Cover Crops:
Crop Rotation, Weed Control and Nutrient Contributions

Annette Wszelaki, Vegetable Specialist

(photo: oregonclover.org)
Overview: Cover crops

• Definitions
• Crop rotation
• Choosing a cover crop
  – Cover crop functions
  – Cover crop costs
  – Nutrient availability
  – Cover crop classification
  – Crops for the Southeast

(Photo from: panoramio.com)

Slide courtesy of David Butler,
UT Organic, Sustainable and Alternative Crops
Cover crops

• Important for preventing nutrient and soil loss
• Grown primarily for soil or agroecosystem improvement rather than for market
• Provide a variety of ecosystem services
• Can also have negative impacts if improperly managed or poor species selection
• Primary fertility and soil management tool available to organic farmers

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops
Cover crops

- **Cover crop**: “covers” the soil with living plants
- **Green manure**: cover crop grown mainly to be turned under for soil improvement
- **Catch crop**: cover crop grown to “catch” water-soluble nutrients remaining after cash crop harvest to prevent leaching, runoff losses
- Most cover crops serve multiple functions

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops
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Why bother?

- A good rotational sequence can accentuate every possible advantage
- Different crops use soil nutrients differently
- All may alter or be altered by the succeeding or preceding crop
- Time spent planning a rotation is never wasted!
- THINK IT THROUGH!
Well-thought-out crop rotation is worth 75% of everything else that might be done, including fertilization, tillage and pest control.

-Firmin Bear
Incorporating cover crops or green manures in your rotation

- Investment in weed and pest control
- Rotations can make nutrients more available
Incorporating cover crops or green manures in your rotation

- Vegetable systems have many windows to include cover crops or green manures
  - Example: Between harvest of early planted spring crop and planting of fall crops
    - Buckwheat, cowpeas, sorghum-sudangrass
Incorporating cover crops or green manures in your rotation

- Plant winter annuals on fields that would lie fallow
- Many vegetable crops can be overseeded with cover crops
  - Select crops that can tolerate shade and traffic
Overview: Cover crops

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  - Crops for the Southeast

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops
Choosing a cover crop

• **Step 1:** Identify what function is needed from the cover crop
  – What is limiting production in a given system?
    low fertility?
    poor soil structure?
    weed or pathogen populations?
  – What functions can cover crops serve?
Functions of cover crops

- **SOIL FERTILITY**
  - Enhance nutrient availability
  - Prevent leaching
  - ↑ yields

- **PESTS**
  - Smother weeds
  - Beneficial habitat
  - Reduce diseases

- **SOIL STRUCTURE**
  - Increase organic matter
  - Slow/prevent erosion

- **WATER**
  - Improve infiltration
  - Retain moisture
  - Protect water quality

Slide courtesy of Gary Bates, UT Forage Specialist
Soil fertility

• Provide nitrogen
  – Legumes- symbiotic relationship between legumes and rhizobia bacteria that fix atmospheric nitrogen in plant root nodules

• Scavenge soil nutrients remaining after a cash crop
  – Potentially available to following cash crop
  – Prevents leaching losses, which improves soil fertility and decreases environmental impact
  – Generally non-legumes, primarily grasses

(Miles and Brown, 2003)
Pest control

• Suppress weeds
  – Through competition, allelopathy, shading, etc.
  – Cereal rye, sorghum-sudangrass, other grasses
  – Rotate cover crops, so that weeds that compete well with that cover crop do not build up
  – Can be used as a killed mulch (mechanically or herbicide) in no-till systems to suppress weeds

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops

(Miles and Brown, 2003)
# Influence of Tillage and Cover Crop on Weed Populations

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Cover Crop</th>
<th>Weeds/ft²</th>
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<tr>
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<td>12</td>
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<tr>
<td>None</td>
<td>None</td>
<td>5</td>
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<tr>
<td>None</td>
<td>Rye</td>
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<tr>
<td>None</td>
<td>Barley</td>
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</tbody>
</table>

(Putnam et al., 1983)
Relaxed Tillage

DELICIOUS!

IT'S JUST RESIDUE!

© ANDERS SUNESON www.teknadebilder.se
Pest control

• Provide habitat for beneficial insects
  – Most applicable in permanent systems (e.g. orchard groundcovers) but also applicable in annual systems

(photos: marabelgroup.com, panoramio.com)

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops

(Clark, 2007)
Pest control

• Suppress soilborne pests and diseases
  – Some species known for their ability to suppress certain pathogens (e.g. sorghum-sudan or sunn hemp and root-knot nematodes)
  – Others are good hosts for root-knot nematodes (certain clovers)
  – Brassicas used for biofumigation, nematode-trapping effects
Brassicas as Biofumigants

Slide courtesy of Gary Bates, UT Forage Specialist
Effect of *Brassica* leaf tissue on *Rhizoctonia solani* growth


Slide courtesy of Gary Bates,
UT Forage Specialist
Effect of leaf tissue on *Pythium ultimum* growth


Slide courtesy of Gary Bates, UT Forage Specialist
Effect of Indian mustard on *Sclerotium rolfsii* growth


Slide courtesy of Gary Bates, UT Forage Specialist
Soil structure

• Increase soil organic matter and soil biological activity
  – Major influence on most soil properties (bulk density, porosity, nutrient and water holding capacity, etc.)
  – High biomass producing cover crops, generally grass species
  – Solubilize less soluble nutrients such as phosphorus

• Prevent soil erosion
  – Covers soil during fallow periods, preventing loss of soil and associated nutrients
  – Rapidly growing species are best, but most cover crops fill this role

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops

(Miles and Brown, 2003)
Water

• Protect water quality
  – Prevent erosion
  – Scavenge nutrients

• Improve soil drainage
  – Deep-rooted cover crop species can break through compacted soil layers and improve drainage
  – Organic matter improves soil aggregation
  – Bell beans, clovers, cereal grains, etc.

• Conserve soil moisture

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops

(Miles and Brown, 2003)
Choosing a cover crop

• Step 2: Identify the cover crop planting niche
  – Where does the cover crop fit in the crop rotation?
    • Warm-season or cool-season
    • Other climatic variables
      – Precipitation
      – Temperature (summer highs, winter lows)
      – Day-length
    • Compatibility with previous and subsequent cash crops
  – Define timing of critical cash crop operations, so that cover crop management does not conflict

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops

(Miles and Brown, 2003)
Choosing a cover crop

• Step 3: Select cover crop that meets goals and requirements of steps 1 & 2
  – Consider benefits and drawbacks (perfect fit unlikely)
  – Consider cost and availability of seed (especially with organic and untreated seed)
  – Consider management costs (field operations needed to plant, kill, etc.)
Cover crop costs

• Direct costs
  – Seed
  – Establishment (e.g. tillage, drilling, irrigation)
  – Termination (e.g. mowing, tillage, rolling/crimping, herbicide)
Cover crop costs

- Indirect costs
  - Interference with following cash crop
    - Soil temperature
    - N release
    - Residue
  - Management issues
    - Difficult termination
    - Weediness

(Snapp et al., 2005)
Cover crop costs

• Opportunity costs
  – Cost of forfeit income if a cash crop alternative was feasible
  – Can be the most important limitation
Nitrogen availability

• N acquired through fixation or plant uptake
• Availability to subsequent crop is variable
  – 10% to more than 50%
  – Transformation from unavailable N to available controlled by interaction of factors:
    • Environment
      – Increases with temperature and moisture
      – Increases with lighter, more aerated soils
    • Management
      – Incorporation > mowing > rolling
    • Tissue quality
      – C:N ratio, lignin, etc. (slower decomposition = slower N release)

Slide courtesy of David Butler,
UT Organic, Sustainable and Alternative Crops

(Seiter and Horwath, 2005)
Carbon to nitrogen ratio

- Important property affecting cover crop residue persistence, nutrient release, etc.
  - High C:N ratio
    - Greater persistence as surface mulch, slower nutrient release
    - In general: grasses > broadleaves > legumes
    - Increase with maturity
  - Low C:N ratio
    - Quicker nutrient release and breakdown, poor persistence
    - Unlikely to tie-up soil nutrients

Slide courtesy of David Butler, UT Organic, Sustainable and Alternative Crops

UT Extension
Cover crop classes

• Cool-season annuals
  – Legumes vs. non-legumes (grasses & broadleaves)
  – Winter-hardy vs. non-hardy

• Warm-season annuals
  – Legumes vs. non-legumes
    • Grasses
    • Broadleaves

• Perennials and biennials/ley/sod crops
Life Cycles

**Annuals**
- germinate, grow, bloom in 1 growing season
- usually easier to kill

**Biennials**
- take 2 years to complete life cycle
- vegetative 1st year, flower 2nd year

**Perennials**
- live more than one year
- more difficult to kill

Slide courtesy of Gary Bates, UT Forage Specialist
Life Cycles

Cool season plants

Slide courtesy of Gary Bates, UT Forage Specialist
Life Cycles

Warm season plants

Germinate, begin to grow

bloom

Slide courtesy of Gary Bates, UT Forage Specialist
Cool-season annual legumes

• Crimson clover (*Trifolium incarnatum*)
  – N contribution 70 to 150 lbs/acre
  – Planted in mid-fall in TN, rapid spring growth
  – Grows well mixed with small grains (e.g. rye, triticale, wheat)
  – Good pollen source for bees
  – Not winter-hardy in colder climates (zone ~ 6 +)

Slide courtesy of David Butler, UT

(Clark, 2007; photos: oregonclover.org)
Cool-season annual legumes

- Hairy vetch (*Vicia villosa*)
  - N contribution 100 to 150 lbs/acre
  - Planted in mid-fall in TN
  - Grows well mixed with small grains (e.g. rye, triticale, wheat)
  - Quickly smothers spring weeds
  - Hard-seeded, can become a weed problem
  - Very winter hardy (zone ~ 4 +)

Slide courtesy of David Butler, UT

(Clark, 2007; photo: USDA-ARS)
Cool-season annual legumes

• Winter Pea (*Pisum sativum ssp. arvense*)
  – N contribution 90 to 150 lbs/acre, as much as 300 lb/acre reported
  – Planted in mid-fall in TN
  – Low water use
  – Not as winter hardy as hairy vetch or crimson clover (zone ~ 7 +)

Slide courtesy of David Butler, UT

(Clark, 2007; photos: agronomy.ifas.ufl.edu, seedsofchange.com)
Cool-season annual legumes

- Lupin (Lupinus albus, L. angustifolus, etc.)
  - N contribution 100 to 150 lbs/acre
  - Aggressive taproots
  - Easy to kill mechanically
  - Not as winter hardy as hairy vetch or crimson clover (zone ~ 7 +; no farther north than the TN valley)

Slide courtesy of David Butler, UT

(Clark, 2007; photos: edamameseed.com; ucdavis.edu)
Cool-season annual legumes

- Fava or bell bean (*Vicia faba*)
  - Grows well in cool conditions
  - High biomass producer
  - Deep taproot
  - Over 100 lbs N/acre
  - Not as winter hardy as other cool-season legumes (~ zone 8+)
  - Can be managed as a winter-killed cover in TN

Slide courtesy of David Butler, UT
Other cool-season annual legumes

- Berseem clover (*Trifolium alexandrinum*)
- Balansa clover (*Trifolium michelianum*)
- Medics (*Medicago spp.*)
- Common vetch (*Vicia sativa*)
- Red clover* (*Trifolium pratense*)
- Sweet clover* (*Melilotus officinalis and M. alba*)

*biennials

Slide courtesy of David Butler, UT

(Clark, 2007; photos: USDA-ARS; tamu.edu, nps.gov, permaculture.org.au, dnr.wi.gov, www.uwyo.edu, potash-info.com)
Cool-season non-legumes

• Rye (*Secale cereale*)
  – Should not be confused with annual (*Lolium multiflorum*) or perennial ryegrass (*Lolium perenne*)
  – Very cold hardy
  – Good nutrient scavenger
  – High early season biomass
  – Allelopathic (DIBOA)

• Other cereal grains
  – Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), triticale (× *Triticosecale*)
  – Certain oat (*Avena sativa*) cultivars can be used when winter-kill is desired

• Good for building organic matter

Slide courtesy of David Butler, UT

(Clark, 2007; photos: ces.ncsu.edu, tamu.edu)
Cool-season non-legumes

- Brassicas
  - Mustards (*Brassica juncea*, *Sinapsis alba*, *B. carinata*, *B. nigra*)
  - Rapeseed & canola (*B. napus*, *B. rapa*, *B. campestris*)
  - Oilseed & tillage radish (*Raphanus sativus*)
  - Arugula (*Eruca sativa*)
  - Pest suppression
  - Potential biofumigants
  - Good nutrient scavenging ability
  - Winter hardiness varies
  - Attract beneficial insects at bloom

Slide courtesy of David Butler, UT

(Clar, 2007; photos: plantsolutionsltd.com, USDA-SARE)
Tillage Radish

- Breaks up compaction
- Controls winter annuals
- Captures N in the fall—releases in the spring
- 16” deep 40 days after planting
- Subsoils without bringing rocks to surface
- Shown to increase corn yield in OH

Information and photo courtesy of Steve Groff, Cedar Meadow Farm
Winter-kill when temperatures drop to the mid-teens on successive nights

Information and photo courtesy of Steve Groff, Cedar Meadow Farm
Cool-season non-legumes

- Annual ryegrass (*Lolium multiflorum*)
  - Good nutrient scavenging
  - Good biomass production with sufficient N and moisture
  - Residue does not persist as well as cereal grains
  - Not as cold hardy as cereal rye
  - Can become a weed

Slide courtesy of David Butler, UT

(Clark, 2007; photos: osu.edu; tennesseeturfgrassweeds.edu)
Cool-season non-legumes

- **Phacelia (Phacelia tanacetifolia)**
  - Native to CA, but developed as cover crop in Europe
  - Good catch crop, smother crop, and pollen source
  - Can be grown as summer or winter annual, though not hardy below ~ 20 F

Slide courtesy of David Butler, UT
Warm-season legumes

- Sunn hemp (*Crotalaria juncea*)
  - Rapid biomass and N production (120 lbs N/acre in 9 weeks)
  - Does best in very warm conditions
  - Limited by seed cost and availability in U.S.
  - Suppressive to root-knot and reniform nematodes

Slide courtesy of David Butler, UT
Warm-season legumes

- Bean-like
  - Cowpea (*Vigna unguiculata*)
  - Velvet bean (*Mucuna pruriens*)
  - Soybean (*Glycine max*)
  - Hyacinth bean (*Lablab purpureus*)
  - Jack bean (*Canavalia ensiformis*)
- High biomass and N production
- Work well mixed with warm-season grasses
- Pest suppression and allelopathy vary

Slide courtesy of David Butler, UT

(photos: J. Cotton Sci.; velvetbean-mucuna.com; cilr.uq.edu.au)
Warm-season non-legumes

- Sorghum-sudangrass hybrid
  *(Sorghum bicolor x S. bicolor var. sudanense)*
- Very high biomass production, great for building soil organic matter
- High allelopathy and very competitive with weeds
- Suppressive against some pathogens and nematodes

Slide courtesy of David Butler, UT

(Clark, 2007; photos: agroatlas.ru)
Warm-season non-legumes

- Millets
  - Pearl millet (*Pennisetum glaucum*), Japanese millet (*Enchinochloa frumentacea*), & German (foxtail) millet (*Setaria italica*)
  - High biomass
  - Very tolerant of drought, heat, low fertility

Slide courtesy of David Butler, UT

(photos: preferredseed.com, uga.edu, hffinc.com)
Warm-season non-legumes

• Buckwheat (*Fagopyrum esculentum*)
  – Rapid growth (maturity in 45 days)
  – Good smother crop
  – Attracts pollinators
  – Can seed easily and become weedy if not well-managed

Slide courtesy of David Butler, UT

(photos: cornell.edu)
Warm-season non-legumes

• Sesame (*Sesamum indicum*)
  – Likely to be suppressive against root-knot nematodes and some pathogens
  – Prefers very warm conditions
  – Extensive root system

Slide courtesy of David Butler, UT

(photo: ksu.edu)
Perennial/ley/sod crops

• Longer fallow periods
• Build soil organic matter
  – Root biomass
• Legumes contribute high N
• Used for grazing, haying, etc
• Options
  – Alfalfa, red clover, white clover
  – Orchardgrass, tall fescue, etc.

Slide courtesy of David Butler, UT

(photos: uga.edu; uvm.edu; nrcs.usda.gov)
Evaluating Fall Planted Cover Crops for Organic Systems in East Tennessee

Mary Rogers, Brandon Smith & Annette Wszelaki
Evaluating Fall Planted Cover Crops for Organic Systems in East Tennessee

- Timing is critical for proper cover establishment
- Cover crop choice is important
  - Grain versus legume
- Choosing a grain-legume biculture may maximize the benefits of both crop types
Objectives:

1. Determine if grain crop/legume biculture results in increased biomass and higher nitrogen than monoculture plantings;
2. Determine effect of planting data on crop growth, soil cover and percent carbon and nitrogen content.
Methods

- Study carried out in 2008 and 2009

- Grains:
  - soft red winter wheat
  - winter rye
  - winter barley
  - winter triticale
  - spring oats, untreated

- Legumes:
  - crimson clover
  - medium red clover
  - ladino clover
  - Austrian winter pea
  - hairy vetch

(Sources Albert Lea Seed House, Albert Lea, MN, Knox Seed and Greenhouse)

(Source Seven Springs Farm, Check, VA)
Methods

• Treatments included all crops in monoculture and all possible grain x legume combinations and a no-crop check plot (36 treatments)
• The planting rate was 120 lbs/acre for all the grains used in monoculture and 30 (C), 4 (L), 10 (r), 40 (V) and 120 (A) lbs/acre for the legumes
• The planting rate was 60 lbs/acre for all the grains used in biculture and 15, 2, 5, 20 and 60 lbs/acre for the legumes
• Field (160 ft x 305 ft) spaded with an Imants Spader (Imants, Reusel, The Netherlands) and cultipacked with a Brillon seed cultipacker (Brillion, WI)
• Plots were 64” wide by 20’ long and seeds were planted 1” deep with a 64”-wide Almaco light duty grain drill (Almaco, Nevada, IA)
Methods

• Prior to planting, legume seed was separated and inoculated
  – vetch: N-Dure (*Rhizobium leguminosarum* biovar *viceae*)
  – clover: N-Dure (*Sinorhizobium meliloti* and *Rhizobium leguminosarum* biovar *trifolii*)
  – Austrian winter pea: Guard-N (*Bradyrhizobium* sp. and *Rhizobium leguminosarum*)

(Source INTX Microbials, LLC, Kentland, IN)
Methods

• In mid-April of the following spring (2009 and 2010), population density was measured by diagonal transect, collecting 10 samples per plot to determine % percent cover
• A 1 ft² quadrant was tossed at random to collect biomass
• Biomass was dried, ground and analyzed for carbon and nitrogen content
• Analysis was done using a NC analyzer (Flash 2000, Thermo Scientific, Waltham, MA).
<table>
<thead>
<tr>
<th>Crop</th>
<th>September</th>
<th>October</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.85 ± 0.07</td>
<td>0.74 ± 0.05</td>
<td>--</td>
</tr>
<tr>
<td>BA</td>
<td>0.35 ± 0.07</td>
<td>0.31 ± 0.06</td>
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<tr>
<td>OA</td>
<td>0.68 ± 0.09</td>
<td>0.79 ± 0.05</td>
<td>0.90 ± 0.2</td>
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<tr>
<td>TA</td>
<td>0.32 ± 0.05</td>
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<tr>
<td>RA</td>
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<td>WA</td>
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<td>0.43 ± 0.06</td>
<td>0.64 ± 0.1</td>
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<tr>
<td>C</td>
<td>0.58 ± 0.05</td>
<td>0.59 ± 0.05</td>
<td>--</td>
</tr>
<tr>
<td>L</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>r</td>
<td>0.34 ± 0.09</td>
<td>0.48 ± 0.09</td>
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<tr>
<td>V</td>
<td>0.85 ± 0.05</td>
<td>0.86 ± 0.09</td>
<td>0.64 ± 0.1</td>
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<tr>
<td>B</td>
<td>0.28 ± 0.05</td>
<td>0.25 ± 0.04</td>
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<tr>
<td>O</td>
<td>0.28 ± 0.09</td>
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<tr>
<td>T</td>
<td>0.40 ± 0.05</td>
<td>0.32 ± 0.04</td>
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<tr>
<td>R</td>
<td>0.54 ± 0.05</td>
<td>0.32 ± 0.05</td>
<td>0.6 ± 0.2</td>
</tr>
<tr>
<td>W</td>
<td>0.21 ± 0.05</td>
<td>0.21 ± 0.04</td>
<td>0.6 ± 0.1</td>
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% N and C of grain and legume monocultures by planting date

<table>
<thead>
<tr>
<th>Month</th>
<th>Crop type</th>
<th>% nitrogen</th>
<th>% carbon</th>
<th>C:N</th>
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<tr>
<td>Sept</td>
<td>grain</td>
<td>0.29 ± 0.0 b</td>
<td>7.7 ± 0.7 ab</td>
<td>26.6</td>
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<tr>
<td>Sept</td>
<td>legume</td>
<td>0.73 ± 0.2 a</td>
<td>7.1 ± 0.8 ab</td>
<td>9.7</td>
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<tr>
<td>Oct</td>
<td>grain</td>
<td>0.27 ± 0.0 b</td>
<td>7.8 ± 0.5 a</td>
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<td>Oct</td>
<td>legume</td>
<td>0.66 ± 0.0 a</td>
<td>7.8 ± 0.1 a</td>
<td>11.8</td>
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<td>Nov</td>
<td>grain</td>
<td>0.58 ± 0.1 ab</td>
<td>8.5 ± 0.1 a</td>
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<td>legume</td>
<td>0.64 ± 0.4 a</td>
<td>5.3 ± 2.8 b</td>
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month (p; df) p = .6009; 2, 9 p = .7275; 2, 9

crop type p = .0015; 1, 9 p = .0120; 1, 9

month*crop type p = .0260; 2, 9 p = .4353; 2, 9
% soil cover by planting date

<table>
<thead>
<tr>
<th>Crop</th>
<th>September</th>
<th>October</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>90.0 ± 0.0</td>
<td>100.0 ± 0.0</td>
<td>40.0 ± 5.8</td>
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<tr>
<td>TA</td>
<td>100.0 ± 0.0</td>
<td>100.0 ± 0.0</td>
<td>73.3 ± 14.5</td>
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<tr>
<td>C</td>
<td>100.0 ± 0.0</td>
<td>86.7 ± 6.7</td>
<td>0.0 ± 0.0</td>
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<td>OC</td>
<td>100.0 ± 0.0</td>
<td>90.0 ± 0.0</td>
<td>0.0 ± 0.0</td>
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<tr>
<td>TC</td>
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<td>95.0 ± 5.0</td>
<td>53.3 ± 8.8</td>
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<td>70.0 ± 17.3</td>
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<td>WC</td>
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<td>80.0 ± 0.0</td>
<td>83.3 ± 8.8</td>
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<td>WL</td>
<td>100.0 ± 0.0</td>
<td>70.0 ± 20.0</td>
<td>70.0 ± 11.5</td>
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<tr>
<td>V</td>
<td>100.0 ± 0.0</td>
<td>95.0 ± 5.0</td>
<td>33.3 ± 12.0</td>
</tr>
<tr>
<td>RV</td>
<td>93.3 ± 6.7</td>
<td>95.0 ± 5.0</td>
<td>100.0 ± 0.0</td>
</tr>
<tr>
<td>WV</td>
<td>93.3 ± 6.7</td>
<td>100.0 ± 0.0</td>
<td>80.0 ± 0.0</td>
</tr>
</tbody>
</table>
## % soil cover by planting date

<table>
<thead>
<tr>
<th>Crop</th>
<th>September</th>
<th>October</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>$86.7 \pm 8.8$</td>
<td>$90.0 \pm 10.0$</td>
<td>$46.7 \pm 26.0$</td>
</tr>
<tr>
<td>T</td>
<td>$93.3 \pm 6.7$</td>
<td>$95.0 \pm 5.0$</td>
<td>$96.7 \pm 3.3$</td>
</tr>
<tr>
<td>R</td>
<td>$90.0 \pm 10.0$</td>
<td>$90.0 \pm 10.0$</td>
<td>$93.3 \pm 6.7$</td>
</tr>
<tr>
<td>W</td>
<td>$76.7 \pm 3.3$</td>
<td>$90.0 \pm 5.8$</td>
<td>$76.7 \pm 8.9$</td>
</tr>
<tr>
<td>A</td>
<td>$76.7 \pm 6.7$</td>
<td>$75.0 \pm 5.0$</td>
<td>$13.3 \pm 3.3$</td>
</tr>
<tr>
<td>L</td>
<td>$0.0 \pm 0.0$</td>
<td>$0.0 \pm 0.0$</td>
<td>$0.0 \pm 0.0$</td>
</tr>
<tr>
<td>OL</td>
<td>$3.3 \pm 3.3$</td>
<td>$0.0 \pm 0.0$</td>
<td>$0.0 \pm 0.0$</td>
</tr>
<tr>
<td>r</td>
<td>$50.0 \pm 17.3$</td>
<td>$10.0 \pm 10.0$</td>
<td>$0.0 \pm 0.0$</td>
</tr>
<tr>
<td>Or</td>
<td>$33.3 \pm 6.7$</td>
<td>$15.0 \pm 5.0$</td>
<td>$0.0 \pm 0.0$</td>
</tr>
<tr>
<td>O</td>
<td>$0.0 \pm 0.0$</td>
<td>$0.0 \pm 0.0$</td>
<td>$0.0 \pm 0.0$</td>
</tr>
</tbody>
</table>
## % soil cover by grain crops

<table>
<thead>
<tr>
<th>Month</th>
<th>Crop type</th>
<th>% soil cover 2009</th>
<th>% soil cover 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td></td>
<td>63.0 ± 2.0 a</td>
<td>28.2 ± 2.8 b</td>
</tr>
<tr>
<td>Oct</td>
<td></td>
<td>63.7 ± 2.4 a</td>
<td>47.9 ± 2.8 a</td>
</tr>
<tr>
<td>Nov</td>
<td></td>
<td>50.0 ± 2.0 b</td>
<td>43.2 ± 2.9 a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>64.0 ± 2.7 b</td>
<td>22.1 ± 3.6 b</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>0.0 ± 2.7 c</td>
<td>26.9 ± 3.7 b</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>79.0 ± 2.7 a</td>
<td>53.9 ± 3.6 a</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>76.0 ± 2.7 ab</td>
<td>51.6 ± 3.6 a</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>75.6 ± 2.7 ab</td>
<td>44.3 ± 3.6 a</td>
</tr>
</tbody>
</table>

### Statistical Analysis

- **Month (p; df):**
  - p = .0008; 2, 23
- **Culture (p; df):**
  - p < .0001; 4, 23
- **Month*culture (p; df):**
  - p = .0197; 8, 23
- **Month (p; df):**
  - p = .0001; 2, 28
- **Culture (p; df):**
  - p < .0001; 4, 28
- **Month*culture (p; df):**
  - p = .0267; 8, 28
## % soil cover by legume crops

<table>
<thead>
<tr>
<th>Month</th>
<th>Crop type</th>
<th>% soil cover 2009</th>
<th>% soil cover 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td></td>
<td>28.3 ± 2.4 a</td>
<td>65.1 ± 4.3 a</td>
</tr>
<tr>
<td>Oct</td>
<td></td>
<td>25.9 ± 3.0 a</td>
<td>50.9 ± 4.3 b</td>
</tr>
<tr>
<td>Nov</td>
<td></td>
<td>6.4 ± 2.4 b</td>
<td>26.2 ± 4.4 c</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>23.3 ± 3.4 b</td>
<td>61.7 ± 4.8 a</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>34.2 ± 3.2 b</td>
<td>65.4 ± 4.9 a</td>
</tr>
<tr>
<td>L</td>
<td></td>
<td>0.2 ± 3.7 d</td>
<td>19.8 ± 4.8 b</td>
</tr>
<tr>
<td>R</td>
<td></td>
<td>6.5 ± 3.1 c</td>
<td>25.5 ± 4.9 b</td>
</tr>
<tr>
<td>V</td>
<td></td>
<td>36.6 ± 3.4 a</td>
<td>64.6 ± 4.8 a</td>
</tr>
</tbody>
</table>

- month (p; df): p < .0001; 2, 23
- culture (p; df): p < .0001; 4, 23
- month*culture: p = .0013; 8, 23

Extension
% soil cover by mono- and bicultures

<table>
<thead>
<tr>
<th>Month</th>
<th>Crop type</th>
<th>% soil cover 2009</th>
<th>% soil cover 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td>monoculture</td>
<td>$68.3 \pm 7.0$ bc</td>
<td>$59.0 \pm 5.3$ bc</td>
</tr>
<tr>
<td>Sept</td>
<td>biculture</td>
<td>$86.9 \pm 2.7$ a</td>
<td>$86.9 \pm 2.1$ a</td>
</tr>
<tr>
<td>Oct</td>
<td>monoculture</td>
<td>$65.5 \pm 8.5$ cd</td>
<td>$81.3 \pm 3.4$ ab</td>
</tr>
<tr>
<td>Oct</td>
<td>biculture</td>
<td>$84.4 \pm 3.7$ ab</td>
<td>$86.0 \pm 2.8$ a</td>
</tr>
<tr>
<td>Nov</td>
<td>monoculture</td>
<td>$36.0 \pm 7.5$ e</td>
<td>$52.0 \pm 7.7$ c</td>
</tr>
<tr>
<td>Nov</td>
<td>biculture</td>
<td>$52.7 \pm 3.8$ de</td>
<td>$68.3 \pm 3.8$ bc</td>
</tr>
</tbody>
</table>

- month (p; df) 
  - p = .0004; 2, 8
- culture (p; df) 
  - p = .0072; 1, 8
- month*culture
  - p = .3919; 2, 8
  - p = .0076; 2, 10
  - p = .0023; 1, 10
  - p = .2610; 2, 10

Extension
# Plant height of grains

<table>
<thead>
<tr>
<th>Month</th>
<th>Culture type</th>
<th>Plant height (cm) 2009</th>
<th>Plant height (cm) 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td>monoculture</td>
<td>71.5 ± 8.4 a</td>
<td>60.8 ± 5.0 c</td>
</tr>
<tr>
<td>Sept</td>
<td>biculture</td>
<td>70.7 ± 3.7 a</td>
<td>66.8 ± 4.0 bc</td>
</tr>
<tr>
<td>Oct</td>
<td>monoculture</td>
<td>67.9 ± 10.3 a</td>
<td>74.9 ± 5.0 abc</td>
</tr>
<tr>
<td>Oct</td>
<td>biculture</td>
<td>68.7 ± 4.6 a</td>
<td>82.3 ± 4.0 a</td>
</tr>
<tr>
<td>Nov</td>
<td>monoculture</td>
<td>41.2 ± 8.4 b</td>
<td>77.6 ± 4.9 ab</td>
</tr>
<tr>
<td>Nov</td>
<td>biculture</td>
<td>36.9 ± 3.7 b</td>
<td>80.7 ± 4.0 ab</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>month (p; df)</th>
<th>culture (p; df)</th>
<th>month*culture (p; df)</th>
</tr>
</thead>
<tbody>
<tr>
<td>p = .0007; 2, 8</td>
<td>p = .7837; 1, 8</td>
<td>p = .8945; 2, 8</td>
</tr>
<tr>
<td>p = .0123; 2, 8</td>
<td>p = .0944; 1, 8</td>
<td>p = .4247; 2, 8</td>
</tr>
</tbody>
</table>
## Plant height of legumes

<table>
<thead>
<tr>
<th>Month</th>
<th>Culture type</th>
<th>Plant height (cm) 2009</th>
<th>Plant height (cm) 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td>monoculture</td>
<td>32.5 ± 5.8 a</td>
<td>45.3 ± 4.0 b</td>
</tr>
<tr>
<td>Sept</td>
<td>biculture</td>
<td>42.8 ± 2.8 a</td>
<td>52.4 ± 4.0 ab</td>
</tr>
<tr>
<td>Oct</td>
<td>monoculture</td>
<td>29.5 ± 7.4 ab</td>
<td>45.7 ± 4.0 b</td>
</tr>
<tr>
<td>Oct</td>
<td>biculture</td>
<td>39.8 ± 3.4 a</td>
<td>55.2 ± 2.5 a</td>
</tr>
<tr>
<td>Nov</td>
<td>monoculture</td>
<td>8.8 ± 6.0 c</td>
<td>45.3 ± 2.6 b</td>
</tr>
<tr>
<td>Nov</td>
<td>biculture</td>
<td>14.1 ± 2.8 bc</td>
<td>47.6 ± 2.5 b</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interaction</th>
<th>p; df</th>
</tr>
</thead>
<tbody>
<tr>
<td>month (p; df)</td>
<td>p = .0009; 2, 8</td>
</tr>
<tr>
<td>culture (p; df)</td>
<td>p = .1263; 1, 8</td>
</tr>
<tr>
<td>month*culture</td>
<td>p = .9887; 2, 8</td>
</tr>
<tr>
<td></td>
<td>p = .1262; 2, 8</td>
</tr>
<tr>
<td></td>
<td>p = .0158; 1, 8</td>
</tr>
<tr>
<td></td>
<td>p = .4280; 2, 8</td>
</tr>
</tbody>
</table>
Things to Consider:

• Crop to be planted
• Maturity differences between cover species
• Ease of killing
  – mowing versus rolling
• End goal (nitrogen, weed control, disease suppression)

Slide courtesy of Gary Bates, UT Forage Specialist
Thank you! Questions?

Annette Wszelaki

annettew@utk.edu

(865) 974-8332

http://vegetables.tennessee.edu

http://organics.tennessee.edu

TN Horticultural Expo: January 26-28

Organic Crops Field Tour: April 26