High Residue Farming under Irrigation

Workshop Digest

This publication summarizes speaker presentations from the 2008 High Residue Farming under Irrigation workshop. For more information contact the WSU Extension office in Ephrata (509-754-2011 ext. 413, amcguire@wsu.edu).

Specific pesticides or uses of pesticides mentioned in this publication may not be labeled for use in Washington State. Always use registered pesticides according to their label.

Workshop Agenda

The Basics of High Residue Farming under Irrigation, Andy McGuire, WSU Extension

- Why Consider High Residue Farming in the Columbia Basin?
- Planters, Drills, and Attachments for High Residue Farming
- Strip-tillage for the Columbia Basin
- Soil Fertility Considerations in High Residue Farming

Managing the Soil as a Habitat, Jill Clapperton
Managing the Soil for Biological Fertility, Jill Clapperton
HRF for Dry Beans, Tom Grebb, Central Bean, Quincy
2008 Season; No-till Corn, Strip-till Profiles, Soil temperatures and Options, Andy McGuire
HRF for Alfalfa and Timothy, Rick Nielson, Mesa
I. Why Consider High Residue Farming in the Columbia Basin?

1) What is high residue farming?

   a) The name *high residue farming* draws attention to the fact that many of the benefits of these systems are a result of keeping the soil covered with a layer of residue.

   b) Everything talked about today is under sprinkler irrigation

2) Reasons why you should be interested

   a) It saves you money

      i) Dramatically reduces the number of passes over the field

         (1) Saves time, fuel, labor and equipment

         (2) $2.50 per gallon diesel was used for this chart (2006 costs). Implement and tractor charges include depreciation, interest, insurance, housing, and repair charges:

            | Fuel use | Fuel & Labor | Implement overhead | Tractor overhead | Total |
            | Gal/ac   | $ per acre   |                  |                 |       |
            | Deep ripping | 1.7   | 6.00       | 1.60       | 5.90       | 13.50 |
            | Chisel plow    | 1.1   | 4.85       | 2.20       | 4.20       | 11.25 |
            | Disk            | 0.6   | 2.10       | 3.50       | 2.60       | 8.20  |
            | Field cultivate | 0.7   | 2.59       | 1.80       | 2.40       | 6.79  |
            | Strip-till      | 0.6   | 3.01       | 3.96       | 2.52       | 9.49  |
            | No-till planting (compared to clean-till planting) | +2.13 |

   (3) The amount saved will depend on your system
(4) The results above would suggest that the typical-till and deep-till systems must either have higher yields, lower pesticide costs, or a combination of higher yields and lower costs in order to have the same profitability as the strip-till and no-till systems.

ii) Fuel savings
   (1) Recently surpassed the past record diesel price, set in 1980
   (2) Now we are back below $2 per gallon. Prices are very volatile, but what will be the long-term trend?
   (3) The era of cheap petroleum is over and we may be close to peak global oil production (not the amount of oil left in the ground, but how much we are producing) to be followed by plateau and then decline:

   “By 2011 ... global growth will marginally exceed supply side expansions.”

   “The time when we could count on cheap oil... is clearly ending.”
   -David O’Reilly, Chairman, Chevron, 2005

   “The era of cheap and abundant petroleum may now be over.”
   -Samuel Bodman, U.S. Secretary of Energy, 2006

iii) Labor
   (1) If it is your time being saved, you can use it to farm more acres, do other things on the farm, or enjoy other activities
   (2) If you are paying someone to do tillage work, it is direct savings

iv) Equipment
   (1) Less demand means less needed, and less wear and tear on that equipment that is needed
   (2) Allows better utilization of the equipment that is needed

v) When all of these small savings are added the result is significant total savings

b) It improves your soil
   i) Met a farmer from Idaho (irrigated land) while attending a No-till Seeding school in Kansas. He was there because he wanted to reverse the trend of declining soil quality on his farm with no-till farming.
   ii) Decreased wind erosion
       (1) Eliminates blown out crops, irrigating just for erosion control (and accompanying wet cool soils and possible leaching)
   iii) Water savings
       (1) Reduces evaporation (see 2006 workshop talk)
           (a) Reduces the E part of ET, EvapoTranspiration
(b) More saved under full irrigation than under dryland conditions

(2) Improved moisture catch and infiltration

| Growing season evaporation (inches of water) including irrigation and rainfall days (Klocke, 2004) |
|---|---|---|---|
| Soil under corn canopy | Water saving from cover |
| | Year | Bare | Straw | |
| Dryland | 1 | 5.2 | 5.2 | 0 |
| | 2 | 6.1 | 5.7 | 0.4 |
| Limited irrigation | 1 | 7.6 | 5.2 | 2.4 |
| | 2 | 8.5 | 5.7 | 2.8 |
| Full irrigation | 1 | 7.6 | 3.8 | 3.8 |
| | 2 | 8.5 | 4.7 | 3.8 |

<p>| Water intake, inches/hour |</p>
<table>
<thead>
<tr>
<th>Wheel traffic rows</th>
<th>Soft rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare soil farming</td>
<td>0.2</td>
</tr>
<tr>
<td>High residue farming w/no-till</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Klein, 2005

<table>
<thead>
<tr>
<th>Water savings, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elimination of tillage</td>
</tr>
<tr>
<td>Reduced evaporation</td>
</tr>
<tr>
<td>Increased storage</td>
</tr>
<tr>
<td>Total:</td>
</tr>
</tbody>
</table>

| Water and power | Value of saved water |
|---|---|---|
| Water | $ per ac | $ per in | $ per ac |
| Deep well water | 80–150 | 3.60–6.25 | 11.90–40.60 |
| Canal water | 70–80 | 2.80–3.60 | 9.20–23.40 |

Costs in above calculations are for the fall of 2006
iv) Increased organic matter

Changes Resulting from the Addition of Organic Matter to the Soil
(Modified from Oshins, 1999)

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c) It works (produces competitive yields).

i) But what about the increased risk?

1) Yes, there is increased risk when you start any high residue farming system
   a) Learning curve
   b) Transition to well structured soil

2) It is similar to the risk that people take when they learn to drive and why insurance companies charge more for 16 yr-old drivers than they do for 30 yr-old drivers. The risk will decrease over time, and attending events like this one (like drivers education) will minimize the risk.
ii) Here are some examples:

(1) Direct seeding
   (a) beans into alfalfa or timothy
   (b) dry corn
   (c) peas

(2) Strip-till
   (a) corn into mint, alfalfa, peas, beans, timothy, bluegrass
   (b) Yields for 2007 National Corn Growers contest, 7.2 tons in the Basin this year, with a strip-till system

(3) Vertical tillage. Example: Great Plains Turbo-Tiller, used for corn and alfalfa into timothy fields

3) Why consider high residue farming?
   a) It saves you money
   b) It improves your soil
   c) It works

4) Farmers have to adapt to changing times

*You can do it on your own terms or wait until you are forced to change*
II. Planters, Drills, and Attachments for High Residue Farming

Andy McGuire, WSU Extension, Grant-Adams Area

1) Drills vs. Planters for direct seeding
   a) Any modern planter can be modified to direct seed
   b) Drills designed for tilled soils cannot be modified for no-till; a no-till drill must be purchased. The lack of no-till drills is a challenge in the Columbia Basin

1. Four steps to successful no-till planting (from Paul Jasa at previous workshop)
   a. Cut the residue
   b. Penetrate the soil to the proper seeding depth
   c. Ensure good seed-to-soil contact
   d. Close the seed slot

2. Think of these as separate operations. In tilled soils, the last two are often combined.

1) Step 1: Cut the residue
   a) Residue management must happen first, but it will not be covered here
      i) Uniform distribution
      ii) Increase decomposition
         (1) Humid Midwest conditions are more favorable to decomposition than our drier conditions
   b) Cutting angle between the cutting tool (disk or coulter) is best between 30-45°. (Think of a pair of scissors)

2) i) For a certain size of disk (or coulter), too shallow an adjustment will hairpin residues, too deep will drag residue piles.
ii) The deeper you go, the larger a disk you can use. Shallower planting depths require smaller disks:

<table>
<thead>
<tr>
<th>Disk or Coulter Depth (in.)</th>
<th>12</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>18</th>
<th>20</th>
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<tr>
<td>0.25</td>
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<td>22.3</td>
<td>21.3</td>
<td>20.4</td>
</tr>
<tr>
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<td>31.0</td>
<td>29.9</td>
<td>29.0</td>
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<td>24.6</td>
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<td>44.4</td>
<td>42.8</td>
<td>41.4</td>
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<td>60.0</td>
<td>55.2</td>
<td>53.1</td>
<td>51.3</td>
<td>48.2</td>
<td>45.6</td>
<td>43.3</td>
<td>41.4</td>
</tr>
<tr>
<td>4.00</td>
<td>70.5</td>
<td>64.6</td>
<td>62.2</td>
<td>60.0</td>
<td>56.3</td>
<td>53.1</td>
<td>50.5</td>
<td>48.2</td>
</tr>
</tbody>
</table>

3) You want to be in the green zone.
   (1) For shallow planted crops, you may want a coulter in front to go deeper than planting depth while cutting the residue. This should be offset from the row because it will disturb the soil in front of the opener.

ii) Disk drills for minimum disturbance
   (1) Single disk drills, good at cutting residue
   (2) Coulter caddy system in front of double disk openers. The coulters cut the residue in front of the openers.
   (3) Disk drills require greater down pressure than drills with hoe-openers, especially a double disk drill with coulters

iii) Coulters
   (1) A gang of coulters in front of the disk openers doubles the required down pressure. You can manage this by either:
       (a) Adding weights to the drill or
       (b) Or taking off coulters and cutting residue with disk openers
   (2) Smooth coulters generally cut residue better than wavy coulters

iv) Row cleaners
   (1) Do you need them?
       (a) Perhaps not in a long-term no-till system where residue is managed well
   (2) Where can they help?
       (a) Where residue is not uniform, to move the piles
       (b) Should not be running continually – they should only move about half the time, for the deeper residue. They should not be moving soil.
   (3) Many types available
(a) Floating, spiked, single, double, for planters and now drills

(4) Placement in relation to coulters

(a) Before

   (i) Useful in heavy residue conditions so that the coulter does not have to cut everything

(b) After

   (i) In lighter residue conditions, usually before double disk openers

v) Problems with cutting the residue

   (1) Worn coulters, replace when worn 1-2” (see chart above)

   (2) Non-uniform residue distribution. Hard to set the planter for variable conditions.

   (3) Long stalks all on ground after grazing
(4) Hairpinning

(a) Soft sandy soils do not provide a firm surface to cut against
   (i) Size residue so it does not need cutting or use hoe openers

(b) Planting into tough residues (wheat) in the fall is a challenge for any equipment setup

(c) Piles of deep residue can be a challenge. If they are not distributed better, the seed can be placed in residue rather than soil – it may germinate but will not thrive and may not survive hot weather.

4) Step 2: Penetrate the soil to the proper seeding depth

a) Openers
   i) Disk openers
      (1) Lower disturbance than hoe openers
      (2) Require more down pressure
      (3) Replace when worn
   ii) Hoe or shank openers
      (1) Higher disturbance
      (2) Higher HP requirement
      (3) Lower down pressure requirement

b) Depth-gauge wheels
   i) Hold the openers at the proper depth
      (1) Reduced inner diameter gage wheels. These can cause problems in heavier, wetter soils

c) Row down pressure
   i) Firmer, untilled soils require higher down-pressures, 300-500 lb per row
   ii) If opener is not getting deep enough, there may not be enough down pressure, or weight on the drill/planter
      (1) Weight of planter should be greater than sum of the row down pressures
   iii) Drills require more weight because of the greater number of rows/openers
   iv) Each coulter or opener for banding fertilizer that is used requires more down pressure
5) Step 3: Ensure good seed-to-soil contact
   a) Seed should be pressed into moist soil at the bottom of the seed furrow. This promotes uniform emergence
   b) What does not work in firm, untilled soils:
      i) Small disks following the opener, with wide closing wheel
      ii) Solid rubber and iron wheels can work, but not in wetter soils
   c) This is often obtained by using seed firmers for planters
      i) Two brands: Keeton or Rebounder
         (1) Added down pressure can be put on the Keetons with add-on devices (Mojo wire)
      ii) Presses seed into bottom of seed furrow
      iii) Can break off if taken across deep circle tracks
      iv) Can be used to apply pop-up fertilizer with seed
   d) Seed firmers for drills
      i) Firming wheels
         (1) Small wheels mud up in wetter soils
         (2) Replacement of wider wheels with narrower wheels has some benefits in dryer soils
6) Step 4: Close the seed slot
   a) Standard rubber closing wheels work OK in softer soils, but can compact wet or firm soils
   b) Spiked closing wheels do better in wet and firm soils
      i) Break up the soil and cover the seed with loose dryer soil
ii) Many types available. Some combinations of solid and toothed wheels used

iii) Do not have to be set aggressive, unlike solid wheels. These do not give seed-to-soil contact and therefore require little or no down pressure.

c) Planter should be level or slightly tail down for these to work
d) Problems
   i) Smearing of the sidewall by openers is not alleviated by smooth closing wheels
   ii) Solid closing wheels can have problems closing the seed slot in wet soils
   iii) Plants emerge through the slot cut by the toothed closing wheels rather than that cut by opener

7) Ideal planting results
   a) Seeds are pressed into moist furrow bottom
      i) Seed draws moisture from soil and air for germination
   b) At desired, consistent depth
   c) Furrow sidewall is shattered to cover seeds uniformly with loose soil
      i) Loose soil slows the loss of water, water pores are broken
      ii) Increased air permeability
      iii) Higher temperatures

8) Four Steps to Successful Planting
   a) Cut the residue
   b) Penetrate the soil to the proper seeding depth
   c) Ensure good seed-to-soil contact
   d) Close the seed slot
III. Strip-tillage for the Columbia Basin

Andy McGuire, WSU Extension

1) Strip-till was developed in the upper Midwest (Northern Corn Belt) where the goals were:
   a) Higher soil temperatures in the spring
   b) Better drainage on heavier, poorly drained soils
   c) Fall fertilizer application

2) Main points
   a) Strip-tillage is pre-plant, limited-width, in-row tillage
   b) Strip-tillage benefits farmers
   c) Strip-tillage has challenges

3) Point #1: Strip-tillage is pre-plant, limited-width, in-row tillage
   a) Pre-plant, either spring or fall. Midwest strip-till is mainly done in the fall
   b) Limited width; clean tillage in a strip 6-12” wide, centered on the crop row. Planting takes place in this tilled seedbed.
   c) Residue is undisturbed between the strips
   d) Basic strip-till machine lineup:
i) Coulters
   (1) Large, 18-24"
   (2) Are generally smooth edged
   (3) Sometimes have depth control bands/wheels along side
   (4) Some are spring loaded

ii) Row cleaners, usually toothed
(1) Placement either in front of coulters or more commonly behind them

iii) Knife or shank
   (1) Many shapes and sizes
   (2) Various tips
   (3) Adjustable to various depths
   (4) Auto-reset or shear bolts for rocky soils

iv) Covering disks/berm builders. These can be adjusted for various strip widths, heights, and field conditions

v) Rolling baskets or other type of “soil conditioners”
   (1) Used to prepare seedbed for planting
   (2) Often left off in fall strip-till

vi) Companies making strip-tillage machines (there may be others)
   (1) Bigham Brothers, http://www.bighambrothers.com/
   (2) Blu-Jet (Progressive Ag Systems), http://blu-jet.com/
   (3) Brillion Farm Equipment, http://www.brillionfarmeq.com/
e) Strip-till options

i) Timing, fall or spring

(1) Fall, to allow soil heating, drainage and fertilizer applications in heavy, poorly drained soils in Northern Corn Belt. Do these same conditions apply to the Columbia Basin?

(2) Spring

(a) One-pass or two-pass

(i) One pass, with planter attached behind strip-tiller

1. Requires significant horsepower depending on the strip tillage depth and number of rows
2. Does not allow warming of soils before planting
3. If residue is loose and not attached to the soil, the wind can blow it over seed rows

(ii) Two pass

1. Allows strip-tilling and planting to be done by separate operators
2. GPS guidance makes it easier, but is not required
3. Depending on the timing, may allow some soil warming

ii) Depth and width of tillage – depends on your goals

(1) Why are you tilling? If it is to treat compaction, the depth of tillage must be below the depth of the compacted layer. If it is just to loosen soil in the seedbed, the depth can be shallow.
(2) The wider the strip, the less water is saved by residue cover. Make strips only wide enough to achieve your goals. Wider strips also make it more difficult for later operations to stay between the rows as wheels tend to drift into soft strips.

iii) Height of tilled mound

   (1) Fall vs. spring

   (a) Fall strip-till aims for a tall mound, 3-4” high, which will then settle by planting time

   (b) Spring strip-till wants a firm seedbed, with less of a mound

iv) Residue management

   (1) Depends on the previous crop – corn residues will take more work than dry beans or peas

v) Fertilizer application

   (1) N, P, K, and depth are adjusted for the crop; wings can place nutrients to side and below the seed row, either liquid, dry, or both.

   (2) Spring more effective for P and K applications.

vi) Other

   (1) Down pressure – requirements will depend on the soil and residue conditions

   (2) Frame strength – continuous corn creates conditions that require a heavier frame as do rocky soils and wider units.

   f) The advantage of strip-till over direct seeding is most apparent in cold, wet springs, not in dry, warm springs. It can also help if compaction or poor residue distribution are problems.

4) Point #2: Strip-tillage offers many benefits for Columbia Basin farmers

   a) Like no-till/direct seeding, the residues left on the soil surface after strip-tilling can help control wind erosion and improve soil quality

   b) Strip tillage helps farmers deal with conditions out of their control

      i) Strip-till can help alleviate compaction due to harvest equipment (especially with processing vegetables) or grazing
(1) There is a question whether soil penetration resistance measurements give a true indication of the resistance to root growth in untilled soil with structure as the roots will follow pores that the penetrometer cannot follow. Untilled, structured soils will be firmer than tilled soils, even if there is no restriction of root growth.

ii) Strip-till can handle non-uniform distribution or high amounts of residues, either because you did not have control of the land during the previous crop or because you do not have the equipment needed to spread the residue adequately.

iii) Short-term leases, where you do not have control of the land before the spring of planting

c) Strip-till reduces costs for labor, fuel, possibly water requirements

i) See tables in other McGuire presentation. Compare the amount of time, labor and fuel between obtaining this: And this:
ii) Example: farmer in George area saved an estimated $20,000 on 8 circles in first year of strip-tilling

d) Strip-till allows more double cropping options
   i) Examples: Late sweet corn after green peas, dry beans after 1st cutting of timothy or alfalfa

e) Strip-till allows planting with little or no planter modification compared to direct seeding, if the strip till does a good job at removing residue from the seed row
   i) A stabilizing coulter can help the planter remain on the rows in a two-pass system

f) Strip-till can warm soils
   i) Midwest vs. Columbia Basin, how often will warmer soils make a difference in yield here in the Columbia Basin?
ii) Crop residues act as a buffer of temperature so that bare soils are warmer during the daytime, but cooler at night than residue-covered soils.

iii) This may be most important in heavy, poorly drained soils where Pythium and other diseases can damage slow-growing crops

g) Continuous corn

i) Strip-till is one way to deal with the large amounts of residue in continuous corn rotations

h) Fertilizer options

i) Strip-till allows application of N, P and K in bands near the seed

5) Point #3: Strip tillage has challenges too

a) GPS guidance, although not necessary, is very helpful with strip-tillage, especially with fall strip-till.

b) Requires the purchase of new equipment and the horsepower to pull it, especially in a one-pass system. $1000-3000+ per row for a strip-till machine.
i) Reduce costs by spreading them over more acres by either farming more ground with the time saved or by doing custom strip-tilling

c) Spring strip-till
   i) Soils have no time to warm up
   ii) Incorporated residues do not break down before planting
   iii) Wet soils limit alleviation of compaction – reduced fracturing of the soil
   iv) Consider direct seeding in warm, dry years

d) Fall strip-till
   i) Limited by time and equipment demands during harvest
   ii) Limits flexibility in choosing crops for next year
   iii) Drier soils may fracture soil better beneath strip

6) Conclusion
   a) Direct seeding is a good practice, but does not fit many of our constraints here in the Columbia Basin. Strip-till is a good compromise between direct seeding/no-till and clean-till.
IV. Overcoming Soil Conditions that Come With HRF with Soil Fertility Management
Andy McGuire, WSU Extension

1) In 1962, a Kentucky farmer named Harry Young Jr. planted the first modern no-till corn field
   a) He used a new herbicide called atrazine
   b) He put two barrels of water on his two-row planter to force it into the pasture soil
   c) In summary, he did what was necessary to overcome the challenges he faced with high residue farming

2) That is what needs to be done today too, especially with regard to the soil conditions that come with high residue farming. We need to take the necessary steps to overcome any of those conditions that may limit plant growth. Adjust the system to make it work.

3) This talk is not about general soil fertility, but about using soil fertility practices to overcome the soil conditions in high residue farming.
   a) Acknowledge HRF soil conditions
   b) Take action to address HRF soil conditions
   c) Be aware of the most common problems due to HRF soil conditions

4) Acknowledge HRF soil conditions
   a) Residue cover
      i) Cools soil
      ii) Affects nutrient availability and location
   b) Cooler soils affect (top 3” or so)
      i) Nutrient availability and uptake
      ii) Seedling growth rate
   c) Non-uniform distribution of nutrients
i) Due to stratification of nutrients in untilled soil and broadcast fertilizers that are not incorporated (vertical non-uniformity)
ii) Banding and strip-tilling of nutrients (horizontal non-uniformity)

5) Take action to address HRF soil conditions. Think of the soil as a bank for nutrients, where they can be safely kept for the long term, if you farm ground that you own.

a) Keep track of your account (sample the soil correctly)
   i) Non-uniform distribution of nutrients
      (1) Vertical: pH, P, K, maybe N
      (2) Horizontal (strip till and banding)
   ii) Increase number of cores, aiming to hit both low and high concentrations to get an average
   iii) Separate layers, 0-3” or 6”, 6-12”
   iv) Compare to plant nutrient levels (every 2-3 years):

<table>
<thead>
<tr>
<th>Soil Nutrients</th>
<th>Plant Nutrients</th>
<th>Problem/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>High</td>
<td>No problems</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Lack of nutrients, fertilize quickly</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>Something interfering with nutrient uptake. Look for causes.</td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
<td>Current needs are met but may need future applications</td>
</tr>
</tbody>
</table>

b) Build soil organic matter (build up your savings)
   i) Requires:
      (1) Deposits
         (a) Crop residues
         (b) Cover crops – decrease the transition time to better quality soils
         (c) Additional nutrients are required to build up organic matter (during the transition period) = putting money in the bank. If your organic matter levels are decreasing, you are mining the nutrients from the soil.
      (2) A transition period of 3-5 years is common before farmers see soil benefits of not tilling the soil. After the transition, these soils do not require more nutrients than tilled soils. They are firm and well drained.
      (3) Guarding your investment, reduce or eliminate losses
         (a) Reduce tillage and erosion
         (b) Avoid compaction
   ii) Nutrient content of your soil’s organic matter (OM)
      (1) A 1% increase will require (on average)
         (a) 940 lb of N
         (b) 400 lb of P
         (c) 80 lb of S
         (d) This increase of organic matter will result in increased availability of many macro and micronutrients- they are “in the bank”
         (e) Also, increased storage capacity for some nutrients

c) Plan on early withdrawal (provide early fertility)
   i) Why?
      (1) To overcome slower root growth of seedlings in cooler soils, especially corn which is a tropical crop that we plant in cool spring soils
(2) To overcome the reduced nutrient availability in cool soils

to overcome the reduced nutrient availability in cool soils

ii) How?

(1) Get P and K levels up in the previous season

(2) Starter fertilizers are necessary for N, P, S and micronutrients (See Rick Koenig presentation at 2007 workshop)

(a) Through strip-till machine

(b) Pop-up fertilizer in seed furrow

(c) Banded

(d) Liquid or dry

6) Be aware of the most common problems

a) Nitrogen

i) Early nitrogen deficiencies due to the high carbon load of the surface residue that can immobilize N. For corn, 70-80 lbs of available N per acre is needed for first 40 days, emergence to V6.

ii) Liquid UAN solutions can be used if enough water is applied to move the nitrogen past the residue cover

b) Phosphorus

i) Purple corn due to inability of corn plant to grow roots fast enough to intercept enough phosphorus. Put it where roots will get it quickly.

ii) Build P and K levels prior to starting high residue farming

c) Potassium, K

i) If the field has not been tilled for awhile and the K is mainly in the surface layer, a pop-up or banded application might help early growth

ii) Broadcast P and K works fine in high residue situations because crop roots can access surface nutrients in moist soil underneath the residue cover.

d) Zinc. Common early season problem with no-till corn because of reduced solubility and diffusion through the soil, even if sufficient levels are present in the soil

e) Sulfur deficiencies may occur because of reduced release of sulfur from organic matter in cool, wet soils
7) Summary
   a) Acknowledge HRF soil conditions
   b) Take action to address HRF soil conditions
   c) Be aware of the most common problems due to HRF soil conditions

8) One last thought… The cost of planting, controlling pests and harvesting are the same for a mediocre crop as they are for a great crop – the only difference may be adequate, balanced soil fertility. Given the options, it is also a good long-term investment

Managing the Soil as a Habitat

Jill Clapperton, Rhizosphere Ecologist, Earthspirit Land Resource Consulting, formerly with Agriculture and Agri-Food Canada Lethbridge Research Centre in Lethbridge, Alberta, Canada

1. Moved from Canada to her husband’s family ranch in Montana
   a. Mostly irrigated alfalfa
   b. 450 cows
   c. Sandy, gravelly soil

2. Where she worked in Lethbridge
   a. 8-12” rainfall zone
   b. Also worked with irrigated farmers

3. Soil biology 101
   a. The process of building soils is the same no matter where you go
   b. Soil is the only asset that every farmer has, it is the foundation of the farm
      i. If you are losing soil, for any reason, it is a disaster
      ii. You are losing more than just the mineral particles
   c. The top 6” of soil drives the soil biology
      i. “We stand in most places on Earth, only six inches from desolation, for that is the thickness of the topsoil layer upon which the entire life of the planet depends.” R. Neil Sampson
      1. Soil is the skin of the earth
      ii. Bacteria and fungi are primary producers and as such are food for everything else that cycles nutrients in the soil
      iii. A healthy soil is, “The capacity of the soil to function as a vital system to sustain the productivity of animals and plants, maintain or improve the water and air quality, and health of the plants and animals within the limits of an ecosystem.” Doran and Zeiss, 2000
         1. Biological cycles drive soil processes including soil fertility; when you manage soils, you are managing a living system
      iv. Soil quality = Soil health
v. Soil productivity
   1. Farmers think yield, but think past yield
vi. Are you producing something that is good for people
d. Soil provides many services
   i. Supplies nutrients
   ii. Decomposition
   iii. Buffers water and nutrients
   iv. Provides physical support to plants
   v. Nitrogen fixation
e. Model for managing soil

![Soil Quality Diagram]

i. The soil’s biology unites the physical and chemical properties together
ii. Livestock as a tool
   1. They are a real advantage
   2. Can learn from livestock producers in the way they concern themselves with the livestock’s nutrition – we should give the same care to people’s nutrition and to people food.
iii. Farmers produce food, not just commodities
   1. The ultimate output is quality food
iv. Biodiversity is the ultimate insurance. It provides
   1. Flexibility
      a. Resilience in drought, temperature extremes, floods
   2. Resistance to pests
f. How do we support diversity in the soil?
   i. Diversity aboveground promotes diversity belowground because the different crops provide different foods for soil organisms which promotes diversity
   ii. Crop rotation – the more different crops we grow, the more soil biological diversity we have
   iii. Cover cropping, especially polycultures (mixtures of plant species)
g. N immobilization shows an imbalance of C:N ration, want 20-30:1 ratio
   i. Plants take up nutrients better when the nutrients are mediated through a biological system
h. Transition to a no-till system
   i. Need to make sure that the C:N ratio is about 30
   ii. Growing legumes puts nitrogen in the bank
i. The organisms that drive the soil processes, especially those above bacteria and fungi in the food web, are sensitive to tillage
   i. Think of them as people who build their homes, roads, tunnels, settle in, and go to work. Tillage destroys all this and those that survive have to start all over.
ii. Like going through a town with a giant cultivator. If this was done often enough, nobody would live there except those who can tolerate the disturbance. The same happens in the soil.

4. Standing on the rooftop of another world, a community of organisms
   a. Just like we have plumbers, carpenters, electricians, the soil has organisms with different tasks
   b. Bacteria and fungi are the first in line for decomposition
      i. Bacteria and fungi first colonize the crop residues
         1. Fungi are especially important in breaking down tough, woody residues
            a. Fungi also build soil structure. The hyphae form a net within the soil, bind small soil particles into larger aggregates, or crumbs
         2. Bacteria and fungi are a top food source for everything else in the soil
         3. Many other organisms feed on the residues colonized by bacteria and fungi
         4. If conditions are right, nutrients are released
   c. Mycorrhizal fungi
      i. Colonize crop roots
      ii. Cannot live without a host plant
      iii. 85-90% of land plants are colonized by these fungi
      iv. They are really important for Zn, Cu, P, Ca supply to the plants they colonize
      v. Trade nutrients for photosynthesis (sugars) from the plant
      vi. They also leak glomalin, a sticky substance that helps build soil structure
      vii. Plants tolerate these fungi because it is a win-win situation for them
      viii. They create a mycorrhizosphere around the plant roots which can host plant growth promoting bacteria
         1. Legumes, corn, potatoes are all good hosts
   d. Mites, collembolan (springtails) and nematodes
      i. Regulate populations of bacteria and fungi, increasing nutrient turnover
      ii. Chew larger pieces of organic matter into smaller pieces stimulating microbial activity
      iii. Increase nutrient release from decomposition by eating and burying organic matter
      iv. Create biopores for better rooting, water infiltration and aeration
   e. Pathogenic nematodes provide entrance for fungal diseases
   f. Macrofauna (ants, termites, insect larvae, and earthworms)
      i. Benefits
         1. Mix organic matter and fecal matter into the deeper mineral soil
         2. Stimulate microbial activity
         3. Create deeper nutrient rich soil
         4. Affect N and C cycling
         5. Create larger biopores for better rooting, water infiltration and aeration
      ii. Earthworms
         1. Look for cocoons (egg cases look like popcorn seed), castings (excrement), and middens (mounds of castings from nightcrawlers)
         2. Increased numbers mean increased soil quality. They are one of the last to respond to reduced tillage. Ecosystem engineers.
         3. Erosion can be a problem where nightcrawlers remove residue leaving bare soil
4. Some can live as long as 10 years
5. Plant roots benefit by growing through earthworm burrows
   iii. Ground beetles
       1. Increase under no-till and with the use of cover crops, 3-5 years
       2. Predators of problem grubs/larvae in the soil
5. The activities of soil biota
   a. Drive nutrient cycling
   b. Stabilize the soil structure
      i. Create a more stable and continuous soil pore network
6. Managing the Rhizosphere (roots and zone right around plant roots)
   a. Rhizosphere interactions and processes
      i. Beneficial
         1. Symbiosis
         2. Growth promotion
         3. Soil stability
         4. Water uptake
         5. Nutrient availability
         6. Nutrient uptake
         7. Enzyme release
         8. Biocontrol
         9. Antibiosis
        10. Competition
        11. Allelopathy
      ii. Deleterious
         1. Growth inhibition
         2. Infections
         3. Phytotoxicity
   b. Roots leak substances into the soil to attract beneficial microorganisms
      i. Different plants leak different substances which leads to changes in the rhizosphere biology
   c. Mycorrhizae and fungi associated with plant roots, but are not pathogens
      i. They extend the plant’s root system
      ii. Increase disease tolerance and drought resistance
      iii. Crops with high dependency on VAM fungi
         1. Potatoes and other root crops
         2. Peas, beans and other legumes
         3. Flax
4. Sunflower
5. Corn and other warm season cereals

iv. Crops with low dependency
   1. Wheat and other cool season cereals

v. Non-hosts of VAM fungi
   1. Mustard and other Brassicas
   2. Lupins

vi. Mycorrhizal fungi form networks in the soil
   1. Disturbed or destroyed by tillage

vii. Highly sensitive to phosphate fertilizer, >20 lbs/ac
   1. Use 10 lbs/ac or less P in starter
   2. Apply P fertilizer on crops not mycorrhizal dependent, cool-season cereals or Brassicas

d. Benefits of growing Brassicas; mustard, turnip, canola
   i. Stimulate soil biology
   ii. Do not grow them before corn, or other crops dependent on mycorrhizae
   iii. Grow cool season cereal afterwards

e. Working with roots
   i. Growing roots is the quickest way to increase soil organic matter
   ii. Vary root types and structures of crops
   iii. When roots grow faster
      1. The plant is less prone to disease
      2. Roots are colonized by more growth promoting rhizobacteria
      3. Greater plant uptake of nutrients
      4. Yield is greater

7. Rebuilding the habitat
   a. Roots are the best source of organic matter
      i. Crops with the most roots are best
      ii. Mixtures of forage crops- create a root canopy
      iii. Cover crop cocktails (mixtures)
   b. Use probiotics- mixtures of inoculants
      i. Mycorrhizae
      ii. N- fixing bacteria (not just for legumes)
      iii. P- solubilizing fungi and bacteria

8. Questions?
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Managing the Soil for Biological Fertility
Jill Clapperton

1. Soil organic matter (OM)
   a. Content
      i. Carbon = 42%
      ii. Oxygen = 42%
      iii. Hydrogen = 8%
      iv. Ash = 8%
         1. Macronutrients (N, P, K, S, Ca, Mg)
         2. Micronutrients (Fe, Mn, B, Zn, Cu, Cl, Co, Mo, Ni)
   b. All humus is OM but not all OM is humus
   c. Raw OM = waste products or remains of organisms not yet decomposed
   d. Humus = decomposed
   e. OM is the primary food source for most soil organisms/animals
   f. Quantity and quality of OM is what drives nutrient cycling. C:N between 20 and 30:1 is ideal for optimized N cycling. This is the equivalent of growing a legume every third year.
   g. How much water can your soil hold? How much OM do you have?
      i. 45 kg (99 lbs) of dry soil:
         1. With 4 to 5% OM can hold 75 to 87 kg (165-191 lbs) of water
         2. With 1.5 to 2% OM it can only hold 16 to 20 kg (35-44 lbs) of water.
            (Walters and Fenzais 1979)
   h. Effects of Organic Matter/Humus
      i. decreases bulk density
      ii. increases pore space
      iii. provides crumb structure that resists compaction
      iv. increases oxygen diffusion rate
      v. improves soil structure

2. Making the transition to HRF system
   a. Initial phase 3-5 yr because of low OM/residue
   b. Soil Rehabilitation
      i. Increase biological activity
         1. “Build it and they will come,” give them the right conditions and they will grow
      ii. Build soil structure
      iii. More N fertilizer needed to overcome immobilization by increased biology and OM
      iv. Grow roots
      v. Incorporate cover crops or forage crops into rotation whenever possible
         1. Reduces transition period
         2. Incorporate livestock to profit from cover crops
         3. Use SARE book Managing Cover Crops Profitably, free online
   c. Be innovative!

3. Measuring soil biology
   a. Direct measures
      i. Microbes
         1. Biolog, FAME, PLFA, direct counts
2. Mycorrhizae
3. FAME, PLFA, direct counts
   ii. Microarthropods and nematodes: FAME (marginal), direct counts (order and family level)
   iii. Earthworms and ground beetles: counting middens, rating activity, pitfall traps
b. Indirect measures
   i. Indirect measurement is all based on activity
      1. % active organic matter
      2. mineralization
      3. respiration
   ii. Stay away from tests requiring plating of the soil to look at diversity.
c. The lab you use should be able to interpret the results
d. Know the method the lab is using and check that the lab is using a valid method
e. Is the lab interpreting the results based on their understanding of large scale cropping agriculture?
f. Use tissue testing and grain testing to measure how many nutrients you are using
   i. Forage analysis
4. “When you are standing on the ground you are really standing on the roof top of a whole other world”

**High Residue Farming for Dry Beans**
Tom Grebb, Central Bean, Quincy

1. Background
   a. In business 25 years
   b. Identity preserved seed
   c. Food Alliance certified
   d. Planting no-till beans for six years
   e. Estimates that 1/3 of the dry bean acreage in WA is direct-seeded
      i. None before 2003
2. Has direct-seeded dry beans after
   a. Cover crop wheat
   b. Timothy
   c. Alfalfa
   d. Green peas (strip-till)
3. Why consider HRF with irrigated dry beans? The benefits are:
   a. Substantially reduced wind and water erosion.
   b. Substantial tillage reduction can mean fewer weeds, and less fuel usage
   c. Improves organic matter levels.
   d. Less disturbance of rocks!
   e. Preservation of the beneficial fungi and bacteria
   f. Typically, as good or better production
4. Challenges of high residue farming with dry beans
   a. Planting
      i. Can be done into cover crops and alfalfa without much adjustment
      ii. Grass/Timothy requires slicing of the sod by no-till planter. This requires significant down pressure from planter and may require coulters.
   b. Irrigation
i. Make sure water penetrates to rooting depth
ii. Water soaks in much more uniformly in hilly conditions because of residues on soil
iii. Appears to be less white mold with HRF

c. Fertility
   i. The top foot is where it happens
   ii. Crops after timothy appear to need the most fertilizer
   iii. Must be available early, before rapid growth and blooming occurs
   iv. Banding at planting can help

d. Herbicides
   i. Make sure the chemical tools used on the previous crop meet plant back restrictions for beans.
   ii. You only have one shot at eliminating the previous crop of alfalfa - make sure application it is sufficient.
   iii. A larger window of opportunity is available for eliminating grasses.
   iv. Be prepared for post emergence weed control, timing is critical.

e. Dry bean varieties
   i. The more upright, the better for cutting. Pods are held above ground better.
   ii. Most new varieties are bred for upright architecture. Merlot for small red beans.
   iii. Many varieties are much shorter season than years ago.

5. Planting
   a. Twin-row Monosem planter with down pressure springs
      i. Twin rows 8” apart, on 30” centers (22” between bean rows)
   b. GPS helps because otherwise you cannot see the rows

6. Emergence
7. Beans into cover crop or wheat crop
   a. Easy to eliminate the wheat with glyphosate
   b. Easy to plant into yet prevents erosion
   c. Great timing for planting fall crops after harvesting beans

8. Following Timothy after first cutting
   a. Dense sod requires different methods
   b. A challenge to get fertility right
   c. Sod increases water infiltration on steep hills
d. Seed firmers can help in planting into Timothy

Seeds with draper headers

9. Timothy challenges
   a. Irrigate following baling to generate green up of grass then desiccate and plant or…..
   b. Plant following baling then water and use grass herbicide when timothy greens up
   c. Planting- getting a slice through the sod is key
   d. Fertility-getting nutrients available early enough
   e. Irrigation –make sure soil moisture is up in root growth zone
   f. No-till corn (the following spring) following beans should be possible

10. Alfalfa to bean challenges
    a. Spraying out the Alfalfa
    b. Spray before cutting alfalfa?
    c. Split application-before cutting-after planting?
    d. Water to get green up of alfalfa then spray?
    e. Depends on target planting date. If you have the time, it is safer to spray regrowth after cutting.

11. Example timeline, Beans after 6th year-alfalfa, 2005 on a 225 ac. circle
    a. June 2 - 1st cutting taken off
    b. June 2-8 - Irrigated
    c. June 13-14 - Sprayed 58 oz. Roundup per acre
    d. June 16 - Planted field, Montcalms (dark red kidney)
    e. June 18 – Planted Redhawks (dark red kidney)
    f. June 20 – Planted light red kidney variety
    g. July 18 - Applied Raptor and Basagram
    h. August 9 - Applied foliar and Dimethoate
    i. August 17 - Second foliar
    j. Sept. 13-15 - Swathed, 21’ wide
Oct. 3, 11, and 12 - Combined different varieties

Yields: Redhawks 27 bags, Lt reds 26.5 bags, Montcalms 23 bags

Example yields, 2007

a. Timothy - Mayflower Navy – 31cwt
b. Timothy - Black Diamond – 33cwt
c. Peas - Seahawks Navy - 37cwt
d. Triticale - Eclipse Blacks - 33cwt
e. Alfalfa - Redhawk Dk Red Kidney - 30cwt
f. Alfalfa - Blush Lt Red Kid - 27cwt
g. Peas - Eclipse Blacks - 27cwt
h. Peas - Cal Early Lt Red Kidney - 26cwt

Peas to dry beans

a. Traditionally takes 2 to 3 tillage passes to manage pea residue and leave a level bed.
b. Could strip-till be used to raise the planting bed higher than the pea residue?

c. Looks promising…

2008 Season; No-till Corn, Strip-till Profiles, Soil temperatures and Options
Andy McGuire

1. Overview
   a. What is the relationship between corn growth, soil temperature, and residue cover?
   b. What is strip-tillage really doing?
   c. 2008 demonstration fields

2. Season details
   a. Very cool spring
   b. Entire summer cooler than average, lost 12-16 days of growth

3. What is the relationship between corn growth, soil temperature, and residue cover?
   a. Monitored soil temperature at 2” depth in no-till field, with and without residue
   b. Results
      i. Soil temperature at 2” depth mainly affected by residue cover and air temperature, not tillage
ii. Without residue, the temperature range is larger with higher highs and lower lows. Residue cover moderates the temperature change. This continues even after the canopy closes, although the differences are less than before canopy closure. This is why there is less evaporation with residue cover.

iii. With corn, soil temperature is important from planting to the six-leaf stage when the growing point rises above the soil surface.

iv. If we are strip-tilling only to warm up the soil, maybe we should just be moving residue off the row instead?

c. Removing residue by itself can significantly warm soils. Soil growing degree days chart below is in untilled soil.

d. Soil temperatures in fall strip-till vs. spring strip-till (fine sand)

i. In early spring, fall and spring strip-tilled soils were warmer than untilled soil at 2” depth
e. Planting dates: Criteria and Strip-till vs. Untilled Soils

<table>
<thead>
<tr>
<th>Criteria for Corn Planting:</th>
<th>Recommended planting date (2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At least 50 °F at 7 am*</td>
<td>Strip-till</td>
</tr>
<tr>
<td>Spring strip-till 1, after corn</td>
<td>6-May</td>
</tr>
<tr>
<td>Spring strip-till 2, after corn</td>
<td>4-May</td>
</tr>
<tr>
<td>Fall strip-till, spring wheat c.c.</td>
<td>&gt; April 14</td>
</tr>
</tbody>
</table>

*Temperature in no-till soil almost always greater than strip-till soil at 7 am*

55 °F at 1 pm

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</tr>
</thead>
<tbody>
<tr>
<td>At least 50 °F at 1 pm</td>
<td>Strip-till</td>
</tr>
<tr>
<td>Spring strip-till 1, after corn</td>
<td>16-Apr</td>
</tr>
<tr>
<td>Spring strip-till 2, after corn</td>
<td>23-Apr</td>
</tr>
<tr>
<td>Fall strip-till, spring wheat c.c.</td>
<td>29-Mar</td>
</tr>
</tbody>
</table>

50 °F for 12 hours

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</thead>
<tbody>
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<td>At least 50 °F for 12 hours</td>
<td>Strip-till</td>
</tr>
<tr>
<td>Spring strip-till 1, after corn</td>
<td>25-Apr</td>
</tr>
<tr>
<td>Spring strip-till 2, after corn</td>
<td>25-Apr</td>
</tr>
<tr>
<td>Fall strip-till, spring wheat c.c.</td>
<td>10-Apr</td>
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</table>

Average daily temp. at least 50 °F (two consecutive days better)

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<tr>
<td>Spring strip-till 2, after corn</td>
<td>17-Apr*</td>
</tr>
<tr>
<td>Fall strip-till, spring wheat c.c.</td>
<td>10-Apr</td>
</tr>
</tbody>
</table>

*(Next day meeting criteria: 25-Apr)*

f. Conclusions
   i. Soil under corn residues cooler than under wheat residues
   ii. “Spot checks” of soil temp. are unreliable
   iii. Soil temp. checks with forecast may be best
   iv. A delay of about 2 days can be expected with untilled soils compared to strip-tilled soils (in fine sands)
   v. Fall vs. spring strip-till? Not sure yet.
   vi. Removing residue by itself can significantly warm soils without tillage
   vii. Strip-till warms the soil by removing the residue cover
   viii. Tillage effect on temperature is not clear
   ix. In 2008, no-till would have delayed planting by ~2 days in these fields (depending on the criteria used)

4. What is strip-till really doing?
   a. What could it do?:
      i. Remove residue
      ii. Loosen soil
      iii. Reduce compaction
      iv. Apply nutrients
      v. Simplify planting - don’t have to worry about planter modifications.
b. Soil penetration resistance across strip-till soil profiles

![Image of soil penetration resistance across strip-till soil profiles]

- Dotted line is about 300 psi, where plant roots may begin to be impeded by compact soil.

e. Conclusions
   i. Fall strip-till may fracture the soil better
      1. Moisture conditions?
      2. Equipment differences?
   ii. Spring strip-till may compact soil between rows
   iii. Need to compare different equipment in the same field, fall and spring
      1. Compare to just removing residue in strip

5. 2008 Demonstration fields
   a. Site details
      i. Following spring wheat, 149 bu/ac and equivalent residue
      ii. Grain corn, Pioneer 37Y11, 99 day maturity, good high residue emergence rating
      iii. S. site, North of Connell, high potential soil
      iv. N. site, South of Ephrata, gravelly soil with lower potential
      v. Planted May 5th and 9th, delayed because of cool soil temperatures
      vi. Stand planted at 40,000 seeds per acre, ended at 38,650 plants/ac (5.4” spacing)
b. Planter

Note weeds where row marker exposed soil

c. Results

i. S. Field yield:
   1. 6.2 tons/ac (15.5%), 222 bu/ac
   2. after 149 bu/ac spring wheat

ii. N. Field yield:
   1. 5.2 tons (15.5%), 184 bu/ac
   2. after 80 bu/ac spring wheat-same residue levels as S. field

iii. Corn yields in region were estimated to be 0.5-1 ton/ac lower than an average year because of the cool season

iv. Getting a good stand was NOT a problem. Planter adapted for no-till conditions planted well.

v. 2009 back to corn:
   1. Better pre-plant weed control and early fertility
   2. Better late weed control
   3. Slightly shorter maturity

High Residue Farming for Alfalfa and Timothy
Rick Nielson, Columbia View Farms, Mesa

1. Previous crop rotation
   a. Alfalfa hay – four years
   b. Potatoes – one year, cash rent
   c. Wheat – one year, alfalfa planted in the fall after wheat harvest

2. Soils
   a. Very low organic matter
   b. Prone to wind erosion
c. Has fields that have been no-tilled for 9 years
   i. Organic matter levels have increased, some above 1%

3. Problems
   a. With old rotation
      i. Wheat was a break-even or money losing crop
      ii. Wheel-lines and corners were not cropped to potatoes
      iii. Nematode counts continued to rise every cycle
      iv. Uncertain digging dates for potato harvest complicated wheat planting
      v. Hard to clean up the field after potatoes
   b. With timothy establishment in tilled soils
      i. Wind erosion
      ii. Water erosion
      iii. Weed control
      iv. Potential for winter kill after late fall plantings

4. Solution to these problems=direct seed timothy into alfalfa

5. Establishing timothy using Roundup
   a. Process
      i. Label allows for harvest of alfalfa 3 days after treatment
      ii. Spray before 4th cutting
      iii. Swath 3 days later
      iv. Baled the field
      v. Drilled timothy into stubble. Problems getting seeding rates low enough with their drill

   b. Worked well – timothy kept in two years

6. Challenges going from timothy to alfalfa without tillage
   a. First experience
      i. Nothing on Roundup label that would allow spraying of timothy before harvest
      ii. After first cutting of timothy, took several weeks to get enough regrowth to spray
      iii. Still had too many escapes
   b. Drilled alfalfa into timothy, then waited for timothy to regrow and sprayed it with Select
      i. This worked fairly well
      ii. Need lots of down pressure to get uniform seeding depth and good seed to soil contact
      iii. Managing soil moisture before emergence is very important
   c. Alfalfa after blue grass seed, one year experience
      i. Very tough conditions, hard to break into sod
      ii. Need weight on drill to keep it in the ground
         1. Drilled it two directions, half rate, got a good stand
      iii. Was not able to kill all the blue grass
         1. Select will not give complete control in his experience
      iv. Next time will try a Velpar/Gramoxone mix

7. Recommendations
   a. Seed alfalfa as soon as timothy is removed from field
   b. Use depth bands on drill, perhaps ¾-1”
   c. Have plenty of down pressure available on openers to cut sod
d. Make sure press wheels give good seed-to-soil contact

8. “If it doesn’t work…you can always go fishing”

e. Manage water carefully

f. Spray out timothy with Select or equivalent herbicide after regrowth begins

For more information go online: grant-adams.wsu.edu

- Previous workshop digests
- Fact sheets
- Links to relevant information

NOTICE

Pesticides or uses of pesticides mentioned in this publication may not be registered for use in Washington State. Always use registered pesticides according to their label.

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