of the surfactant in this mixture is to emulsify the oil in the spray solution and lower the surface tension of the overall spray solution. Crop oil concentrates attempt to provide the penetration characteristics of the oil while capturing the surface tension reduction qualities of a surfactant. Crop oil concentrates are also important in helping solubilize less water-soluble herbicides such as Assure, Poast, Fusilade, Select, and atrazine on the leaf surface. Crop oil concentrates are used at 1 to 3 pints per acre or at 1 percent v/v (1 gal/100 gal) unless otherwise directed.

Vegetable oil concentrates are similar to crop oil concentrates and are becoming more popular. Manufacturers are improving plant or vegetable-based oils by increasing their nonpolar or lipophilic characteristics. The most common method has been through esterification of common seed oils such as methylated sunflower, soybean, cotton, and linseed oils. The methylated forms of these seed oil concentrates (e.g., methylated seed oil, MSO) are comparable in performance to traditional (petroleum) crop oil concentrates so their importance has increased. In taking it one step farther, organosilicone-based methylated vegetable oil concentrates are also available. These adjuvants boast the surface tension-reducing properties of silicone but have the advantages of a methylated vegetable oil concentrate. The more widely available oil-based additives are given in Table 3.

Nitrogen Fertilizer

Nitrogen fertilizers are frequently added to the spray solution as an adjuvant to increase herbicide activity. Ammonium salts (NH_4^+) appear to be the active component of these fertilizer solutions and have improved the performance consistency on some weeds. It is still unclear how ammonium salts improve herbicide performance. Herbicides that appear to benefit from the addition of ammonium are the relatively polar, weak acid herbicides such as Basagran, the sulfonylureas (Classic, Harmony, Option, and Steadfast, etc.), and the imidazolinones (Pursuit and Raptor). Nitrogen fertilizers may replace surfactant or crop oil concentrate with some of the contact-type herbicides, but they are usually added in addition to surfactant or crop oil concentrate with systemic products.

Velvetleaf and some grassy annual weeds in particular have been responsive to the addition of nitrogen fertilizer in the spray mix. In general, velvetleaf control has improved by as much as 10 to 25 percent by the addition of an ammoniumbased fluid fertilizer (28, 30, or 32 percent UAN, 10-34-0, or 21-0-0) compared to crop oil concentrate or surfactant. Common rates are 2 to 4 quart/acre of 28, 30, or 32 percent UAN, 1 quart/acre of 10-34-0, or 17 pounds/100 gallons dry ammonium sulfate. Some broadleaves and grasses show little or no response with the inclusion of ammonium fertilizer solutions.

Ammonium-based fertilizers and, in particular, ammonium sulfate (AMS) are also being promoted to reduce potential antagonism with hard water or antagonism with other pesticides. Both hard water antagonism and pesticide antagonism can occur with some herbicides. Roundup (glyphosate) is one product that specifically recommends on its label the addition of ammonium sulfate (or a higher rate of Roundup) for hard water, cool air temperatures, or drought conditions. Because of the increased use of glyphosate in Roundup Ready crops, many adjuvant products have been developed that have multiple functions, including drift control and/or retention agents with or without AMS and/or defoamer. Examine the specific pesticide label, water source, and environmental conditions to determine the need for AMS or other adjuvants.

ADJUVANT SELECTION

Adjuvant selection should be based on several factors including what the pesticide calls for, what the adjuvant claims to be, cost of the adjuvant, and what is available in your area. The primary source in deciding whether an adjuvant is necessary and the type of adjuvant used should come from the pesticide label. The following are some general guidelines to consider when given a choice of adjuvants.

- If both oil concentrate (crop or vegetable oil) and nonionic surfactant are listed, then use nonionic surfactant under normal weather conditions when weeds are small and well within label guidelines. Use oil concentrate if weeds are stressed due to dry weather or with more mature weeds.
- If labeled, include oil concentrate for control of grasses.
- Include nitrogen fertilizer only if it is recommended on the herbicide label.
- If the potential for crop injury is great, then use nonionic surfactant instead of oil concentrate.
- To improve crop safety, do not include oil concentrates with plant growth regulator-type herbicides (e.g., dicamba, 2,4-D)

Manufacturers of most products and particularly the newer materials have invested time and money in adjuvant research. Some labels are very specific in their recommendation of adjuvants. For example, the Pursuit label for postemergence use in soybean states “use a nonionic surfactant containing at least 80% active ingredients and apply at 1 qt/100 gal or a petroleum or vegetable seed-based oil concentrate at 1.5 to 2 pt/acre and a nitrogen-based fertilizer such as 28% N, 32% N, or 10-34-0 at 1 to 2 qt/A.” Other product labels such as Buctril on corn are not as specific and simply state that “Buctril can be applied in combination with sprayable liquid fertilizer or spray additives such as surfactants or crop oil concentrate.” When pesticide labels are not specific enough, other important sources include university crop management guides (e.g., *Penn State Agronomy Guide*) and industry-based publications.

Next, select an appropriate product within the required group or type of adjuvants recommended. This can be confusing since some products contain several different types of adjuvants. The claims made for an adjuvant product on the label and in the active ingredient statement can be helpful in selecting the best adjuvant for your needs. In particular, pay close attention to the percent active versus inert ingredients. For example, Activate Plus from Winfield Solutions is a nonionic spreader/activator that is typical of nonionic surfactants recommended for use with postemergence herbicides. The active ingredient portion of Activate Plus includes AAPOE, free fatty acids, and isopropyl alcohol.

These three ingredients make up 90 percent of the product with the remaining 10 percent being inert ingredients. Agri-Dex from Helena claims to be a nonionic spray adjuvant or more specifically a crop oil concentrate that is recommended for use with pesticides requiring an oil concentrate adjuvant. The active ingredients make up 99 percent of the formulation and include paraffin-based petroleum (crop oil), fatty acid esters, and AAPOE or APOE, which all contribute to the active portion of the adjuvant. Loveland Products manufactures Chem-Trol, which is identified as a spray additive for deposition and drift retardation. The active ingredient in Chem-Trol is a polyvinyl polymer at 1 percent with 99 percent inert ingredients. This product is not recommended to enhance pesticide activity but rather to reduce pesticide drift. Be sure to thoroughly read the label.

The active ingredient portion of the label can also be helpful in comparing costs. If two products have the same or similar active ingredients yet slightly different concentrations, you can calculate the cost of each product on an active ingredient (ai) basis. For example, two adjuvant products cost $11.00 per gallon. Product A has 90 percent active ingredient, while Product B contains 80 percent. Both products serve the same principal function. Product A's actual cost is $12.22 per gallon of active ingredient (11.00/0.90), while Product B's is $13.75 (11.00/0.80). Which would you choose? This may become even more important as new higher-cost adjuvants enter the marketplace.

SUMMARY

The type of adjuvant added to the spray tank can enhance or reduce the performance of the pesticide. Both herbicide and species influence the appropriateness of the adjuvant. Although a number of different kinds of activator adjuvants are on the market, their primary purpose is to reduce the surface tension, improve the wetting action, and increase the penetration of the pesticide. To choose the correct additive for a specific product, first read the pesticide label. An appropriate adjuvant assures maximum performance and crop safety. The wrong adjuvant increases the risk of poor performance and crop injury.

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Prepared by W. S. Curran, professor of weed science, and D. D. Lingenfelter, weed science extension agronomist.

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Rainfastness of Pesticides[1]

Bonnie Wells and F.M. Fishel[2]

Introduction

Applicators of pesticides often question whether an application they have made will be effective if rainfall occurs too soon after the application. But what is too soon? Is it 10 minutes, an hour, 4 hours, 24 hours, etc.? Rainfall occurring after application can have a significant effect on the residual activity and efficacy of pesticides. A pesticide's rainfastness, or its ability to withstand rainfall, is an important factor affecting the efficacy of foliar-applied pesticides. Generally, it is best to avoid pesticide application when rainfall is likely; however, weather can be unpredictable, so it is best to choose a product with good rainfast characteristics.

Definition of Rainfastness

A pesticide is considered rainfast after application if it has adequately dried or has been absorbed by plant tissues so that it will still be effective after rainfall or irrigation. The degree of rainfastness of pesticides is highly variable. The best source for determining rainfastness for a particular product is to consult its label. Some products contain statements that specifically address the length of time necessary for rainfastness to occur (Figure 1). In many cases, limited or no information about rainfastness is included on the label, and the wording is often vague (Figure 2). Some product labels will expressly prohibit an application if rainfall is expected within a stated timeframe (Figure 3). Others may *recommend* that a product is not applied within a stated timeframe (Figure 4).

Rainfastness
Fusilade DX Herbicide is rainfast 1 hour after application.

Figure 1. Label wording example seen on a pesticide label.
Credits: CDMS Agrochemical Database, http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=

Rainfastness: Heavy rainfall soon after application may wash this product off of the foliage and a repeat application may be required for adequate weed control.

Figure 2. Label wording example seen on a pesticide label.
Credits: CDMS Agrochemical Database, http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=

USE PRECAUTIONS
- **DO NOT** apply this product through any type of irrigation system.
- **DO NOT** apply this product if rainfall is expected within 24 hours of application.
- **DO NOT** feed gin trash, treated foliage or immature crops to livestock.

Figure 3. Label wording example seen on a pesticide label.
Credits: CDMS Agrochemical Database, http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=

FOLEX 6 EC is effective when applied to cotton with a heavy dew. Once FOLEX 6 EC has dried on the leaf, subsequent rainfall or dew does not adversely affect its activity. Application of FOLEX 6 EC is not recommended when a heavy rainfall is expected within 1 hour after treatment. Conditions which delay absorption into the leaves are primarily those which cause the cotton leaves to be wilted, toughened, or leathery. When these conditions prevail, use diesel oil instead of water.

Figure 4. Label wording example seen on a pesticide label.
Credits: CDMS Agrochemical Database, http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=

1. This document is PI238, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date August 2011. Revised September 2017. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. Bonnie Wells, Extension agent II; and F. M. Fishel, professor, Agronomy Department, and director, Pesticide Information Office; UF/IFAS Extension, Gainesville, FL 32611.

Impact of Rainfastness on Pesticide Performance

Rainfall can adversely affect a pesticide application by (1) directly washing the pesticide away or physically removing it, (2) diluting the product to a less effective form, (3) redistributing the active ingredient, or (4) extracting the pesticide from the plant tissue altogether. The overall rainfastness of a pesticide depends on which of these factors or combinations of these factors are occurring, the time between the application and the rainfall event, the amount of rainfall, the formulation of the pesticide, and the properties of the target surface. Research conducted in Michigan suggests that the duration of a precipitation event is relatively unimportant, but the amount of rainfall will significantly impact the insecticide residues remaining on the fruit and leaves of the plant (Table 1) (Wise 2017). Removal of pesticides is greatest when rainfall occurs within 24 hours after application (McDowell et al. 1985).

While it is important to know the rainfastness of a pesticide when considering re-application following a rainfall event, the target pest's biology, behavior, and threat to the crop must also be considered. For example, a pesticide may be highly susceptible to wash-off, but the pest may be highly sensitive to the active compound, and adequate residues remain on the crop for protection. Also, the potential for wash-off can be different for foliar, fruit, or soil-applied compounds.

Effects of Formulation on Rainfastness

The formulation of a pesticide is the mixture of active ingredients with other inert ingredients, and it has a significant effect on the rainfastness qualities of the product. Inert ingredients are added for ease of applicability and safety and to improve the accuracy and effectiveness of the pesticide. Solvents, wetting agents, stickers, powders, and granules can be added to active ingredients to yield a more durable and effective product. Some modern pesticides are formulated for slow release. A single pesticide can have many formulations, so the best formulation for each job overall should be considered.

Dusts and wettable powders are more susceptible to wash-off than emulsion formulations of pesticides (Ebeling 1963). Dusts are finely ground mixtures of the active ingredient with clay, talc, or other such materials, and they usually contain a low percentage of active ingredients. This would allow rain to easily wash off the active compound. Wettable powders (W or WP) are similar to dusts, but contain a wetting and dispersing agent. Wettable powders have a more concentrated active ingredient than dusts, but are still generally prone to wash-off. For emulsifiable concentrates (E or EC), the active ingredient is dissolved in an oil or a solvent, and then an emulsifier is added so that it can be mixed with water for application. Emulsifiable concentrates and wettable powders are the most commonly used formulations. Biopesticides are generally not as rainfast as modern conventional products.

Adjuvants to Improve Rainfastness

Adjuvants that increase absorption of the product into plant tissues can be added to increase the rainfastness and overall performance of a pesticide. Adjuvants can either be included in the formulation or added to the spray tank before application. Adjuvants to enhance rainfastness of pesticides can include surfactants, oils, deposition agents, and thickeners. In particular, organosilicone surfactants are commonly used to improve rainfastness, reduce surface tension, and enhance spreading ability (Figure 5). A simulated rainfall study showed that several latex-based adjuvants improved rainfastness of chlorpyrifos, an organophosphate insecticide, when it was applied in its emulsifiable concentrate formulation (Thacker and Young 1999). Some products' labels will state to use an adjuvant to improve the rainfastness characteristics.

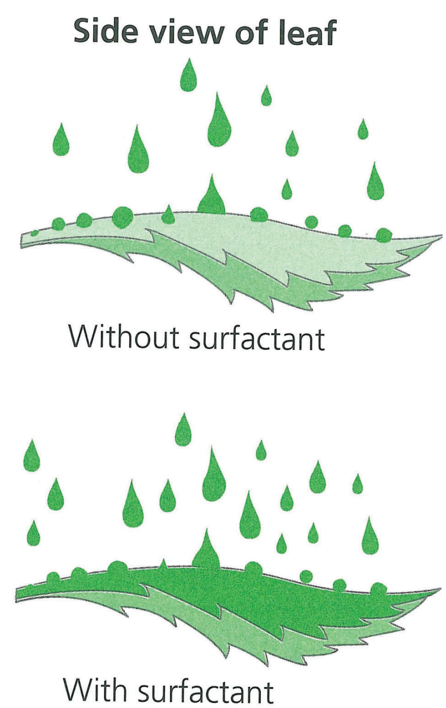

Figure 5. Surfactants increase spreading a pesticide evenly over a leaf.
Credits: National Pesticide Applicator Certification Core Manual, http://www.nasda.org/workersafety/

Conclusions

Always consult the product's label for information if there is any question regarding rainfastness of a pesticide. If the label states a specific length of time is required following the application for rainfastness to occur, never make an application if a rainfall event is scheduled to occur within that timeframe. If no such specific information exists on the label, or the information is stated in vague terms, use common sense. For such products, don't make foliar applications if a rainfall event is forecasted within the next 24 hours.

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Table 1. Insecticide rainfastness ratings.[1]

Insecticide class	Rainfastness ≤ 0.5 inch		Rainfastness ≤ 1.0 inch		Rainfastness ≤ 2.0 inch	
	Fruit	**Leaves**	**Fruit**	**Leaves**	**Fruit**	**Leaves**
Organophosphates	L[2]	M	L	M	L	L
Pyrethroids	M	M	L	M	L	L
Carbamates	M	M	L	M	L	L
Insect growth regulators	M	H	ND	ND	ND	ND
Neonicotinoids	M, S	H, S	L, S	L, S	L, S	L, S
Spinosyns	H	H	H	M	M	L
Diamides	H	H	H	M	M	L
Oxadiazines	M	M, H	M	M	L	L
Avermectins	M, S	H, S	L, S	M, S	L	L

[1] Source: 2017 Michigan Fruit Management Guide E-154 (Wise 2017).
[2] H – Highly rainfast (≤ 30% residue wash-off), M – moderately rainfast (≤ 50% residue wash-off), L – low rainfast (≤ 70% residue wash-off), S – systemic residues remain within plant tissue, ND – no data available.

Nutritional Characteristics and Silage Potential of Sweetpotato Vines

Lead Author: Wendy Mussoline, PhD
UF/IFAS Multi-County Agriculture Extension Agent

Co-Author: Luiz Ferraretto, PhD
UF Assistant Professor, Animal Science Department

Introduction

Sweetpotato (*Ipomoeabatatas L.*) is an attractive crop for Florida since it thrives in tropical and subtropical regions of the world. It is known for its high productivity on low-quality, arable lands and minimal demands for fertilization and irrigation. Sweetpotatoes require less than half of the nitrogen as potatoes and they have lots to offer in regards to versatility. The starchy root is a nutritious carbohydrate that can be grown for tablestock and specialty varieties have also been developed as biofuel (ie. Ethanol) feedstock. Nearly all of the ethanol generated in the US comes from corn, but sweetpotato certainly has great potential to become a biofuel producer for Florida.

Although the primary target of the crop harvest is the storage root, the sweetpotato vines contribute a substantial fraction of the overall crop yield. The nutritional value of the vines is recognized in some parts of the world as they are harvested for human food in many parts of Asia and Africa. Several studies have also demonstrated their effective use as a protein-rich supplement for livestock, including cows, pigs, goats and poultry (1-4). Unfortunately, sweetpotato vines are not currently utilized in the USA and most producers discard them at harvest. A more sustainable approach to agriculture would be to collect the vines as crop byproducts and feed them to cattle, benefiting both crop and cattle producers.

There are a few potato growers in the Tri-County Agriculture Area (TCAA), which includes Putnam, Flagler and St. Johns Counties, that are currently growing sweetpotatoes as a summer crop in rotation with their winter potato crop. The crops are very similar and so the same equipment can be used for harvesting the roots (both potato and sweetpotato). The vines represent nearly 50% of the fresh biomass yield for the entire crop depending on the cultivar (5). Therefore, the vine biomass should be removed prior to harvest to prevent entanglement within the equipment. Thus, it is beneficial for growers to cut, bale and remove the vines prior to harvest. Cattle producers in the TCAA have an interest in wrapping and ensiling the vines to be used as an alternative winter feedstock for their herd. In cow-calf operations, nutrient requirements are highest during the third trimester, during the birthing process and in the nursing stages. This typically correlates to the winter months (December through March) when common pasture forages are at their lowest quality and availability. Therefore, alternative feedstocks are necessary to support successful livestock breeding programs in the beef cattle industry. Sweetpotatoes are typically harvested in November/December and thus they can be available in the winter months when cattle nutritional demands are high and available forages are lean.

The goal of this research is to partner with crop and cattle producers in the TCAA to evaluate the potential for using locally grown sweetpotato vines as an alterative feed for beef cattle in the winter months. The specific objectives are (1) to demonstrate harvest and baling capabilities of the vines and (2) to evaluate nutritional quality of the vines compared with other common forages and (3) to determine the most appropriate wilting age for ensiling the vines to promote efficient fermentation.

Methods

Forage Quality

Sweetpotato vines were collected from a new variety of purple-flesh sweetpotatoes that were grown at Blue Sky Farms in the TCAA. The vines were collected using a PTO-powered crimper that detached the vines from the root and a round baler. Sweetpotato vine samples for nutritional analyses were collected 122 days after planting (DAP) and immediately following harvest (i.e. no wilting time). Additional samples were collected at 134 and 152 DAP to determine if maturity age influences the nutritional value of the vines. This is relevant since sweetpotatoes can be harvested over a broad range of time, depending on the desired size of the root. Pearl millet and sorghum sudangrass grown on nearby pastures during the same season were also collected. Each sample was analyzed for dry matter (DM), crude protein (CP), total digestible nutrients (TDN), neutral detergent fiber (NDF), acid detergent fiber (ADF), and relative feed value (RFV) by Dairy One forage testing laboratory in Ithaca, NY.


Figure 1. (Left) Chance Clay with Clay Ranch examines fresh sweetpotato vines harvested from Blue Sky Farms; (Right) Round bale of harvested sweetpotato vines

Silage Trials

Silage trials were conducted at lab-scale to determine the appropriate time for wilting and the length of time necessary for complete fermentation to occur. Vine samples were collected from the field and the entire length of the vine was used for the silage trials. The vines were chopped into 3-4 inch lengths and then placed in 2-gallon plastic vacuum-sealed bags. Four replicates were evaluated for each variable. The variables included wilting time of the vines in the field and storage time for the ensiled bags. Wilting time was measured at "0W" (samples collected immediately following harvest), "1W" (samples collected 1 day after harvest) and "2W" (samples collected 2 days after harvest). The purpose of the wilting stages was to determine if it was beneficial for fermentation if they dried out in the field over the course of 24 to 48 hours. The ensiled material at each wilting stage was evaluated at Day 0, Day 30 and Day 60 to determine the appropriate amount of time required for complete fermentation to occur. No inoculant was added to induce fermentation. DM, pH, CP, water soluble carbohydrates (WSC), and total volatile fatty acids (VFA) were analyzed for each replicate at the UF Animal Science Laboratory and results were statistically evaluated using SAS.

Figure 2. (Left) Vacuum sealer used to ensile the vines; (Right) One replicate sample of ensiled sweetpotato vines used in the silage trial

Analytical Results

Forage Quality

The analytical results from the nutritional analyses of all three forage samples are included in Table 1. Sweetpotato vines had a much higher TDN and much lower fiber content (both NDF and ADF), resulting in a much higher RFV than the other two forages. NDF is correlated with animal intake whereas ADF is correlated with digestibility, thus lower NDF and ADF values are preferred to improve forage quality. As an example, a 1200-lb lactating beef cow that calved within the last 30 days is producing approximately 30 lbs of peak milk. According to Hersom (2017), she requires 11.5% CP and 61% TDN (6), which can adequately be provided by sweetpotato vines.

The results from the differing maturity ages showed CP decreased slightly with maturity from 11.8% on 122 DAP to 9.5% on 152 DAP (DM basis). TDN remained relatively stable at 62% (DM basis) as well as the relative feed value at the different maturity ages. These results demonstrate a clear opportunity for the use of locally-grown sweetpotato vines as a valuable, low-fat supplement for animal feed that offers relatively high protein and TDN concentrations.

Table 1. Compositional analyses of sweetpotato vines compared to other forages

High Quality [1]		> 59	< 35	< 28		>170
	CP (%DM)	TDN (%DM)	NDF (%DM)	ADF (%DM)	Fat (%DM)	RFV [3]
Sweetpotato vines [2]	11.8	62	36.8	25.1	3.6	175
Pearl Millet [2]	13.5	50	64.9	44.7	3.2	77
Sorghum Sudangrass [2]	11.0	57	67.2	42.0	3.4	78

Notes:

1. "High quality" values are defined by Hersom, 2017 (6).
2. All samples were grown in the TCAA in 2017 and evaluated by Dairy One Laboratories. The sweetpotato vines were harvested 122 days after planting.
3. RFV is relative feed value which is used to compare cool season forages to a standard alfalfa hay in full bloom, which is assigned a value of 100.

Silage Trials

The results showed that wilting did promote a loss of moisture in the vines over time. DM increased from 15.6% immediately following harvest to 20.5% after 24 hours to 24.8% after 48 hours. Typically, forages are much drier before they are ensiled, but sweetpotato vines maintain their moisture more than common forages. Thus, the silage trials were conducted on fairly wet material. As part of the fermentation process, the sugars (represented by WSC) are converted into VFAs by fermentative bacteria. The pH trend for each of the wilting stages at Day 0, 30 and 60 is shown in Figure 3. The pH drop after 30 days is a clear indication that fermentation is occurring, and the pH drops slightly between 30 and 60 days. The decrease in pH is relatively consistent across all of the wilting ages at both 30 and 60 days. Therefore, pH is an indicator, but is certainly does not provide an in-depth look at the fermentation process. The more complete story is revealed by evaluating the WSC (sugar) and total VFA (acid) concentrations at each stage of the fermentation process. WSC and VFA concentrations for each of the wilting stages are shown in Figures 4 and 5 over the course of the experiment.

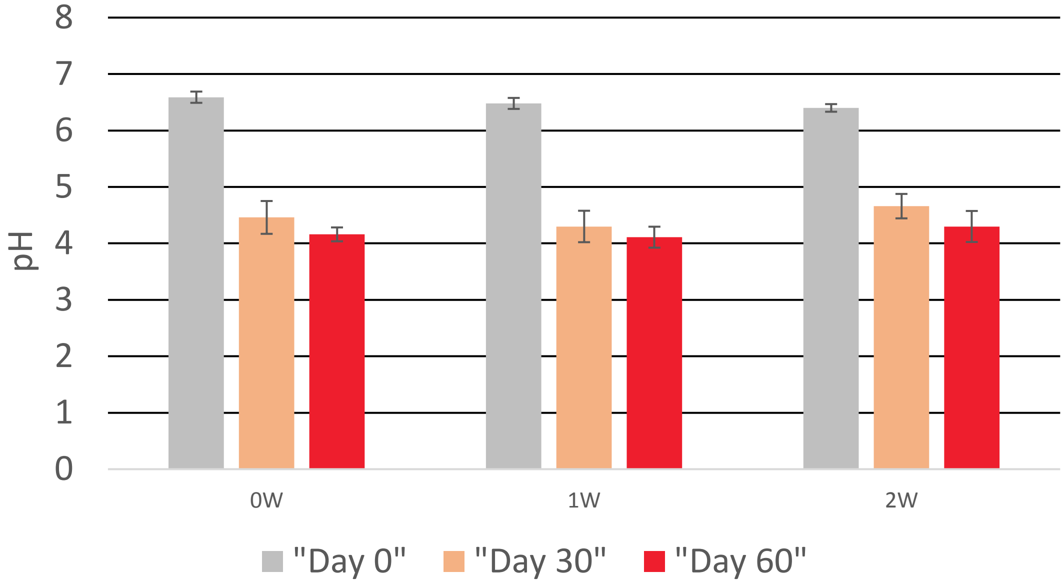

Figure 3. pH Trend for each wilting stage

The WSC concentrations drop most significantly from 16.5% DM to 3.1% DM in the no wilt (0W) sample after 30 days. It continues to drop to 2.4%DM after 60 days. Simultaneously, the VFA concentration increases from 0 to 12.4%DM to 14.5%DM after 60 days. These concentrations show a near complete conversion of sugars to acids after 60 days of fermentation for the no wilt samples. The wilted samples (after both 24 and 48 hours) show incomplete fermentation evidenced by relatively higher sugar concentrations and lower VFA concentrations after 60 days, when compared to the no wilt samples. This data suggests that sweetpotato vines will ferment most efficiently when they are ensiled immediately following harvest. This, however, creates a difficult challenge in the field since the material will be wet (15% DM) and the bales will be excessively heavy. Future work is necessary to determine if fermentation will be as efficient when the material is ensiled in wrapped bales.

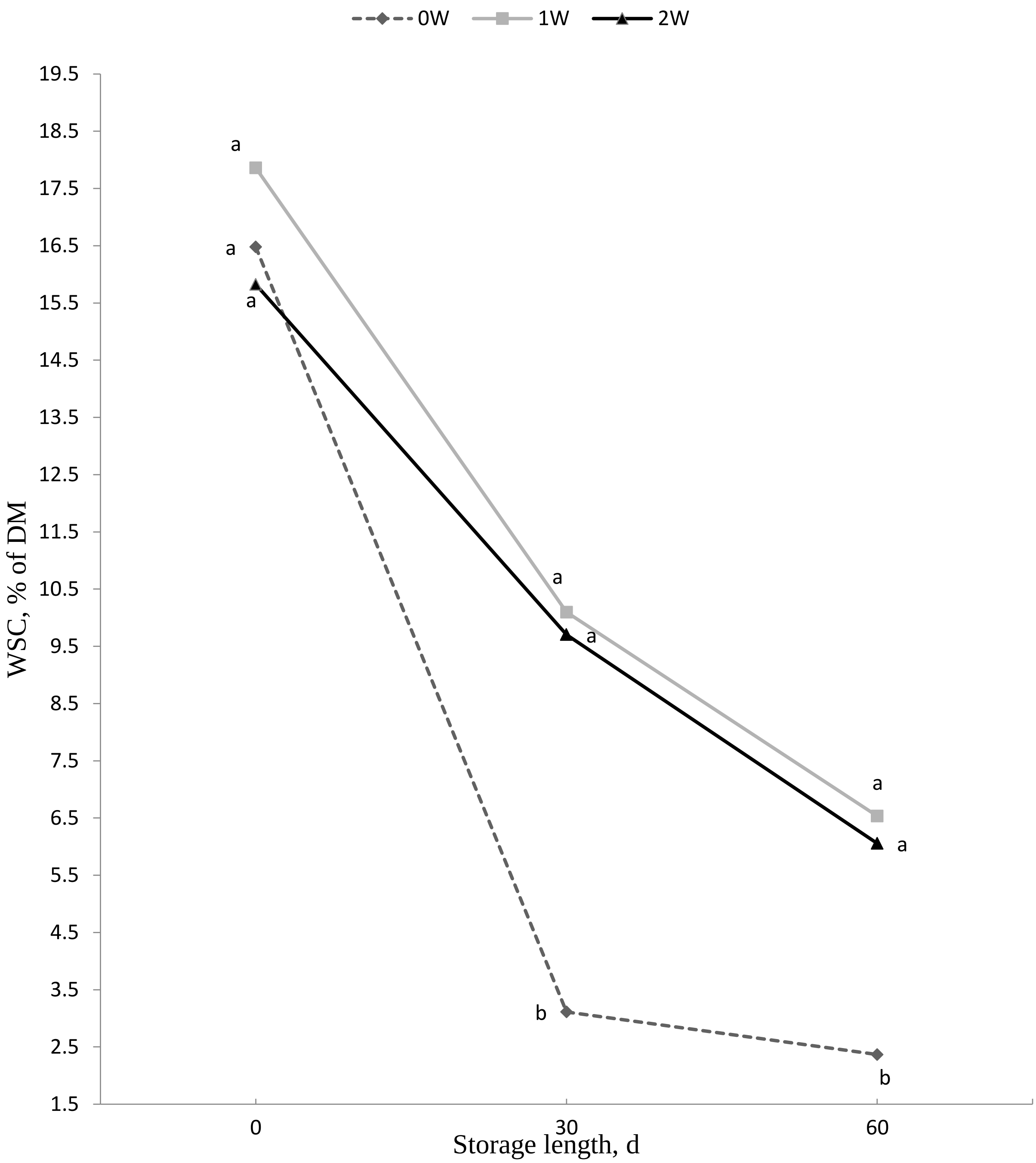

Figure 4. WSC concentrations for each wilting stage (different subscripts within a particular day are statistically different, thus the differences between wilting are shown)

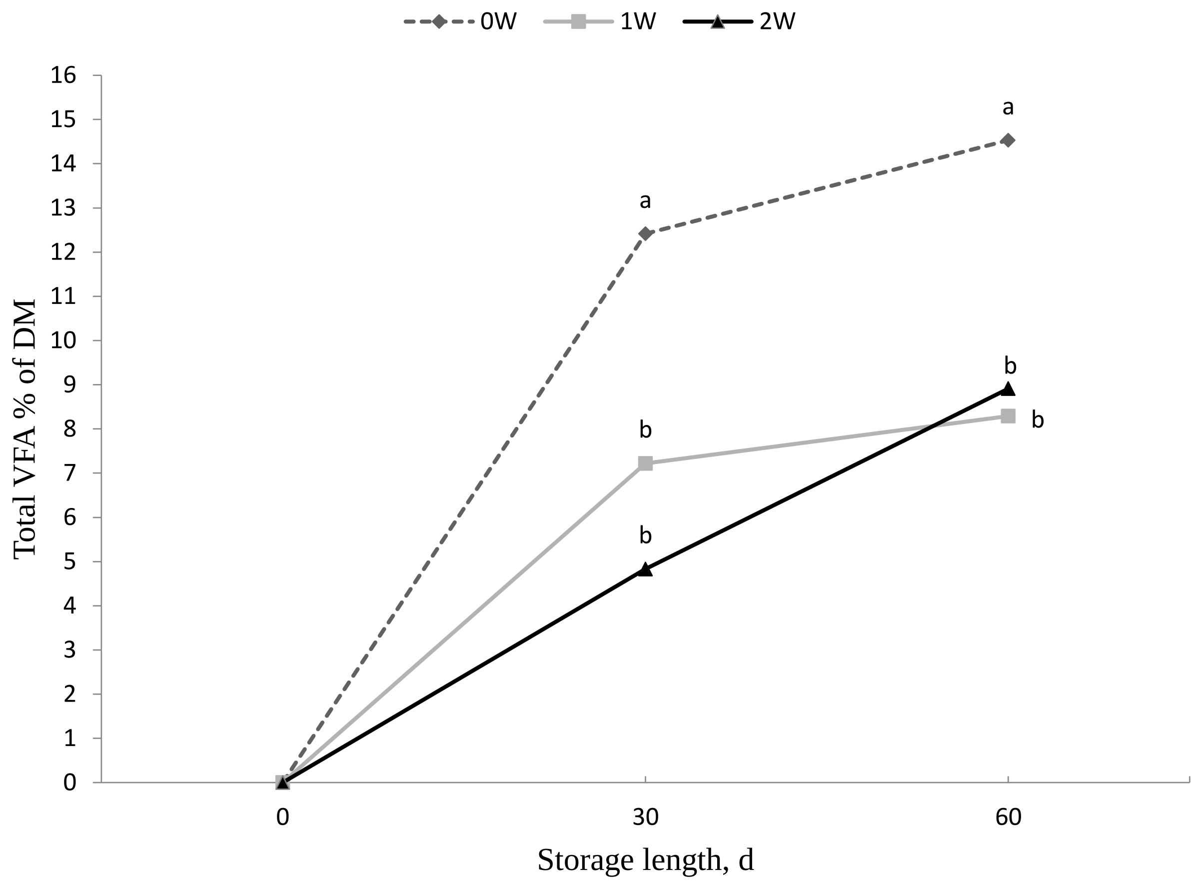

Figure 5. VFA concentrations for each wilting stage (different subscripts within a particular day are statistically different, thus the differences between wilting are shown)

Future Work

As the sweetpotato industry grows across the TCAA, the vines can become a viable alternative feedstock for cattle producers in the area. They are relatively high in CP and TDN and provide adequate nutrients for lactating cows. Future work involves upscaling the silage production in the field using a McHale round baler (with knives to better chop the material) and a bale wrapper to ensile the material. The silage quality should be evaluated on the wrapped bales after 30, 60 and 90 days. An informal palatability trial on both fresh and ensiled material should also be conducted using a small herd of beef cows.

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DEVLOPING FEEDING ALTERATIVES BY ADDING VALUE TO CULLED COMMODITIES

Tim Wilson, UF/IFAS Extension St. Johns County – Production Agriculture Agent
Dr. Matt Hersom, UF/IFAS Animal Science Department – Extension Beef Cattle Specialist
Gary England, UF/IFAS Extension Hastings Agricultural Extension Center – Director
David Baggett, UF/IFAS Extension Hastings Agricultural Extension Center
Dr. Wendy Mussoline UF/IFAS Extension Flagler and Putnam Counties – Agriculture Agent
Chris Prevatt, UF/IFAS Extension State Specialized Agent – Beef Cattle and Forage Economist
T. Hines, UF/IFAS Extension St. Johns County – Intern
G. Laibl, UF/IFAS Extension Flagler and Putnam Counties – Intern

The Tri County Agricultural Area (TCAA; St. Johns, Putnam and Flagler Counties) located in Northeast Florida produces more than 26,000 acres of row crops. Approximately 14,000 acres of potatoes are harvested in this region from late April to early June and large amounts of cull potatoes are discarded. Cull potatoes, like many other culled vegetables, are fed to cattle at harvest; unfortunately, potato harvest for this region does not occur in the winter months when other feed resources are not available. Winter feed costs account for approximately 55% of the annual maintenance cost for producing cattle which is why many ranchers look for alternative feed resources to meet the nutritional needs of their herd.

Building on pilot data collected in 2017, the University of Florida/IFAS Extension in the TCAA conducted a field demonstration that involved ensiling low-quality bahiagrass hay and spring harvested cull potatoes to develop a feed resource that could potentially be used to meet the nutritional requirements of cattle during the winter months.

On May 17, 2018, twenty-three thousand pounds of silage was prepared using a mixture of 70% potato and 30% low quality bahiagrass hay to determine if a value-added product could be developed. Hay and potato samples were tested independently of each other to determine the nutritional value of each feedstuff used at ensiling. Results for bahiagrass hay was 6.5% CP and 49% TDN and cull potatoes was 11.5% CP and 82% TDN prior to ensiling (Table 1).

Silage samples were taken on September 14, 2018 (120-days after ensiling) and tested for nutrient composition and mycotoxins. Some mycotoxins were detected but were well below acceptable thresholds. The finished potato silage feed tested 8.55% CP and 53.75% TDN. Compared to hay alone, the silage resulted in an increase of 2.05% in CP and an 4.75% increase in TDN (Table 2).

Although the potato silage that was produced does not meet all the nutritional needs for cattle during the winter months, it does provide an improvement compared to bahiagrass hay when fed alone.

Project Phase 2
Now that we have developed a potential feed resource, the questions that must be asked are 'will the cattle eat it, will they gain weight and what is the cost per pound of gain?' To make-up for the shortage in crude protein, dried distillers grain will be top-dressed in combination with the potato silage. On March 4, 2019, 10 head of feeder steers were weighed (600 lb avg.) and placed in a dry-lot to be fed a combination of approximately 40 lbs of potato silage and 5 lbs of dried distillers grain/hd/day for approximately 52-days. Cattle will be weighed again and weights will be recorded to determine if gain was achieved. Although feeding cattle for this amount of time could be considered a short period of time, this project is a demonstration to determine if additional research should be conducted.

Project Phase 3
Once this project a complete, an economic assessment will be conducted to determine the feasibility of making potato silage using cull potatoes and low quality bahiagrass. The cost of developing potato silage will be used to determine the cost per pound of gain once the feeding demonstration is completed.

If successful, this feedstuff could be an alternative option for commercial potato and beef producers by adding value to a product that otherwise would be discarded.

A project timeline can be seen in Figures 1 – 15.

Research funding for this project was provided by Hastings Agricultural Extension Center, supported by a grant from the St. Johns County Board of County Commissioners. Additional in-kind contributions were made by collaborating partners, (Chance Clay, Teddy Siehler and Acme Barricades) that included concrete barricades, land use, hay, equipment use and labor.

Table 1. Nutritional composition of Bahiagrass hay and potato

Item	Hay	Potato
Dry Matter, %	92.6	15.7
analysis on DM basis		
TDN, %	49	82
Net Energy maintenance, mcal/lb	0.36	0.90
Net Energy gain, mcal/lb	0.12	0.60
Crude Protein, %	6.5	11.5
ADF, %	40.8	5.3
NDF, %	72.4	6.6

Table 2. Comparison of upcycled Bahiagrass hay and potato ensiled mixture to Bahiagrass hay

	Hay:Potato Mixture	
Item	Silage	Diff Silage and Hay
Dry Matter, %	39.7	-52.9
analysis on DM basis		
TDN, %	53.8	4.75
Net Energy maintenance, mcal/lb	0.46	0.10
Net Energy gain, mcal/lb	0.21	0.09
Crude Protein, %	8.55	2.05
ADF, %	32.3	-8.6
NDF, %	50.4	-22.0
Ammonia, %	0.58	0.58
Starch, %	24	20.5
VFA Score	4.4	
Lactic Acid, %	1.57	1.57
Total Acid, %	3.11	3.11

Project Timeline


Figure 1. 16,000 lbs. of cull potatoes (May 2018).


Figure 2. 10 (700 lb.) Rolls of Bahiagrass hay (May 2018).


Figure 3. Barricades used to make temporary silage pit (May 2018).


Figure 4. Mixing potatoes with hay using a hay grinder (May 2018).


Figure 5. Potato/bahiagrass mixture (May 2018).


Figure 6. Packing potato/bahiagrass mixture (May 2018).

Figure 7. Potato/bahiagrass mixture ready to ensile (May 2018).

Figure 8. Team members (May 2018).

Figure 9. Wrapped potato silage (May 2018).

Figure 10. Sampling potato silage 120-days after ensiling (September 2018).

Figure 11. Sampling potato silage 120-days after ensiling (September 2018).

Figure 12. Ensiled potato silage ready to feed (March 2019).


Figure 13. Final product (March 2019).


Figure 14. Steers consuming potato silage (March 2019).


Figure 15. Feed bunks following initial feeding. All feed was consumed within 24 hours (March 2019).