SOIL HEALTH, NUTRIENT MANAGEMENT & COVER CROPPING

University of Minnesota

North Central SARE
Sustainable Agriculture Research & Education

Soil Health, Nutrient Management and Cover Cropping

Red Lake, MN

Sept 13-14, 2017

September 13th, 9am-5pm

Time	Topic
9-10	Welcome, Workshop Intro
10-11	Soil Basics
11-11:15	Break
11:15-12	Soil Quality and Organic Matter
12-1	Lunch
1-3	Soil Quality and Organic Matter in practice: NRCS activity
3-3:15	Break
3:15-5	Nutrient Management

September 14th, 9am-5pm

Time	Topic
9-9:30	Check-in for questions from yesterday
9:30-10:30	Cover Crop Basics
10:30-11	Break and travel to garden site
11-12	Cover Crop Demonstration
12-1	Lunch
1-2	Calculating Nitrogen contribution
2-4	Fitting cover crops into your farm (workshop/activity)
4-5	Questions, wrap-up, oral evaluation

Learning objectives for this workshop

Participants will:

1. Understand basics of soil structure and how soil type impacts management
2. Understand how organic matter impacts soil, ways to add organic matter and improve soil structure, and benefits of improved soil structure.
3. know why and how to collect and submit a soil test, how to read a soil test report, and make management decisions based on soil test results.
4. Understand how cover crops are different from other inputs including manure, compost, and synthetic amendments and fertilizers.
5. Understand what a cover crop is, why you would use a cover crop, and how to choose and use specific cover crop species
6. Understand how to estimate the nitrogen contribution of cover crops
7. Know how to plan cover crop use on your farm, how to identify planting windows, choose species, and terminate cover crops effectively.

Welcome

Soil Health, Nutrient Management and Cover Cropping

Introductions

- What is your farming background?
- What is your experience with cover crops?
- What are you hoping to learn during this workshop?

Workshop Objectives

- Understand basics of soil structure and how soil type impacts management
- Understand how organic matter impacts soil, ways to add organic matter and improve soil structure, and benefits of improved soil structure.

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Soils: More Than "Just Dirt"

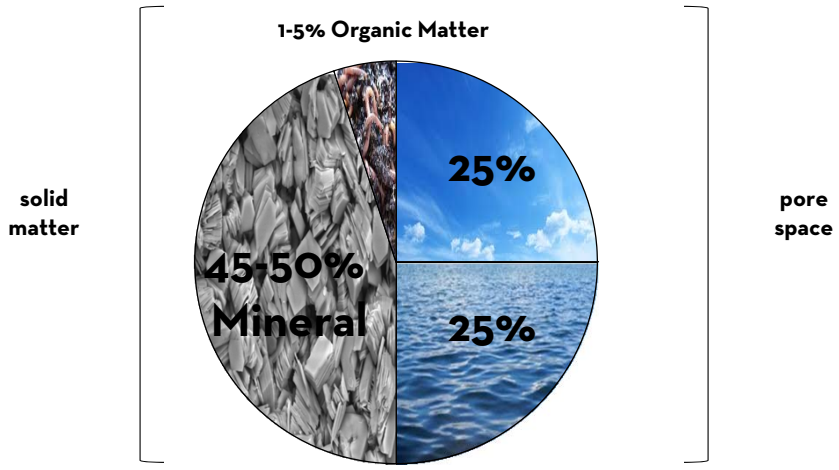
- **Hold up plants**
- **Provide air and water to plants**
- **Supply nutrients**
  - **Plants need sufficient quantity but not too much**
- **Provide habitat for soil organisms**

How would you describe great soil?

Characteristics of ideal soil

- Fertile
- Deep
- Well drained/aerated
- High in organic matter
- Friable
  (soil is easily worked)

What is soil?



Solid matter: Mineral and organic components

- Broken down rock particles
  - Clay particles hold nutrients
  - Particle size determines pore space, drainage, etc
- Organic matter (containing carbon)
  - Decomposed plant and animal matter
  - Ideal soil is about 5% organic matter
  - Source of food for soil microorganisms
  - Source of nutrients for plants
  - Holds minerals against loss due to leaching

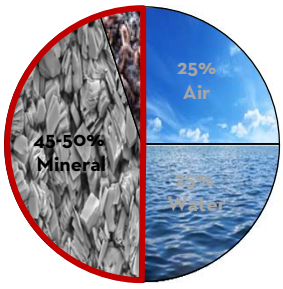
The not-solid stuff: Pore Space

- Air (~25% of total soil volume)
  - Oxygen supports soil life
    - Roots
    - Microbes
  - Air can be displaced by water
- Water (~25% of total soil volume)
  - Carries nutrients to plants

Soil is only 1/2 solid

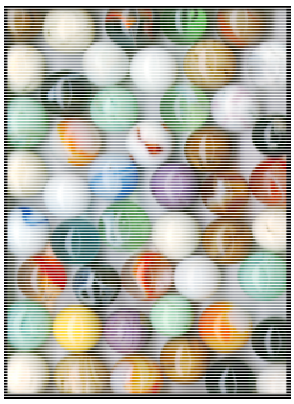
Mineral particles are divided into 3 size classes:

- sand
- silt
- clay



The amount of each particle size determines soil "texture"

Soil texture: Sand



- Sand particles range in size from 0.2 mm for the very finest sand to 2 mm for the coarsest
- Feels gritty if rubbed between your fingers
- Warms up and dries early in spring
- Low in nutrients
- Larger gaps

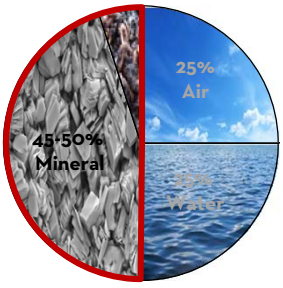
Soil texture: Silt

- 0.002 to 0.05 mm
- About as thick as a strand of hair!
- Feels like flour
- Don't till more than necessary, or this good soil will get washed away!

Soil texture: Clay

- Soil particles are less than 0.002 mm in size
- Feels sticky when wet
- Does not drain easily and is difficult to work
- Dries slowly in spring
- Root growth is poor due to small spaces between soil particles
- Usually high in nutrients
- Small gaps

Soil Texture



Soil Types

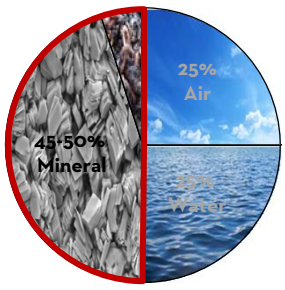
- Most soils are a mixture of different soil textures
  - Often a soil type will be dominated by a particular texture
- Can group soil types by how well drain and major texture class they contain
  - Heavy soils
    - Contain a high proportion of clay
  - Light soils
    - Contain a high proportion of sand
- Important to know the soil type because it will determine the management practices you need to use

Soil is only 1/2 solid

Organic Matter can make up anywhere from 1 to 5% of soil

It's VERY important!

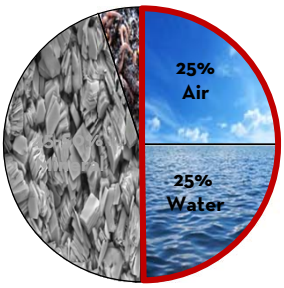
We <u>can</u> change how much is in soil with how we manage soil



Soil is half pore space

Soil pore space is made up of air and water:

- **when it rains, it's more water than air**
- **when it's been dry, it's mostly air.**



Soil is half pore space

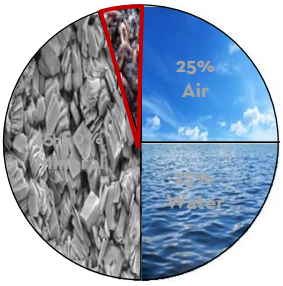
Why do plants need both air and water?

Soil Organic Matter (SOM)

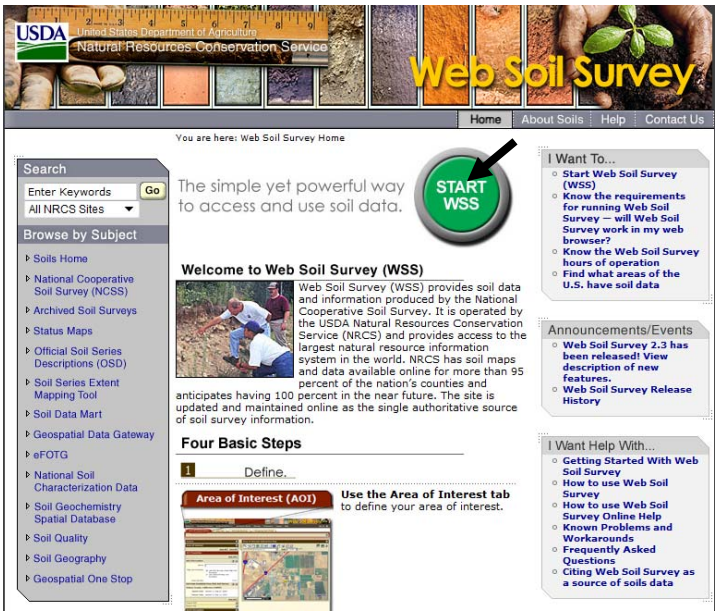
organic = materials that were once alive, either recently or *thousands* of years ago

Mostly a source of carbon (C) and nitrogen (N), but can also provide other nutrients – very nutritious!

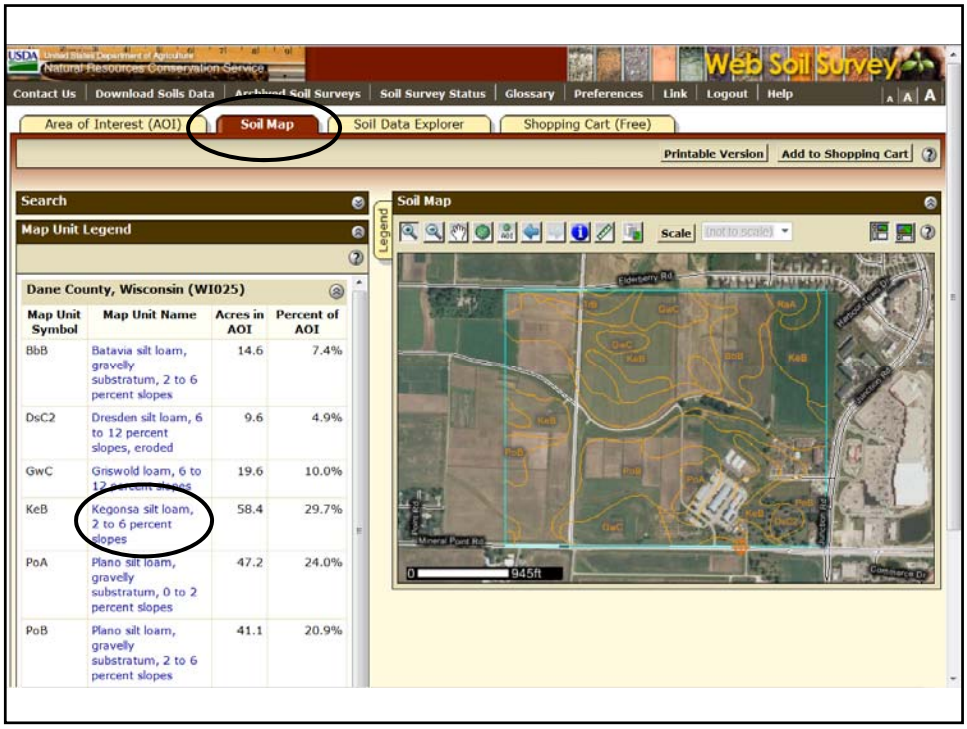
More on this in the next unit…

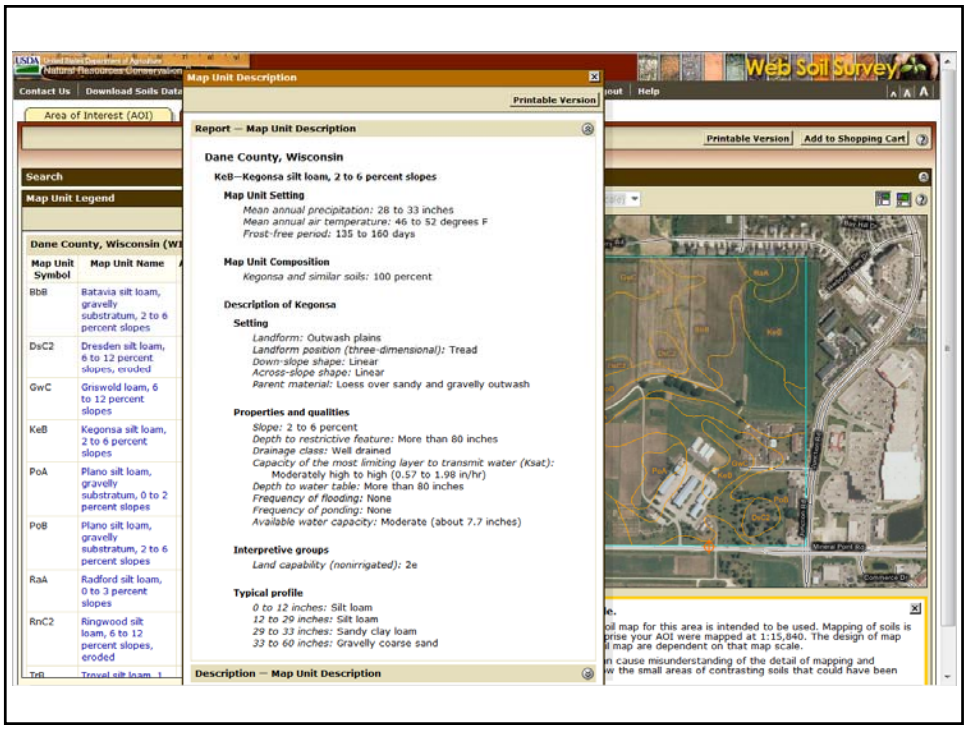


Finding your Soil Type



http://websoilsurvey.nrcs.usda.gov/


Web Soil Survey
Contact Us | Download Soils Data | Archived Soil Surveys | Soil Survey Status | Glossary | Preferences | Link | Logout | Help
Area of Interest (AOI) | Soil Map | Soil Data Explorer | Shopping Cart (Free)
Printable Version | Add to Shopping Cart
Search
Map Unit Legend
Dane County, Wisconsin (WI025)
Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI
BbB | Batavia silt loam, gravelly substratum, 2 to 6 percent slopes | 14.6 | 7.4%
DsC2 | Dresden silt loam, 6 to 12 percent slopes, eroded | 9.6 | 4.9%
GwC | Griswold loam, 6 to 12 percent slopes | 19.6 | 10.0%
KeB | Kegonsa silt loam, 2 to 6 percent slopes | 58.4 | 29.7%
PoA | Plano silt loam, gravelly substratum, 0 to 2 percent slopes | 47.2 | 24.0%
PoB | Plano silt loam, gravelly substratum, 2 to 6 percent slopes | 41.1 | 20.9%
Soil Map
Legend
Scale
945ft


Web Soil Survey
Map Unit Description
Printable Version
Report — Map Unit Description
Dane County, Wisconsin
KeB—Kegonsa silt loam, 2 to 6 percent slopes
Map Unit Setting
Mean annual precipitation: 28 to 33 inches
Mean annual air temperature: 46 to 52 degrees F
Frost-free period: 135 to 160 days
Map Unit Composition
Kegonsa and similar soils: 100 percent
Description of Kegonsa
Setting
Landform: Outwash plains
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess over sandy and gravelly outwash
Properties and qualities
Slope: 2 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Moderate (about 7.7 inches)
Interpretive groups
Land capability (nonirrigated): 2e
Typical profile
0 to 12 inches: Silt loam
12 to 29 inches: Silt loam
29 to 33 inches: Sandy clay loam
33 to 60 inches: Gravelly coarse sand
Description — Map Unit Description

Discussion

- How could you use this information to choose a farm site?
- How can this information help you manage your land?


What you'll learn:
• What soil health means
• How organic matter makes soil healthy
• Why we should care about soil health
• What we do that affects health of soil


Soil quality is the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal, and human health
- Doran and Parkin, 1994

Why Should I Care about Soil Health?

- What conditions let crops do well? What is soil like when crops are healthy?
- How did you manage soil where you farmed previously? How do you manage it here? Are the practices you use different?
- What did you do when you farmed before to re-energize the soil? Have you discovered alternative methods that are more or less suitable for re-energizing soil here?

Why Should I Care about Soil Health?

Having a more diverse soil food web can mean that inputs are broken down more efficiently for plants to use

Why Should I Care about Soil Health?

Why Should I Care about Soil Health?

Why Should I Care about Soil Health?

Having healthier soil can improve crop resistance against pests and environmental stresses


MORE PRODUCTIVE CROPS


How Can I Help Soil Health?

How Can I Help Soil Health?

How Can I Help Soil Health?

How Can I Help Soil Health?

Discussion

- What practices do you use on your farm to maintain or improve soil health?
- Are there any practices that you would like to use in the future?

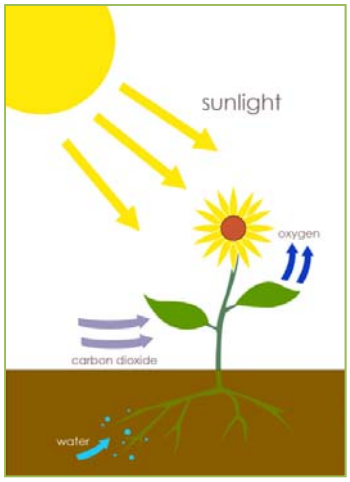

Nutrient Management
University of Minnesota


What you'll learn:
• Understand plant nutrients
• Do's and don'ts of soil sampling
• Reading and using a soil test report

A GENERAL OVERVIEW OF NUTRIENTS IN SOILS

Plants need nutrients…

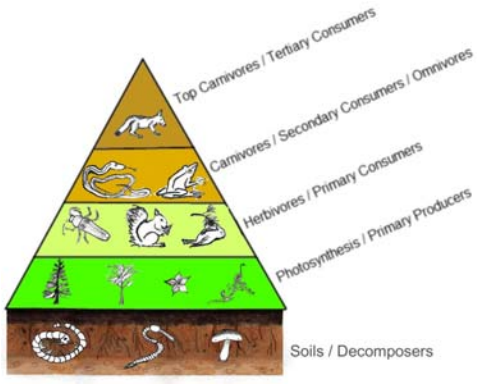
- …starting with Carbon.
- Plants grow through *photosynthesis*, which uses:
  - sunlight
  - CO_2 from the air
  - water
- to make carbon-based plant matter.



plants

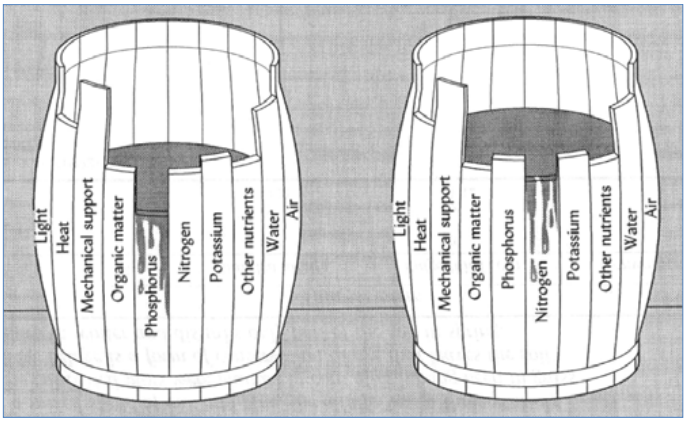
Where does C come from?

- All living things (plant or animal) contain carbon, because they either photosynthesize or eat things that photosynthesize.
- This process starts with plants when they fix (change) CO_2 into carbohydrates, using it to grow.



carbon

The law of the minimum



Soil nutrients

- Ability of a soil to hold nutrients and release them to plants depends on
  - Presence and availability of nutrients
  - Soil texture
  - Organic matter
- Clay size particles and organic matter both hold nutrients but make them available to different degrees
- HOW?

Nutrients travel with water

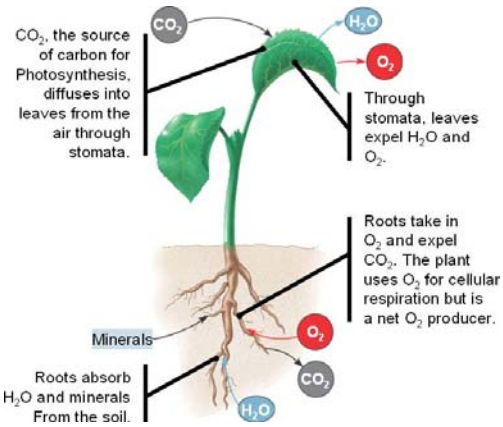
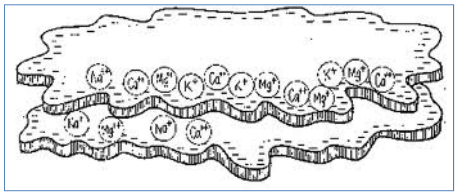


Image from: http://www.wonderwhizkids.com/index.php/biology/plant-form-and-function/nutrients-in-plants

Soil acts as a magnet

- Attracts and retains charged particles (ions) in soil solution
- Prevents them from moving downward with water (leaching)
- Some nutrients have a stronger connection than others and are thus held more strongly in the soil



Cation Exchange Capacity (CEC)

- The ability of clay, organic matter, and humus to attract positive ions
  - Clay, organic matter, and humus all have negative charges on their surfaces
  - Most nutrients (P, K, Ca, etc) are cations or have positive charges
  - "Opposites attract"
- The higher the cation exchange capacity, the more closely the nutrients are held and the less likely they are to be lost to leaching
- (soils also have anion exchange and it works the same way)

Soil type affects nutrients

Soils with low % clay

- low nutrients and organic matter
- low water holding capacity
- requires more frequent fertilizer and lime amendments
- prone to leaching

Soils with high % clay

- moderate to high organic matter content
- high water holding capacity
- less frequent need for fertilizers (except N)
- low leaching potential
- On the other hand, their physical properties may make it difficult for a farmer to cultivate, irrigate or maintain good aeration

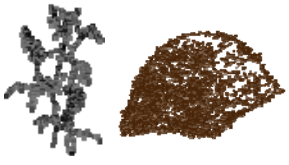
In general…

- Sandy soils
  - larger particles
  - less nutrient holding ability
- Clayey soils
  - smaller particles
  - greater nutrient holding ability

MACRO-NUTRIENTS IN SOIL

Where does N come from?

Organic
(carbon based)



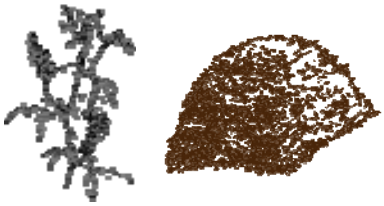
SOM, plant matter, compost

Inorganic
(not carbon based)

nitrate (NO_3^-) or ammonium (NH_4^+) based

Where does N come from?

Organic (carbon-based)

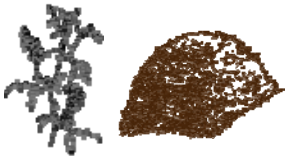


- **Organic N needs to be turned into nitrate (NO3-) or ammonium (NH4+), which is called "mineralization", by soil microorganisms before plants can use it.**
- **These are "made available" over time as microbes mineralize them, not all at once like fertilizers.**

nitrogen

Where does P come from?

organic



SOM, plant matter, compost

mineral

weathering from rock → HPO_4^{-2} and $H2PO_4^{-1}$

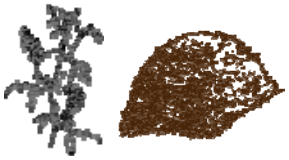
inorganic

P_2O_5

phosphorus

Where does P come from?

organic



SOM, plant matter, compost

mineral

weathering from rock → HPO_4^{-2} and $H2PO_4^{-1}$

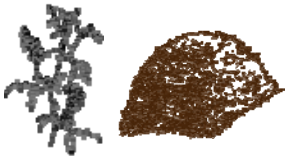
Plants can only take up inorganic and soluble P.

Like N, P from organic sources must be mineralized over time by microbes.

phosphorus

Where does K come from?

organic



SOM, plant matter, compost

mineral

weathering from rock (feldspar and mica) → K^+

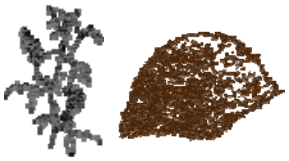
inorganic

K_2O

potassium

Where does K come from?

organic



SOM, plant matter, compost

mineral

weathering from rock (feldspar and mica) → K^+

Plants can only take up K ions (K^+).

K^+ adheres to SOM, which keeps it from leaching and helps some of it stay available to plants.

potassium

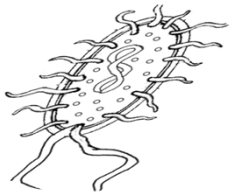
If plants get carbon from the *air*, why do we need to build SOM?

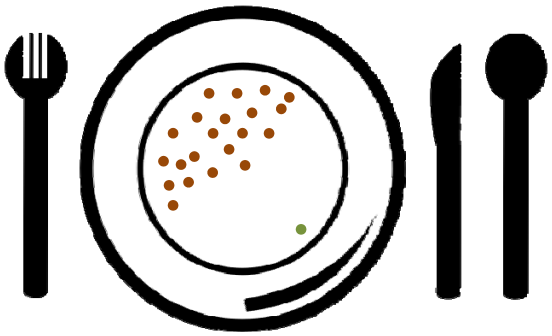
If plants get carbon from the *air*, why do we need to build SOM?

SOM holds other nutrients like nitrogen and phosphorus! When microbes eat SOM, they mineralize N and P, which makes them available for plants.

THE MINERALIZATION PROCESS

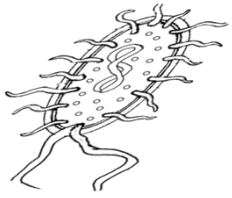
C and N in SOM

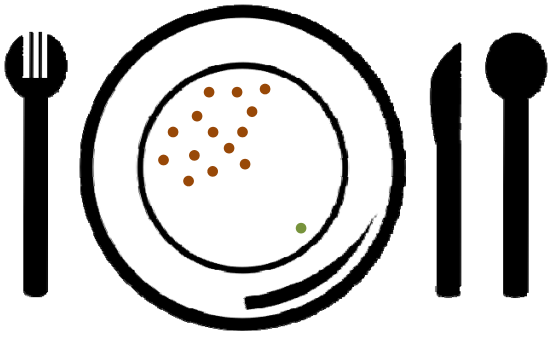




C and N in SOM

Mineralization….



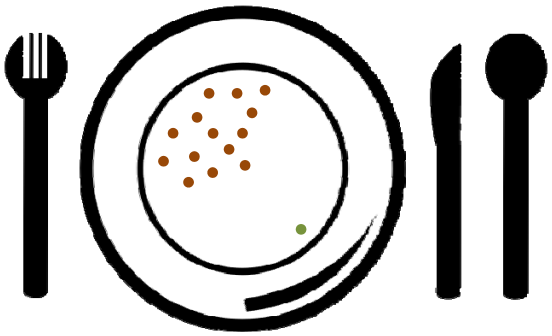


25 (*or less*) parts C to 1 part N

C and N in SOM

Mineralization....

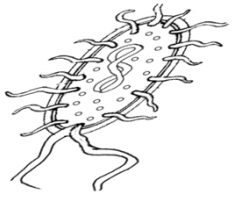
when microbe food is high in N, they excrete excess N back into soil as mineral forms that plants can use

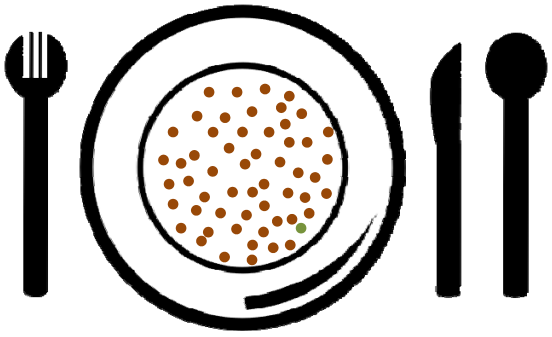


25 (*or less*) parts C to 1 part N

C and N in SOM

....or Immobilization



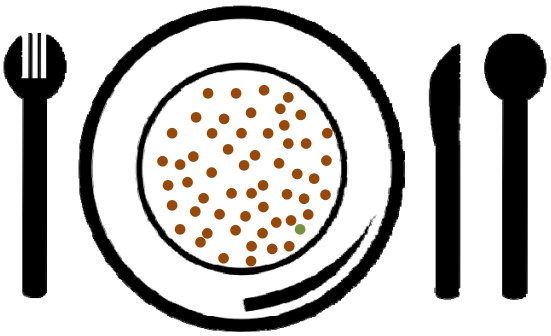


25 (*or more*) parts C to 1 part N

C and N in SOM

....or Immobilization

when microbe food is low in N, they have to use N from the soil to metabolize the available carbon, effectively taking away N that plants could have used



25 (*or more*) parts C to 1 part N

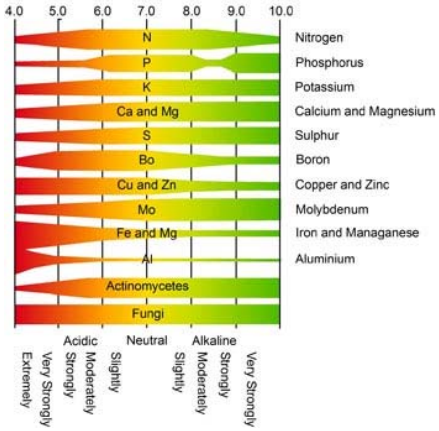
C and N in SOM

Low C:N (10:1) is better than High C:N (40:1)

Nutrient requirements

- **The correct nutrient balance …**
  - **–Depends on soil type and texture**
  - **–Varies by plant**
  - **–Is affected by climate**

Soil pH



More isn't better

- Too much of any nutrient can be negative
  - Poor fruit set
  - Run-off or leaching resulting in environmental pollution
  - Soil acidification through reaction with nitrogen
  - May lead to inability to take up other essential nutrients

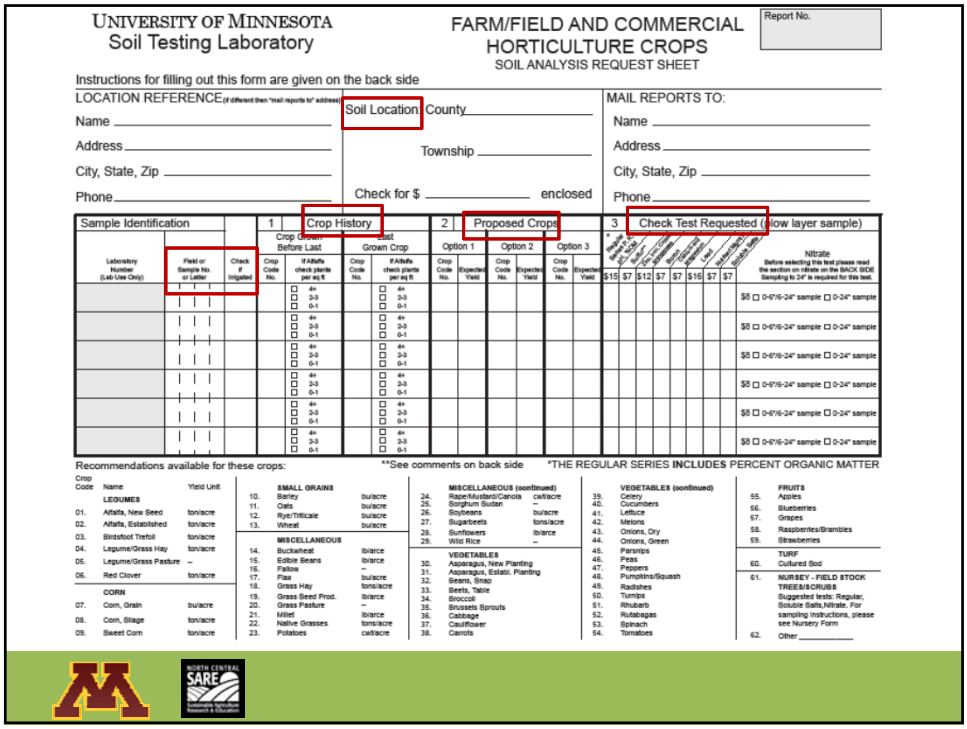

SOIL TESTING


Soil Testing

- You can submit multiple samples
- Many "composites" make up one sample – for instance, take 10 soil cores and combine them in a bucket, and submit the total
- Take representative samples (only composite soil from uniform areas)
- Don't include surface plant material
- Sample as deeply as you till (usually 6-8" deep)
- The more variable your landscape (hilly, different crop rotations, different soil types, etc.), the more composites you should take!

Soil Testing

- The University of Minnesota has a Soil Testing Laboratory!
- Mail samples to:
  - Soil Testing Laboratory, University of Minnesota
    Room 130, Cargill Building
    1500 Gortner Ave., St. Paul, MN 55108
- They have a great website: soiltest.cfans.umn.edu
- A normal soil report costs $15 per sample
  - NOTE: this does *not* include nitrogen!
- However, plant available nitrogen can be estimated from other values on the soil test report
- When you drop off the samples, you will be asked to fill out the following form....



UNIVERSITY OF MINNESOTA
Soil Testing Laboratory

FARM/FIELD AND COMMERCIAL HORTICULTURE CROPS
SOIL ANALYSIS REQUEST SHEET

Report No.

Instructions for filling out this form are given on the back side

LOCATION REFERENCE (if different then "mail reports to" address)
Name
Address
City, State, Zip
Phone

Soil Location County
Township
Check for $ enclosed

MAIL REPORTS TO:
Name
Address
City, State, Zip
Phone

Sample Identification | 1 Crop History | 2 Proposed Crops | 3 Check Test Requested (allow layer sample)

Laboratory Number (Lab Use Only) | Field or Sample No. or Letter | Check if Irrigated | Crop Grown Last Year Before Last | Crop Grown Last Year | Option 1 | Option 2 | Option 3 | Regular (P, K, pH, Buffer pH, Organic Matter) $15 | Micronutrients (Ca, Mg, Zn, B, Cu, Mn) $7 | Boron (Hot Water) $12 | Sulfate-Sulfur $7 | Chloride $7 | Nitrate $16 | Lead $7 | Sodium (Na), Sodium Adsorption Ratio (SAR), Soluble Salts $7 | Nitrate — Before selecting this test please read the section on nitrate on the BACK SIDE. Sampling to 24" is required for this test.

Crop Code No. | If Alfalfa check plants per sq ft | Crop Code No. | If Alfalfa check plants per sq ft | Crop Code No. | Expected Yield | Crop Code No. | Expected Yield | Crop Code No. | Expected Yield

4+ 2-3 0-1

$8 ☐ 0-6"/6-24" sample ☐ 0-24" sample

Recommendations available for these crops: **See comments on back side *THE REGULAR SERIES INCLUDES PERCENT ORGANIC MATTER

Crop Code | Name | Yield Unit

LEGUMES
01. Alfalfa, New Seed ton/acre
02. Alfalfa, Established ton/acre
03. Birdsfoot Trefoil ton/acre
04. Legume/Grass Hay ton/acre
05. Legume/Grass Pasture –
06. Red Clover ton/acre

CORN
07. Corn, Grain bu/acre
08. Corn, Silage ton/acre
09. Sweet Corn ton/acre

SMALL GRAINS
10. Barley bu/acre
11. Oats bu/acre
12. Rye/Triticale bu/acre
13. Wheat bu/acre

MISCELLANEOUS
14. Buckwheat lb/acre
15. Edible Beans lb/acre
16. Fallow –
17. Flax bu/acre
18. Grass Hay tons/acre
19. Grass Seed Prod. lb/acre
20. Grass Pasture –
21. Millet lb/acre
22. Native Grasses tons/acre
23. Potatoes cwt/acre

MISCELLANEOUS (continued)
24. Rape/Mustard/Canola cwt/acre
25. Sorghum Sudan –
26. Soybeans bu/acre
27. Sugarbeets tons/acre
28. Sunflowers lb/acre
29. Wild Rice –

VEGETABLES
30. Asparagus, New Planting
31. Asparagus, Estab. Planting
32. Beans, Snap
33. Beets, Table
34. Broccoli
35. Brussels Sprouts
36. Cabbage
37. Cauliflower
38. Carrots

VEGETABLES (continued)
39. Celery
40. Cucumbers
41. Lettuce
42. Melons
43. Onions, Dry
44. Onions, Green
45. Parsnips
46. Peas
47. Peppers
48. Pumpkins/Squash
49. Radishes
50. Turnips
51. Rhubarb
52. Rutabagas
53. Spinach
54. Tomatoes

FRUITS
55. Apples
56. Blueberries
57. Grapes
58. Raspberries/Brambles
59. Strawberries

TURF
60. Cultured Sod

61. NURSERY - FIELD STOCK TREES/SHRUBS
Suggested tests: Regular, Soluble Salts,Nitrate. For sampling instructions, please see Nursery Form

62. Other

Soil Testing

- **Basic soil test:**
  - **pH – alkaline or acidic?**
  - **% organic matter**
  - **soil texture**
  - **potassium (K) and phosphorus (P)**
- **Additional tests (both add to cost):**
  - **can measure micronutrients (Ca, Mg, Zn, B, Cu, Mn)**
  - **can also measure nitrate**
  - **soluble salt concentrations**

University of Minnesota
Soil Testing Laboratory

SOIL TEST REPORT
Farm and Field

Client Copy
Department of Soil, Water, and Climate
Minnesota Extension Service
Agricultural Experiment Station

FARMER DOE
ROUTE 1
ANYWHERE MN 55000

Page **1**
Report No. **12**
Laboratory No. **18**
Date Received **10/16/07**
Date Reported **10/18/07**

INTERPRETATION OF SOIL TEST RESULTS

Soil Texture Code:
C (coarse): sand, loamy sand, sandy loam
M (medium): loam, silt loam
F (fine): clay loam, silty clay loam, silty clay

	Organic Matter	Phosphorus	pH	Potassium
Very High				
High				
Med				
Low	O	P	H	K

SOIL TEST RESULTS

Sample/ Field Number	Estimated Soil Texture	Organic Matter %	Soluble Salts mhos/cm	pH	Buffer Index	Nitrate NO3-N ppm	Olsen Phosphorus ppm P	Bray 1 Phosphorus ppm P	Potassium ppm K	Sulfur SO4 -S ppm	Zinc ppm	Iron ppm	Manganese ppm	Copper ppm	Boron ppm	Calcium ppm	Magnesium ppm
1	Medium	3.0		7.6			6	4	75								

RECOMMENDATIONS **Crop Before Last: Sweet Corn; Last Crop: Cabbage**

Crop and Yield Goal	Method	Lime #ENP/A	N lb/A	P2O5 lb/A	K2O lb/A	S lb/A	Zn lb/A	Fe lb/A	Mn lb/A	Cu lb/A	B lb/A	Ca lb/A	Mg lb/A
Sweet Corn	Broadcast	0	150	60	100								
8 tons/acre	Row/Drill			35	40								
Comments: 4,5,18													
Cabbage	Broadcast	0	180	150	200								
	Row/Drill												
Comments: 18,50,57													
Tomatoes	Broadcast	0	130	150	200								
	Row/Drill												
Comments: 18,50,57													

County: MARTIN For additional information, contact the soil extension specialist at: JOHN LAMB, 612-625-1772

Soil Testing

So what if you want to know how much nitrogen you have, but you don't want to pay (and wait) for nitrate measurements?

We can do the math!

- **All the soil in the top 6 inches of an acre weighs about 2,000,000 pounds.**
- **If we have 3% SOM, like in the report, that means we have 0.03 x 2,000,000 = 60,000 lb/ac of SOM**
- **But SOM is only about 7% nitrogen…**
- **So in the soil, about 60,000 x 0.07 = 4,200 lbs of nitrogen exist as SOM (org N)**
- **BUT, finally, only about 2% of this is mineralized annually…**
  - **4,200 x 0.02 = 84 lb mineral N per acre (quite a lot!)**

FERTILIZER CALCULATION EXAMPLE

Calculating amendments

- How to Convert an Inorganic Fertilizer Recommendation to an Organic One

https://secure.caes.uga.edu/extension/publications/files/pdf/C%20853_5.PDF

Additional Resources

- Forever Green video about MN cover crops
- Basic Soil Science:
  - Chapter 3. Concepts of Basic Soil Science, W. Lee Daniels and Kathryn C. Haering, Department of Crop and Soil Environmental Sciences, Virginia Tech
  - *www.mawaterquality.org/capacity_building/mid.../chapter3.pdf*
- *Calculating organic amendments:*
  - How to Convert an Inorganic Fertilizer Recommendation to an Organic One, *Revised by Julia Gaskin, David Kissel, Glen Harris and George Boyhan. Original manuscript by Wayne McLaurin, retired Horticulture Professor, and Water Reeves, retired Horticulture Educator*
  - *http://www.caes.uga.edu/Publications/displayPDF.cfm?pk_ID=7170*

What is a cover crop?

COVER CROP
grown to prevent soil erosion and manage SOM

GREEN MANURE
maintain SOM and increase plant available nitrogen

COVER CROPS

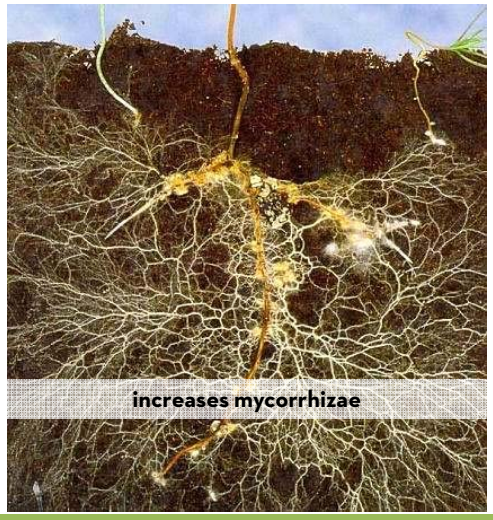
CATCH CROP
retrieves left over nutrients to prevent pollution

Benefits of cover crops

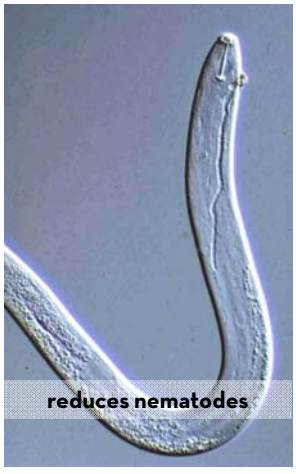
How are cover crops different from other amendments?

Benefits of cover crops

Benefits of cover crops

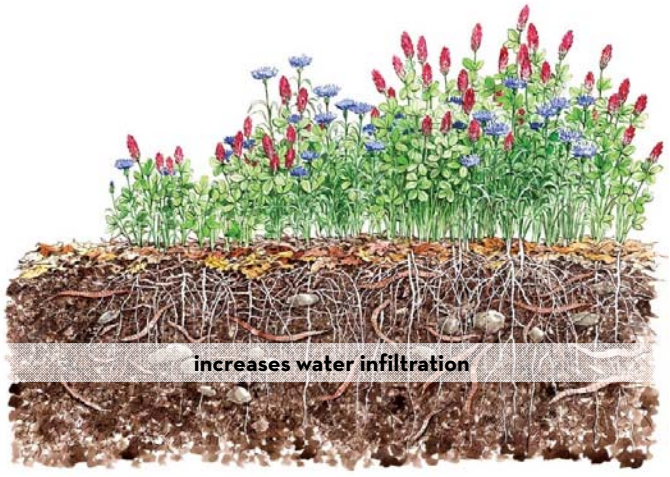


Benefits of cover crops



Benefits of cover crops

Benefits of cover crops



Benefits of cover crops

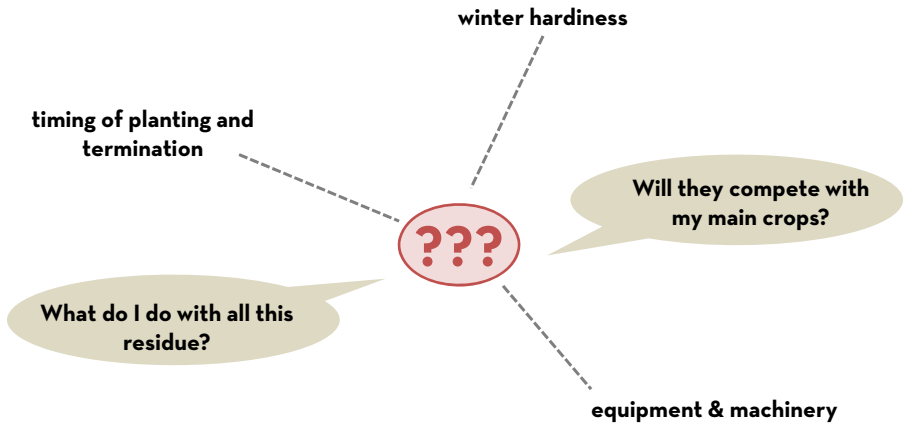
Benefits of cover crops

Benefits of cover crops

Benefits of cover crops

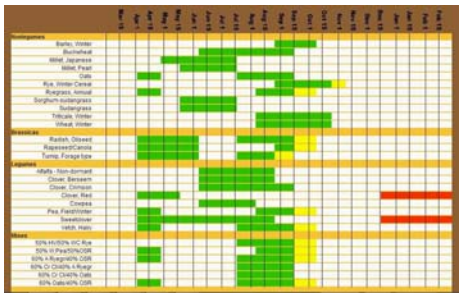
Have you used cover crops?

Challenges of cover crops



Timing

- Fitting cover crops in between cash crops can be a challenge.
- Consider different options through the year
  - Winter-killed covers for early spring planting
  - Over-wintered covers for late spring/early summer planting
  - Mid-summer cover between spring and fall crops



Winter-hardiness

- Choose varieties that are proved to do well in cold climates.
- Light snow cover and windy conditions make winter survival more challenging

Cash crop competition

- Correct timing of planting and termination can reduce or eliminate cash crop competition
- Plan for some time (1-2 weeks) between cover crop termination and cash crop planting
- Cover crops can often be seeded into a standing cash crop.

Management

- Plan termination before planting!
- Many cover crops can be managed well with small equipment
  - Peas, buckwheat, clover, any winter-killed crops
- Tall grasses may be especially difficult to manage without large equipment.
  - Plant winter rye and sorghum-sudan grasses with care.

Types of Cover Crops

- Non-legume
  - Grasses, brassicas, buckwheat
- Uses
  - Add organic matter
  - Suppress weeds
  - Reduce erosion
  - Scavenge nutrients
  - Do NOT contribute N


Types of Cover Crops

- Legume
  - Vetch, clover, peas, alfalfa
- Uses
  - Fix nitrogen
  - Reduce erosion
  - Usually less organic matter and biomass than a grass



Selecting a cover crop
1. Make a goal
2. Establish seasonal windows
3. Make plans for termination
4. Start small, experiment!


Estimating N credits

Estimating N credits

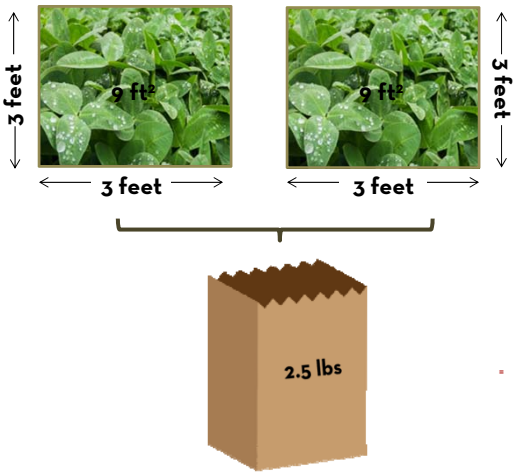
1. How much plant material is in a given area?
2. How much nitrogen is in that material?
3. How quickly will the material decompose and become available?
4. Do you need extra nitrogen?

Estimating N credits

- Use a ruler or yardstick to measure out a known area in your cover cropped area
- Clip the plants within the square *at several places in your field*
- Dry the samples in the oven until they are crunchy dry

1. How much plant material is in a given area?

Estimating N credits



HOW MUCH BIOMASS PER ACRE DO I HAVE?

lb biomass/ac =

$$\frac{\text{dry sample weight (lb)}}{\text{area sampled (ft}^2\text{)}} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}}$$

$$= \frac{2.5\ \text{lb}}{18\ \text{ft}^2} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}} = 6{,}050\ \text{lb biomass}$$

1. How much plant material is in a given area?

Estimating N credits

Cover Crop	Examples	% N
Legumes	Hairy vetch Clovers Pea Sunn hemp	4% at flowering 3% is seeds are maturing
Non-legume grasses	Rye Oat Sorghum sudangrass	3% at flowering 2% is seeds are maturing
Non-legume broadleaves	Buckwheat Tillage radish Canola	Similar or a little less than grasses

2. How much nitrogen is in that material?

Estimating N credits

the cover crop was flowering red clover
→ 4% N

6,050 lb/ac x 0.04 = 242 lb N/ac

2. How much nitrogen is in that material?

Estimating N credits

MICROBES HAVE TO EAT THE MATERIAL
FOR IT TO BE AVAILABLE FOR PLANTS

Will you leave the cover crop on the surface, or incorporate it belowground?

40% will be available in year 1

242 lb N x 0.4 = 97 lb N/ac

50% will be available in year 1

242 lb N x 0.5 = 121 lb N/ac

How quickly will the material decompose and become available?

Estimating N credits

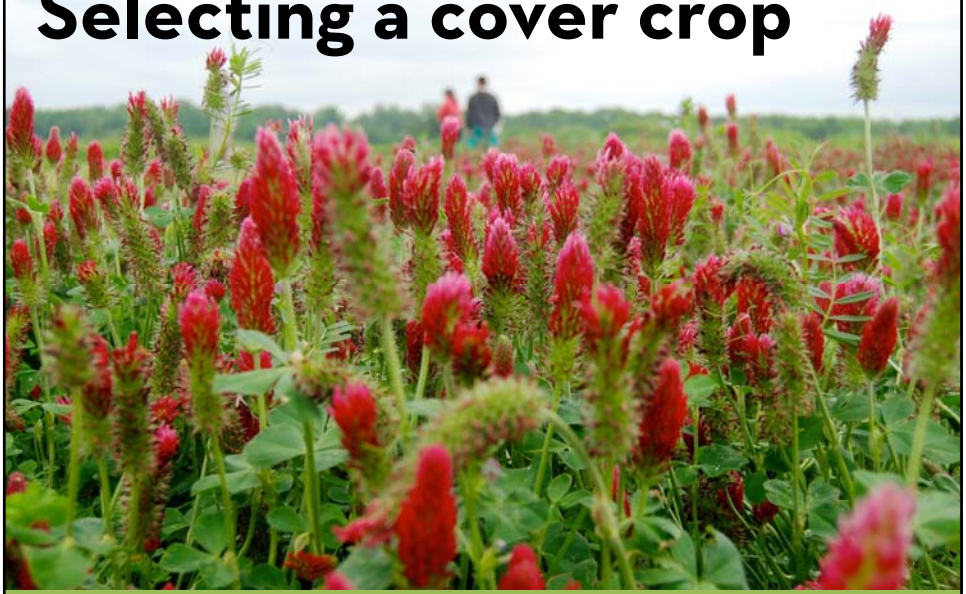
What are you planting now?

Cabbage removes approx. 220 lb N/ac
→ will need 220 – 121 = 99 more lb N if we tilled in the clover

WHAT NOW?

Use manure, compost, or fertilizer; or, rely on accumulated soil organic N from all the organic matter you have been adding!

Selecting a cover crop



Choose a goal

- Reduce erosion
- Provide N
- Fall catch crop
- Add organic matter

Choose a time

- Summer
  - usually between spring and fall crops
- Winter-killed
  - usually precedes early spring cash crops
- Over-winter
  - usually precedes summer cash crops

Consider termination

- **What equipment do you have available to terminate cover crops?**



Thank You!

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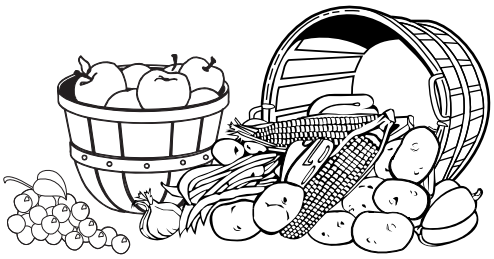
Nutrient Management for Commercial Fruit & Vegetable Crops in Minnesota

Introduction

There are 17 essential nutrients required for plant growth: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl) and nickel (Ni). Of these 17, all except carbon, hydrogen, and oxygen are derived from the soil. When the soil cannot supply the level of nutrient required for adequate growth, supplemental fertilizer applications become necessary.

Recommendations for fertilizing fruit and vegetable crops in Minnesota are based in part on soil test results. Soil testing provides information on lime and fertilizer needs prior to planting and is particularly well calibrated for nutrients such as phosphorus, potassium, magnesium, calcium, sulfur, zinc, and boron. Soil testing prior to planting takes the guesswork out of making fertilizer recommendations and leads to more efficient nutrient management. Fertilizer recommendations in this bulletin are intended for field-grown fruit and vegetable crops. For container-grown crops, such as transplants or vegetables grown in the greenhouse in pots, different soil tests should be used. Contact the University of Minnesota Soil Testing Laboratory (612-625-3101), for the appropriate form to fill out for container-grown crops or check online at http://soiltest.coafes.umn.edu/

For fertilizer requirements of established perennial crops and for fine-tuning fertilizer needs of annual crops, a combination of soil testing and tissue analysis should be used.



Taking a Soil Sample

Proper interpretation of soil test results for making fertilizer recommendations is dependent on collecting a representative sample. The procedure for taking a meaningful soil sample is summarized below.

Soil samples can be collected any time of the year, although spring and fall sampling are usually the most convenient. If soil test results from a given field are to be compared over the years, it is best that samples be collected at the same time of year.

Each field to be sampled should be divided into uniform areas. Each area should have the same soil texture and color, cropping history, and fertilizer, manure, and lime treatments. One sample should not represent more than 20 acres on a level uniform field, or 5 acres on hilly or rolling land. Samples are most easily collected using a soil tube, soil auger, or a garden spade. To take the soil sample, scrape off all surface residue and litter and take the sample to a depth of 6-8 inches for annual crops and 10-12 inches for perennial crops. Usually 15 to 20 subsamples (one core per subsample) should be collected from randomly selected areas in the field. The soil should be thoroughly mixed in a clean plastic pail and about 1 pint of this mixture should be placed in a sample bag or box.

Samples can be sent directly to the University of Minnesota Soil Testing Laboratory, 135 Crops Research Building, 1902 Dudley Ave., St. Paul, MN 55108. Sample submission forms and other soil testing information can be obtained from: http://soiltest.coafes.umn.edu/

A number of private laboratories also offer soil testing services. Contact your Regional Extension Office or fertilizer dealer for information about commercial laboratories in your area or look in the yellow pages of your phone book under “laboratories.”

The nitrate test on a 0- to 2-foot soil sample can be used for nitrogen recommendations for selected crops grown in western Minnesota on nonirrigated soils. For more information on the nitrate test, refer to the section on nitrogen (**page 13**).

Cover crops on the intensive market farm

John Hendrickson
UW-Madison Center for Integrated Agricultural Systems
College of Agricultural and Life Sciences

June 2009

This report is a product of the **Center for Integrated Agricultural Systems (CIAS)**, a research center for sustainable agriculture in the College of Agricultural and Life Sciences, University of Wisconsin-Madison. In addition to its role in facilitating the development of this report, CIAS provided layout and publishing services. CIAS fosters multidisciplinary inquiry and supports a range of research, curriculum and program development projects. It brings together university faculty, farmers, policy makers and others to study relationships between farming practices, farm profitability, the environment and rural vitality. Go to www.cias.wisc.edu or call 608-262-5200 for more information. Go to www.thinkIPM.org to learn more about IPM resources in Wisconsin.

Support from the following organizations made this report possible:

The **UW Extension Fresh Market Team** is made up of researchers and UW-Extension outreach specialists who work with fresh market growers throughout Wisconsin. Many are associated with the UW's Integrated Pest Management Program.

The **Integrated Pest and Crop Management Program** at the UW-Madison seeks to expand the use of IPM in Wisconsin crops to reduce the use of chemical pesticides, increase the use of cultural and biological pest control tactics, improve production efficiency and maintain the competitiveness of Wisconsin growers by producing crops with the lowest level of pesticide inputs necessary. Go to ipcm.wisc.edu for more information.

The original version of this report was funded through a grant from the Wisconsin Farmers Union Foundation, working with the US Environmental Protection Agency - Region V in Chicago as part of their Agricultural Stewardship Initiative.

Photos by John Hendrickson, CIAS.
Publication design and layout by Ruth McNair, CIAS.

This report is printed on recycled paper.
Revised June 2009 from a September 2003 original.

Cover crops on the organic market farm

John Hendrickson, CIAS Outreach Specialist

Introduction

Crops that are grown solely to provide soil cover or for the purposes of increasing soil fertility are referred to as cover crops or green manures. In general, these crops are incorporated into the soil while green or just after flowering. Due to their ability to protect and enhance soils, cover crops are considered a fundamental aspect of any sustainable cropping system. However, the benefits of cover crops extend beyond soil quality. In particular, more and more growers are realizing the insect, disease and weed management benefits of cover crops.

This publication is meant to serve as a practical guide to using cover crops on small- to moderate-size fresh market vegetable operations. For more complete and thorough information on cover cropping principles, see the "Other recommended resources" section on page 15.

The benefits of cover cropping

Cover crops bring a host of benefits to farms of all types. Due to the intensive nature and high fertility needs of fresh market produce farms, cover crops assume a vital role. By using rotations of both leguminous and nonleguminous cover crops, growers can begin to "close the nutrient loop" on their farms and rely less on purchased and imported fertilizers. The soil quality benefits of cover crops include:

- protection against soil erosion
- building and maintaining both active and stable organic matter
- improving soil structure and tilth
- improving the capillary action, or upward movement of water, within soils
- increasing the biological activity in soils
- the fracturing of hardpan by deeply rooting cover crops
- the addition of nitrogen to the soil by legume cover crops (peas, clovers, vetch, etc.)

Cover crops at work: fall-planted rye on the left, spring-planted oats on the right

On market farms using organic and other sustainable agricultural practices, cover crops also can play an extremely important role in managing weeds, insects and

diseases. One fundamental way to minimize the impact of pests is to ensure overall plant and crop health. By improving soil quality and fertility, cover crops contribute to a holistic pest management strategy. However, there are more direct benefits as well. Cover crops can:

- smother or suppress weeds
- break insect and disease cycles, and provide habitat, pollen and nectar for beneficial insects

Additional benefits of cover crops include:

- providing animal feed
- providing a source of mulch
- adding to farm aesthetics
- helping balance the stress of increased production with the satisfaction of soil building

Oats and vetch are a great cover crop combination

Questions and challenges

The benefits of cover crops seem clear. But questions and challenges remain as vegetable growers at different scales of operation try to maximize those benefits, given the limitations of time and equipment. One challenge is the relationship between soil building and tillage. The most commonly employed implements on most market farms—namely the rototiller, moldboard plow and disc—can damage soil structure. It is easy to overwork the soil, especially when growing on a small scale and relying on a rototiller for field preparation.

Another challenge facing market growers is how to balance soil building and fertility management with the demands of succession planting and harvesting. The demands of making a living on the land may not always align with the needs of the soil. Furthermore, many market growers lack enough land to implement adequate cover crop rotations—especially longer term rotations involving season-long cover crops. Market growers who farm near urban areas with high land prices can be pressured into pushing the land to produce as much as possible.

Finally, how can growers maximize the pest management benefits of cover crops? There is both anecdotal and researched evidence about cover crops reducing weed, insect and disease pressure, but far more research and experimentation is needed in order to maximize and consistently replicate beneficial results.

The market farmer's advantage

While market farmers face the real challenges of time availability, lack of necessary equipment, land availability and economic pressures, they have some advantages as well.

1. Short season vegetables allow for many cover cropping options.
2. Small fields are ideal for experimenting with a wide range of cover crop varieties.
3. Cover cropping can create interest and open doors with neighboring farmers.
4. Cover crops make a garden or market farm look lush and dynamic throughout the entire growing season.
5. Cover crops help keep growers' busy lives in balance by keeping them focused on long-term soil building in addition to the next day's produce delivery.

There is no shortage of creative, devoted market growers who are adept at finding new solutions to age-old problems. The rest of this publication is devoted to sharing ideas and information that will help both new and experienced vegetable growers make the best use of cover crops in their farming systems.

Equipment needed to effectively manage cover crops

Seeding: A simple broadcast seeder can be used on a small (garden) scale with good success. A drag, harrow or cultipacker helps cover seeds and provides adequate seed to soil (seed to moisture) contact. Many market farms use old six-foot grain drills to plant cover crops. These can be found at auctions or used equipment dealerships for a reasonable price ($100-400). The hand-pushed Earthway seeders that growers commonly use to plant vegetable seeds can also be used for drilling in cover crops on a small scale, or in narrow strips or beds. Compared to broadcast seeding, less seed is needed for drilling and more uniform stands can be achieved. Even with a drill, a cultipacker will hasten germination. Higher seeding rates are used for grasses and legumes grown as cover crops than for seed or forage production. Like all plants, cover crops need water to germinate. Timing a planting before rain is ideal. As a last resort, sometimes overhead irrigation is used in order to germinate a cover crop in a timely manner and get a jump start on any weed species present.

A small seed drill works well for planting cover crops

Residue management: A flail chopper (or stalk chopper) is the implement of choice for cutting or clipping cover crops before the residue is incorporated into the soil. A small (6') used flail chopper can be purchased for around $300 to $1,000. These

A flail chopper works well for clipping cover crops

require a tractor with sufficient horsepower: at least 30 to 40hp. Old sickle bar mowers are often less expensive, but they do not chop as finely and can leave a relatively thick mat of vegetation. Furthermore, a sickle bar mower often cannot handle a dense stand of vetch. Without tractor-mounted implements, it is wise to clip more often so as to avoid a tall, dense stand. A good tool for clipping at a small scale is a walk-behind sickle bar mower—although these can be expensive. Rotary mowers can also be used, especially for cover crops that become too tall or dense for a flail chopper. In a small market garden, it is best to stick with low-growing, "succulent" covers such as oats, peas and low-growing clovers. Avoid dense, matting cover crops such as hairy vetch that are very difficult to manage with small scale equipment. Appendix A on page 16 includes cover crops that are best suited for smaller-scale growers.

Mowing at the flowering stage is the most effective way to kill a cover crop before incorporation (or if using the cover crop to produce a layer of mulch). Another option is to use a roller-crimper. This kills and lays down the cover crop to form a mulch residue. For more on this technique, see "No-till vegetables" on page 8.

Tillage: Cover crops are most commonly incorporated with rototillers at smaller scales, and tractor-mounted rotovators at larger scales. Spaders, either walk behind or tractor mounted, can also be used. These do less damage to soil structure than rototillers. A more traditional approach is to turn under cover crops using a moldboard plow and then follow this with a series of cultivations using some combination of a disc, field digger and harrow. Turning the cover crop under, however, places it in an anaerobic, or oxygen deprived, environment—not the ideal condition for decomposition. Inverting the soil also brings weed seeds to the surface where they can germinate. Field diggers and power harrows are effective tools that are gentler on the soil. The following basic sequence, used by Dan Guenthner at Common Harvest Farm in Wisconsin (2), will incorporate most cover crops and create a nice seed bed:

1. First, flail chop the cover crop.
2. At least 24 hours later, follow with a field digger with sweeps that operate at four to six inches deep.
3. Follow with a power harrow—such as a Lely Rotera—or a rotovator. The power harrow will stir the soil and lightly incorporate the residue without inverting the soil profile. The rotovator will chop and mix the cover crop into the soil.
4. Finally, use a chisel plow that operates at 12 to 18 inches deep to aerate the soil and lay out your beds.

Between stages 3 and 4, you can allow some weeds to germinate and use the harrow again to create a clean seed bed.

A field digger and spike tooth harrow can be used to prepare the ground for seeding

If a moldboard plow or disc are used—these tools move soil horizontally and can create a plow pan—it is recommended to alternate their use with tools that work vertically, like chisel plows and subsoilers.

At a small scale, rototillers or small spading tillers are about the only options (aside from hand digging). Because rototillers can damage soil structure—especially if they are overused—it is generally best to use them at shallower depths and at lower revolutions per minute (RPMs). Another option is to hire a neighboring farmer to till your soil with a tractor-mounted digger and/or chisel plow before using a rototiller for final seedbed preparation.

Regardless of the tools employed, keep them in working condition so that when the time comes to plant, clip or till, you can act quickly and efficiently. Timing is important, and you need to be ready to take advantage of relatively short windows of opportunity during various seasons and between rainstorms.

The vegetable crop that follows the cover crop often determines when the cover crop is killed and incorporated. However, early or delayed incorporation can have negative consequences. Researchers recommend tilling just before or at full bloom. This results in slower decomposition of the cover crop residue and a release of nutrients over a longer period of time. "Incorporating before bloom when foliage is green and succulent results in rapid increase in soil biological activity, rapid decomposition of the cover crop, and a quick release of nutrients into the soil" (5). If mowing and tillage occur after bloom, the cover crop may reseed itself. Furthermore, waiting too long also results in higher carbon to nitrogen ratios. This slows decomposition and delays nutrient availability. "In most cases, it is necessary to make tradeoffs between practices that maximize the growth of the cover crop and practices that maximize the marketable yield and profitability of the vegetable crop grown that season" (5).

Some growers leave cover crop residue on the surface as mulch and use no-till transplanting or strip tilling in order to reduce tillage and control weeds. For more on this, see the "No-till vegetables" section on page 8.

Cover cropping sequences

There are several different windows of opportunity for planting cover crops and a variety of possible cropping sequences, based on the length of the cropping season. For example, in a field or section of a field that will be planted to early spring crops (peas, spinach, radishes, etc.), it is best to plant a cover crop the preceding fall that will winterkill, making it easy and quick to till and plant in the early spring. In an area that will be planted later with main season crops (such as tomatoes, peppers or squash), a perennial cover such as winter rye can work well. This strategy will prevent soil erosion and keep weeds in check until it is time to till and plant. There are many options for a full season of cover cropping. The following are sample sequences that market growers in the Upper Midwest have found useful and successful.

Cover crop options

(Crops listed by season planted. Specific planting times are included in Appendix A.)

Spring	Summer	Fall
Mow fall seeded rye/vetch	Rape	Rye
Oats and peas	Millets	Rye and vetch
Nitro alfalfa with oats	Sudangrass	Winter rape
Berseem clover	Oats and peas	Peas
	Buckwheat	Turnips
	Clovers	Oats
	Fallow cycle (for weed control)	

Cover cropping sequence notes:

- A one- to three-week fallow cycle serves as a transition between each cover crop and garden crop. This fallow period is an opportunity to allow weeds to germinate. A shallow cultivation just after weeds germinate provides a stale seed bed for the coming garden crop. Over time, these fallow periods can be reduced as weed pressure diminishes.
- Garden crop foliage should be flail chopped shortly after harvest is complete in order to expedite cover crop seeding.
- Most cover crops (except buckwheat) can be clipped one to three times to encourage tillering. Tillers are shoots that sprout from the base of grass plants. Clipping also prevents the cover crop from going to seed and becoming a weed in the next garden crop. It also prevents the growth of a dense stand that makes cutting and incorporating difficult with smaller scale equipment. This is especially true for Sudangrass and millet.
- Buckwheat can become a weed if the seeds are allowed to mature. The challenge is to walk a fine line between providing flowers for pollinators and clipping the stand before it has set too much seed.

Cover crop sequence options[1]

Full Fallow Season

Spring	Summer	Fall	Spring
Crop residue or cover crop from previous fall	Buckwheat OR Sudangrass	Oats and peas	Spring vegetable crops
Crop residue from previous fall OR spring-sown oats and peas	Buckwheat	Winter rye	Plow rye 2-3 weeks before planting a vegetable crop Summer/fall vegetable crops
Oats and nitro alfalfa or oats and clover	Mow oats to prevent seed set	Overseed winter rye into nitro alfalfa, which will winterkill or leave clover to overwinter	Summer/fall vegetable crops
Clover or clover/grass mixture planted previous June or July	Mow, plow and fallow period to express and cultivate weeds	Rye/vetch OR oats and peas	Summer/fall vegetable crops OR spring vegetable crops

Early Spring Garden

Fall	Spring	Summer	Fall
Oats and peas that winterkill	Early spring vegetable crops	Buckwheat or Sudangrass or oats and peas	Winter rye or rye/vetch mix or leave oats/peas to winterkill
Fall plowed field	Early spring vegetable crops	Buckwheat or Sudangrass or oats and peas	Winter rye or rye/vetch mix or leave oats/peas to winterkill

Main Season Garden

Fall	Spring	Summer	Fall
Winter rye or rye/vetch mix	Plow rye 4-6 weeks before planting vegetable crop	June-planted vegetable crops	Winter rye or oats
Clover or clover grass mixture	Plow clover 3-4 weeks before planting vegetable crop	May and June-planted vegetable crops	Winter rye or oats
Oats and vetch planted in late August or early September	Plow vetch 3-4 weeks before planting vegetable crop	May and June-planted vegetable crops	Winter rye or oats

Fall Garden

Fall	Spring	Summer	Fall
Clover or rye	Mow as needed to control weeds or manage cover crop	Garden planted in July and August	Leave crop residue or seed winter rye in crops harvested before early October

[1]Adapted from a handout created by Dan Guenthner, Common Harvest Farm, Osceola, Wisconsin

- Winter rye is an aggressive plant that can regrow under moderately moist conditions. It is best to clip rye before it gets too tall. If this cover crop exceeds 10 to 12 inches tall before the first clipping, its regrowth potential diminishes.
- Annual rye (annual ryegrass) and winter rye ('cereal' or 'grain' rye) are different plants. Ryegrass is a tender annual. Winter rye is a hardy species that grows into the fall and early winter, and overwinters before growing vigorously the following spring, flowering and going to seed. If your goal is weed suppression, winter rye can be allelopathic. Allelopathy refers to chemicals in some plants that inhibit the germination or growth of other plants. Unlike cereal rye, annual ryegrass has no allelopathic effect. Winter rye's allelopathic effect, which may suppress the germination of small-seeded vegetables, lasts four to six weeks after turning it under. Keep this in mind if you plan to seed a market crop behind it. The most commonly used cover crops on organic market farms in Wisconsin and Illinois are winter rye, clover, vetch and buckwheat (3).

Buckwheat can become a weed if the seeds are allowed to mature

Relay planting

Relay planting is the establishment of cover crops between rows of vegetables, usually during the summer or early fall. When the vegetable crop is harvested, the cover crop is already in place and poised to protect the soil during the winter. Growers and researchers have found success with using rye, vetch and red clover in relay systems with corn, beans, spinach and brassicas. With sweet corn, varieties that do not cast heavy shade are recommended.

Although relay planting is a bit more involved than seeding into bare ground, it can help ensure that a greater percentage of land is planted to cover crops in the fall. Relay planting also provides cover crops with additional time to grow before frost and decreasing day length terminate the growth of tender annuals, or limit the growth of hardy crops. Relay planting can potentially increase the amount of farmland protected by cover crops. In Wisconsin and Illinois, 45 percent of organic vegetable growers plant less than 50 percent of their land in vegetables to cover crops by season's end. Twenty-two percent plant 50 to 74 percent of their cropland to cover crops, and a third of these growers plant 75 to 100 percent of their cropland to cover crops in the fall (3).

No-till vegetables planted into cover crop mulch

Given concerns about the impacts of tillage on soil health and erosion, growers and researchers have been developing various no-till vegetable systems. In addition to being good for the soil, no-till reduces weed pressure by leaving a layer of mulch on

the surface and not bringing weed seeds to the surface via tillage. The most prominent no-till system uses a combination of hardy winter cover crops, often winter rye with a legume such as hairy vetch. These cover crops are planted in the late summer or early fall and mowed or rolled after they begin to flower the following spring, usually in late May. This allows time to transplant a warm-season vegetable crop directly into the resulting layer of organic mulch. Crops such as tomatoes, peppers, eggplant, squash or cucumbers are planted with a no-till transplanter, while large-seeded crops such as sweet corn or beans are seeded directly using a no-till drill.

Late spring is a good time to mow rye and vetch

Experiments with a wider range of cover crop species for no-till vegetables planted in other seasons are yielding promising results (not necessarily tested in the Upper Midwest), according to researchers at the Rodale Institute (9). "Cool-season annuals like oats and fava beans can be planted in early spring, and then killed in mid summer for late plantings of cucumber, bean or summer squash. Summer annual (frost-tender) cover crops like millets, cowpeas or soybeans can be planted after the spring frost date, and then knocked down at the end of summer to plant fall brassicas or other fall crops. Finally, cover crops that are not winter hardy in a given location can be planted in mid to late summer and allowed to winterkill, forming a mulch for no-till spring vegetables" (9).

The timing of mowing or rolling is particularly important in no-till systems. For example, "if vetch is cut before the bud stage, it regrows and competes with the crop" (5). Roller crimpers are relatively expensive, so some growers are making them themselves.

Finally, it is worth noting that no-till does have potential drawbacks. First, undecomposed cover crop residues may produce allelopathic chemicals that interfere with the germination and growth of the following vegetable crop. Second, unincorporated residues yield less organic nitrogen in the rooting zone for the following cash crop. Organic no-till systems are still quite new and experimental.

Cover cropping for fertility management

Different legume crops typically supply varying amounts of nitrogen to the following vegetable crop. Vetch produces high levels of nitrogen—as much as 100 to 150 lbs/acre. Clovers are also excellent nitrogen fixers, contributing about 80 to 100 lbs of nitrogen per acre while peas and beans often fix 40 to 80 lbs of nitrogen per acre

Yellow blossom sweet clover is one of the best cover crops for warm-season nitrogen production

(7, 8, 10). The amount of nitrogen produced will be greater if the legume is in place for the entire previous season. In the case of summer- and fall-planted legumes, the earlier the legume is planted and the better the stand, the more biomass and nitrogen that will be produced.

Not all of this nitrogen will be available to the following crop, and the timing of its availability can vary with decomposition rates and field and weather conditions. In many cases, additional nitrogen may need to be supplied with a fertilizer. Growing at least a portion of your own nitrogen is still a good practice, and cover crops have other direct and indirect benefits such as pest, weed and disease control.

A cover crop combination of a grass and a legume usually results in more biomass production, enhanced weed suppression and higher levels of organic matter. Grass-legume mixtures also balance the carbon to nitrogen ratio. This results in a more gradual release of nitrogen for the following vegetable crop. In contrast, an all grass cover crop tends to tie up nitrogen because the residue is high in carbon. A stand-alone legume cover crop is prone to a rapid release of nitrogen, which can potentially leach into ground and surface water. Legumes and grasses affect other nutrients as well: legumes often increase the availability of phosphorus, while many grasses increase the availability of potassium (9).

Maximizing the pest management benefits of cover crops

Research and experimentation on using cover crops to manage pests is increasing as both growers and researchers recognize the potential for biological and farming system approaches to address pest management challenges. Specific cover crops, as well as cover cropping sequences and practices have been identified that can help address disease, insect and weed problems. However, some weed, insect and disease suppression research results have proven difficult to replicate. Some information about pest management benefits is purely anecdotal. The following is a partial overview of what is known about using cover crops to manage pests, but growers may find it challenging to get the same results in all circumstances.

Cover cropping for weed management

Cover crops suppress weeds by competing for light and nutrients or, in some cases, releasing compounds that inhibit the germination or growth of weeds through allelopathy. Weed suppression by cover crops varies by species, management (planting

dates, planting densities, tillage and residue management, etc.), existing weed populations and weather conditions. Particular cover crops and management approaches can suppress, have no effect on, or even stimulate weed growth. Accordingly, shifts in weed populations can occur when using cover crops in annual rotations. Because of this, it is best to match cover crops and management to the particular weed problems in a given situation (4).

A swath of spring-sown oats and peas next to a recently plowed bed

Cereal grains and grasses are excellent choices to suppress late fall and spring weeds because they establish themselves quickly in cooler temperatures, cover the soil, remain in place through winter and grow rapidly in the spring. Legumes grow too slowly to be effective, but they can be used in combination with grains and grasses to suppress weeds and fix nitrogen. Drilling, rather than broadcasting, is the recommended planting method because this hastens germination and results in a more even stand. Higher seeding rates (by as much as 50 percent) are also recommended (1, 4).

The tillage required to incorporate winter cover crops can bring new weed seeds to the surface, however. As noted above, some growers are experimenting with no-till systems that leave cover crop residues on the surface as mulch. This can create obvious challenges with direct-seeded crops (particularly those that require a fine seed bed) as well as transplanting. Summer weeds can be smothered with warm season annual cover crops such as buckwheat or Sudangrass, or with season-long cover crops.

As mentioned above, some cover crops have an allelopathic effect, cereal rye being the most notable. Rye and rye/vetch combinations are common winter covers that are tilled before transplanting or seeding large seeded crops such as beans. Another approach is to bale the rye and then use it for mulch. In addition to rye, oats and barley can inhibit germination and root growth (1). Simply incorporating large amounts of residue, especially if succulent, often causes a sharp increase in soil-borne pathogen populations, especially damping-off fungi, which attack seeds as they germinate. This may account for some of the reduced weed and crop germination rates observed shortly after killing and/or incorporating cover crops (4). Because of this effect, it is wise to wait three weeks or so after incorporation before planting direct-seeded crops.

Many new vegetable growers face enormous weed pressure as they convert old hay fields, pastures and lawns into vegetable gardens. Appendix B on page 20 contains several cover cropping scenarios to ease this transition.

Cover cropping for insect management

Cover crops can affect a farm's insect community in several ways. They can attract both pests and beneficial insects by providing shelter and food, as well as making cash crops more difficult to locate. Management is complicated given that cover crops can act as a source and/or a sink for beneficial and pest insects (6). Given this complexity, careful observation, planning and timing are important.

The simplest strategy to achieve insect management benefits is to provide a diverse array of vegetation (6). Diversity in plant species and habitats contributes to overall farm diversity and helps ensure a balanced insect community, including beneficial predators. Increased diversity can be achieved by:

- selecting a diversity of cash crops
- utilizing a diversity of cover crops (such as planting both buckwheat and Sudangrass as summer cover crops since each has unique insect associations—see the chart on page 13)
- establishing permanent or semi-permanent hedgerows
- planning cover crop plantings and mowings to ensure that something is always in bloom (such as waiting until buckwheat has flowered before plowing a rye/vetch combination or mowing/plowing only portions of a stand at a time)
- strip cropping (the practice of growing crops in strips between adjacent stands of cover crops)

A solid stand of rye and vetch is suitable for strip cropping

Strip cropping can be a particularly useful strategy because it provides habitat for beneficial insects close to cash crops. For example, a solid stand of rye/vetch or clover can be mowed and plowed in strips, leaving habitat for ladybugs and other predators. The list of cover crops in Appendix A includes notes on whether various cover crops are suitable for strip cropping.

Planting special hedgerows to attract beneficial insects is another approach. Some seed companies (such as Johnny's Selected Seeds) offer mixtures that can be used to create borders or strips of beneficial habitat. Some growers have created

more permanent hedgerows that not only attract and harbor beneficials, but also yield a marketable crop such as curly willow or various types of perennial flowers and herbs. For example, members of the Umbelliferae family (such as caraway, dill and fennel) are attractive to parasitic wasps. Flowers in the Compositae family (sunflowers, asters, goldenrod, daisy, cone flower, etc.) attract insects such as lady-bugs, pirate bugs and spined soldier bugs, can be maintained in permanent beds and are readily marketed as cut flowers (6).

The following table, published by Plotkin (6), lists insects (both pest and beneficial) attracted to common cover crop species.

Insects attracted to common cover crop species

Cover crop	Beneficial insects	Pest insects
Buckwheat	Parasitic wasps, ladybugs tachinid and hover flies, lacewings	Tarnished plant bugs and aphids (note: aphids can act as a food source for beneficials)
Clovers	Parasitic wasps, big eyed bugs, minute pirate bugs, ladybugs, tachinid flies, and aphid midges	Spider mites & flower thrips (note: flower thrips can prey on spider mites and provide food for several predatory insects)
Hairy vetch	Minute pirate bugs, ladybugs predatory and parasitic wasps	Tarnished plant bugs
Cereals/grains	Ladybugs	Aphids

In addition to above-ground interactions, plants can impact soil-dwelling species. Oats, barley and sorghum-Sudangrass have been shown to reduce root-knot nematodes—a pest that can reduce carrot quality and affect other vegetable crops such as onions and potatoes. Research on various sorghum-Sudangrass hybrids and cultivars reveals that the leaves of these plants produce a nematicidal compound. To take advantage of this, sorghum-Sudangrass must be mowed and well-incorporated before first frost and while still green (1).

Other cover crops may actually increase detrimental species. Vetch can cause increases in root-knot nematodes as well as the soybean cyst nematode.

Cover cropping for disease management

Cover crops can help reduce disease problems in vegetables in various ways. Most obviously, cover crop rotations break disease cycles in the soil. Other benefits can come from strip cropping or utilizing cover crops as mulches. Mulches can delay

the onset of early blight in tomatoes by reducing soil splash onto leaves. Preliminary research suggests that oats may help reduce vegetable crop diseases caused by *Rhizoctonia* (1). Because some cover crop species are related to cash crops (most notably field peas), it is wise to rotate cover crops. Pea diseases such as *Sclerotinia* can build up quickly if peas are planted in successive years in the same location (1).

Seed sources

Some cover crop seed, such as oats and rye, can be bought from neighboring farmers. Other types, such as grain and field pea mixtures, clovers and sorghum-Sudangrass, are readily available at a local co-op elevator or feed store. More specialized seed, such as hairy vetch, rape, ryegrass, berseem clover, annual alfalfa and millet, is available from various seed companies throughout the Midwest and beyond. Sources for organic cover crop seed can be found by using the *Organic Resource Directory* published by the Midwest Organic and Sustainable Education Service (MOSES). This publication is free and is also available online at: www.mosesorganic.org/resourcedirectory.html.

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9. Schonbeck, M. and R. Morse. 2004. "Choosing the best cover crops for your organic no-till vegetable system: A detailed guide to using 29 species." Rodale Institute. Accessed 5/28/09. (newfarm.rodaleinstitute.org/features/0104/no-till/chart.shtml)
This resource offers a complete rundown of cover crops for use in no-till systems.

10. Sullivan, P. 2003. *Overview of Cover Crops and Green Manures*. USDA-ATTRA. Accessed 5/28/09. (attra.ncat.org/attra-pub/PDF/covercrop.pdf)

Other recommended resources

- Anne and Eric Nordell produced a 72-minute DVD and a 42-page booklet on cover cropping and tillage. The DVD costs $15 plus $3 shipping and handling; the booklet costs $10 plus $3 shipping and handling. Anne and Eric Nordell, 3410 Route 184, Trout Run, PA 17771.
- Appropriate Technology Transfer to Rural Areas (ATTRA). Call and ask for free information about cover crops and green manures. 1-800-346-9140. www.attra.org
- University of California SAREP Cover Crop Database: www.sarep.ucdavis.edu/cgi-bin/ccrop.exe
- *Green Manuring: Principles and Practice*, 1989, Woods End Agricultural Institute.
- *Green Manuring: Principles and Practice*, 1927 (out of print and hard to find but worth the search).
- Cover Crop decision tool: Cornell website that identifies cover crop options for different situations. www.nysaes.cornell.edu/hort/faculty/bjorkman/covercrops/decisiontool.php
- Midwest Cover Crop Council: A multi-institutional website maintained by Michigan State University with many links and free resources. www.mccc.msu.edu
- *Vegetable Farmers and Their Innovative Cover Cropping Techniques*. [Video]. Vernon Grubinger. 2006. University of Vermont Extension. Available from: www.uvm.edu/vtvegandberry/Videos/covercropvideo.html
- *Vegetable Farmers and their Sustainable Tillage Practices*. [Video]. Vernon Grubinger. 2006. University of Vermont Extension. Available from: www.uvm.edu/vtvegandberry/Videos/tillagevideo.html

Appendix A: Management Guide for Specific Cover Crop Species*

Crop	Characteristics	Planting Time	Seeding rate: #/1000ft²	Seeding rate: #/acre	Management and Comments	Suitable for small scale?
Alfalfa	Deep-rooted perennial legume. Excellent N fixer; drought tolerant; does not tolerate wet soils or flooding. Requires soil pH above 6 and moderate levels of P and K. Use alfalfa/clover inoculant.	Spring or late summer to early fall.	1/2 to 2	15 to 20	There are 2 kinds of alfalfa: dormant and non-dormant. Dormants stop growing in mid-autumn and are very winter hardy. Non-dormants (such as Nitro) grow faster but are less hardy. Excellent forage crop and soil-builder but not an ideal cover crop—unless a grower has haying equipment and use or market for hay. If grown, Nitro is the best choice for market growers.	No. Heavy equipment needed for incorporation.
Clover (red and white)	Red (Medium, Mammoth, Alsike) and white (Dutch, New Zealand, Ladino) clovers are slow growing legumes. Whites are shorter and longer lasting. Tolerates soils too wet for alfalfa. Use alfalfa/clover inoculant.	Late winter (for frost seeding), spring or July/August (if moisture is adequate)	1/2 to 1	Red: 8 to 15 White: 5 to 15	Clovers grow slowly in the seeding year but rapidly the second year. Mow as needed to control weeds. Reds are the better N fixers, as is the New Zealand white. Clovers mixed with oats or annual ryegrass produce large amounts of biomass for soil improvement. Seed at lower rates if sown with grasses. White and red clovers can also be mixed. Well suited as cover crops.	Reds best incorporated by plows, chisels or heavy tillers; lower growing whites can be incorporated with rototillers.
Yellow Blossom Sweet-clover	A biennial. Flowers and completes life cycle after overwintering. Deep taproot, drought tolerant, excellent nitrogen fixer, and adapted to all soils except wet. Use alfalfa/clover inoculant.	Late winter (for frost seeding), spring, summer, or fall (40 days before killing frost)	1/2 to 1	10 to 20	Mow as needed to control weeds and growth. Mow high; it is intolerant of low mowing. Plow under in fall if an early vegetable crop will follow in spring. If overwintering, plow before flowering; do not allow to set seed. Mature sweetclover is fibrous and breaks down slowly. Excellent choice for intercropping if planted before the veg. crop or 1-year soil building crop. Mix with oats for added biomass. Cheap and easy to plant.	No. Requires plowing to incorporate.
Berseem Clover	Extremely vigorous, tall annual white clover. Tolerant of wet conditions. Excellent nitrogen fixer. Use alfalfa/clover inoculant.	Spring or late summer (if moisture is adequate)	1/2 to 2	15 to 25	Best if drilled but can be harrowed in. Makes excellent hay or heavy quantities of mulch. Cut when 7-20 inches. Don't mow close; leave 1-3 inches of stubble. Berseem leaves a friable seedbed so spring tillage requirements are minimal. Transplant directly into beds. Excellent weed suppresor. Good for interplanting because of slower summer growth. Mix with oats for biomass or 1-season soil building.	Yes. Can be controlled by mowing and no heavy tillage is needed.

* Adapted from information published by Charles Marr, Rhonda Janke and Paul Conway in "Cover Crops for Vegetables Growers" Kansas State University, 1998.

Crop	Characteristics	Planting Time	Seeding rate: #/1000ft²	Seeding rate: #/acre	Management and Comments	Suitable for small scale?
Soybean	Upright bushy legume. Must be planted in warm soil. Strong N fixer. Grows on most soils. Use soybean inoculant.	Late May through early August	2 to 4	50 to 150	Drill or harrow in. Excellent for planting after early vegetables; mowed residue leaves friable seedbed next spring. Early plantings best incorporated by Sept. to maximize benefits. If field is new or weedy, plant a fast-growing cover crop first (buckwheat). Let beans grow 80-100 days to maximize biomass. Can be plowed, disked or mowed (leaving residue on the surface). Cost, availability, rapid growth and N fixing make it an excellent choice.	Yes.
Field Peas	Grow like garden peas, only taller. Very cold tolerant and good N fixers (most N fixed before flowering). Use pea/vetch inoculant.	Spring	2 to 8	50 to 200	Drill or broadcast and harrow. For max. biomass, N, and weed supression, seed heavily. Mow and disk to incorporate. Heavy stands will clog sickle bar mowers. Produces so much biomass that small seeded crops cannot be sown immed. following. Peas mix well with oats or barley. Pea, oat, and hairy vetch mixtures are excellent for soil building and available from some suppliers. Best use is on ground to be planted in June/July.	Yes. Mow to control peas. Tilling is easier if vines rot 1-2 weeks or are removed and used as mulch.
Annual White Clover	Similar to yellow-blossom sweetclover. Deep taprooted and a strong N fixer. Use alfalfa/clover inoculant.	Spring or early fall	1 to 2	15 to 30	Drill or broadcast and harrow. Grows rapidly and can become woody when mature and difficult to incorporate. Mow as needed. Mix with oats for a nurse crop. Later plantings make good growth before being winterkilled. Seed is hard to find (most common variety is Hubam). As most clovers are biennial, make sure what you are getting is annual sweetclover.	Yes.
Oats	Fast growing and frost-tolerant annual. Extensive, fibrous roots hold soil and produce biomass. Tolerant of wet soils and low pH. If allowed to mature, oats will reseed and new growth will winterkill.	Late winter (frost seeding) and spring or fall	2 to 4	100 to 140 (1-2 bushels) if mixed; up to 4 bushels if seeded alone.	"Feed" or "seed" oats are acceptable for cover crop use. Drill or broadcast and harrow. To produce mulch, mow when needed. Oat straw decomposes rapidly and acts like leaf mulch in the forest. Oats are a good trap crop; late summer plantings will hold N from manure applications. Oats provide good winter erosion control. Oats are excellent for mixing with legumes. Versatile, available and cheap.	Yes.

Crop	Characteristics	Planting Time	Seeding rate: #/1000ft²	Seeding rate: #/acre	Management and Comments	Suitable for small scale?
Buck-wheat	Fast-growing, warm season annual (matures in 40-50 days). Not drought or frost tolerant.	Late spring to late summer	2 to 3	50 to 100	Drill or broadcast and harrow. Fast growth enables buckwheat to smother weeds and for several sequential plantings to be made in one season. Once mowed, residue decomposes rapidly and soil is friable; little tilage is necessary for next crop. Will reseed itself and can become a weed if flowers mature to seed. Buckwheat residue can be a good winter cover if late plantings are thick and growth is adequate.	Yes. Excellent choice to follow early vegetables or to help clean up a weedy field.
Japanese Millet	Fast growing summer annual grass. Limited frost tolerance and will winterkill. Requires fertile soil for rapid growth. Tolerates frequent clippings and makes excellent forage/ hay. Tolerant of both droughty and wet soils.	Late spring through August	1 to 1 ½	25 to 30	Drill or broadcast and till shallow. Manure or fertilize for best results. When intended as summer long trap crop, mowing is important. Clip before heading out (~60 days) and leave 3" of stubble. Not suitable for mixing but a good choice for a full season smother crop following early vegetables. Good choice for cleaning weedy fields or converting land to vegetable production. Also excellent if there is a need for mulch or feed.	Yes, but make sure soil is fertile enough to support multiple cuttings.
Sorghum-Sudan-grass	Fast growing, drought tolerant annual grass. Will grow over 6' if left uncut. Grows on most soils but needs fertile soils for best results. Winterkills.	Late spring through July	1 to 2	15 to 40	Drill or broadcast and harrow. A good N trap crop and excellent smother crop that produces tremendous biomass (more than any other cover crop) even with mowing. Decomposes slowly; allow 1 month before planting next crop. Needs plentiful manure to reach full potential. If left too long it can become unmanagable.	No. Too rank in growth habit. Even large-scale farmers need heavy duty mowers to cut for hay or silage.
Forage brassicas (cabbage family crops)	Most common types are turnips, rape and kale. Use readily available cheap varieties such as Purple Top Turnips. Will tolerate low fertility but do best under fertile condiitons. Rape's long tap root loosens heavy soils.	Spring, summer or fall	1/4 for turnips 1/3 for rape or kale	5 to 7 for turnips 8 to 15 for rape or kale	Drill or broadcast with light incorporation. Not recommended if vegetable brassicas are grown nearby. Will tolerate mowing or grazing. Will trap N and other nutrients and provides ground cover after winterkill. Value as a cover crop is limited unless livestock forage is needed. Best used following early vegetables, mixed with summer legumes, or in mixes with peas, oats, vetch, etc. Can also be used under sweet corn.	Doesn't require heavy equipment but value is limited unless livestock forage is needed.

Crop	Characteristics	Planting Time	Seeding rate: #/1000ft²	Seeding rate: #/acre	Management and Comments	Suitable for small scale?
Hairy Vetch	Cold tolerant viney legume. Excellent N fixer (100 lbs/ acre). Needs pH of 6 or 7 for best results. Tolerates most soils but will not survive flooding. Drought tolerant once established. Tolerant of mowing but intolerant of shade. Use pea/vetch inoculant.	Spring, summer or fall (summer plantings generally less sucessful)	1 to 2	25 to 50	Best if drilled but can be harrowed in. Sow with a nurse crop of small grain in 1:1 or 1:2 ratio by volume (vetch to small grain). For overwintering, plant 3-4 weeks before a hard frost. A wet spring can delay incorporation and a mature small grain may hinder breakdown of the vetch following incorporation. Mow vetch/small grain mixtures if incorporation is delayed. Incorporate in April for a May-planted cash crop. Plow to incorporate or use heavy disk and chisel plow. Spring-sown vetch is easier to manage and can be left standing, tilled under or disked in the fall.	In general, no. It can be mowed until it dies, but other crops are easier to manage. Viney growth will quickly clog a rototiller.
Other Vetches	Less winter hardy than hairy vetch. All require pea/ vetch inoculant.	Same as hairy vetch	Same as hairy vetch	Same as hairy vetch	Similar to hairy vetch but not as exacting. Seed prices are higher.	Yes.
Grain Rye (winter rye)	Very hardy small grain. Grows longer in fall than other grains and resumes growth earlier in spring. Grows on most soils. Extremely efficient nutrient scavenger, making it an excellent N trap crop. Dense, fibrous roots help build organic matter and make soil more friable.	Late summer to fall. Can be spring planted but will die before flowering and cheaper options exist.	2 to 5	50 if mixed with legume. 60-200 if seeded alone.	Can be broadcast and tilled but best if drilled. Can germinate on the surface if moisture is adequate. In spring, till when rye is 6-8” or wait until it flowers. Can be used as windbreak by leaving strips between beds. Often sown with hairy vetch but this mixture can get away from you unless soil is sandy or very well drained. Rye shows weed suppressing (allelopathic) abilities (include rye straw) and is useful to help clean weedy areas. Tremendous biomass production can create challenges for incorporation and problems with planting and germinating small seeded vegetables. Main challenge is having time for adequate incorporation between spring rains.	It can be managed without plows or heavy disks if incorporated early enough. Or let flower, mow, allow to decompose, and plant summer legume or fall cash crop.
Annual Ryegrass	Fast growing cool season grass. Tolerates most soils, including wet. Dense root system is excellent for trapping N, holding soil and loosening heavy soils. Growth habit compliments clovers. Not drought tolerant. Will self seed.	Spring or late summer to early fall	1 to 2	18 to 40	Best drilled but can be tilled in shallowly. Easy to establish and grows rapidly. Mowing is not necessary except to avoid setting seed. Unlike other mature small grains, annual ryegrass stays green and is easier to incorporate, although the dense root system can take time to decompose (small seeded vegetables are not recommended following ryegrass). Excellent choice as a nurse crop with legumes or for pathways.	Yes. Easily incorporated if tilled early in spring.

Appendix B: Bringing land into production and tackling persistent weeds

Getting off to a good start is important in any new enterprise. Decisions made early in your planning process can have significant influence on the success of the farm for years to come. Rather than delve into the question of how to find land suitable for vegetable farming, this section assumes you already have a site selected.

The first question to answer is: ***Has the land been in crop production in the preceding year?*** If a row crop (corn or beans) or a small grain has been grown in the previous season, the tillage necessary to convert the land to vegetables will be considerably less than if you are following extensively rooted crops such as alfalfa, pasture or grass hay ground.

Many beginning market growers are forced to convert a deeply rooted sod into productive vegetable land. It is likely that this sod will contain Quackgrass and other rhizomes with well-established root structures. These grasses are difficult to control using organic methods. However, in the process of preparing your ground for intensive vegetable production, these same grasses can teach you about your soil structure, weed pressure and how water moves over and through your soil.

Here are some general guidelines for bringing fallow ground into production:

1. ***Start early.*** Plan on starting this process a full season before you intend to grow vegetables. Bringing new land into production in July or August of the preceding year allows time to cultivate the ground a number of times to dry up the rhizomes in the sod. By starting this process in mid-summer, you also avoid having too much exposed ground during the traditionally rainy months of May and June. Following a four- to six-week cultivating process, plant a fall-seeded cover crop of winter hardy rye or oats and peas.

2. ***Be careful not to overwork the ground.*** A heavily matted sod may require the use of a moldboard plow. If you do not own one, consider hiring a neighboring farmer to plow your field or garden for you. If you do plow, do so only to the depth of the root zone of the sod. In this process, the plow is used as an under cutter. The resulting action will turn the sod up to dry rather than burying it deep where it may not fully decay and may create a sponge-like mat that disrupts the capillarity of the soil. Many gardeners use rototillers to dice up this heavy sod structure. In doing so, they can spread the rhizomes rather than keeping them intact and

effectively drying them up. An excellent tool for working new ground is a 5-shank field cultivator with 16" sweeps. This tool undercuts the residue at a depth of four to six inches. This type of field cultivator can be used in conjunction with a power harrow or rotovator that stirs the soil and knocks off the roots of the sod residue.

3. ***Observe and gather information.*** By starting early to bring land into production, you will have an opportunity to learn about your soil. It is useful to know the cropping history of your farmland going back as far as possible. It is recommended to test your soil and correct the pH level, if necessary. One of the most important reasons for starting to prepare ground early is to gain a better understanding of the ***variety and amount of weeds to anticipate your first season.*** This window of time allows you an opportunity to express weeds and identify areas of your field that may be better suited for specific crops. Carrots and onions in particular benefit tremendously from being planted in areas with less weed pressure.

Starting a year ahead also allows ample time to measure or pace off a new field and mark row lengths and room necessary for headlands and roadways. Getting to know the texture, slope and general qualities of your soil a full season ahead will pay immediate dividends.

Tackling persistent weeds

Even after a year of cover cropping, troublesome weeds may remain. Dealing with grassy areas—and Quackgrass in particular—can be a challenge, but there are cover-cropping methods that can greatly reduce, if not eliminate, these weeds. Here are several approaches that have worked for other growers:

- ***Buckwheat – Buckwheat – Rye***.[1] This method will sacrifice growing a marketable crop for one season, but can be very effective. It also contributes nutrients and improves soil structure and tilth. Till the area in the spring as soon as the soil is dry enough. If the area is small, you can walk over it and remove exposed rhizomes and roots. When the weather turns warm and all danger of frost is past, plant the first crop of buckwheat. It will likely be necessary to till immediately before planting to eliminate grassy regrowth and early spring weeds that may have sprouted. Seed the buckwheat heavily (60-90 lbs/acre or 3 lbs per 1,000 square feet). The buckwheat must form a dense canopy in order to be effective. Till the buckwheat when it just begins to flower to prevent it from setting seed. Allow weeds to germinate and then till the area again and reseed buckwheat at the same heavy rate. This second crop should be tilled under in late summer or early fall, at least three weeks before first frost.

Let the area rest for one week before seeding winter rye at a rate of 90-120 lbs/acre or 3 lbs per 1,000 square feet. It will germinate and grow a few inches before going dormant for the winter. In early spring, the rye will green up with new growth. Till in the rye at least two weeks before planting vegetable crops. In any case, do not let the rye grow much beyond 12 inches tall as it will become very difficult to till down with small-scale equipment.

- ***Winter cover – Fallow – Winter cover.***[2] Anne and Eric Nordell in Pennsylvania grow back-to-back winter cover crops to manage weeds. A brief stint of aggressive summer tillage between the two cover crops keeps annual weeds from setting seed. First, yellow blossom sweet clover is overseeded at 20 to 24 lbs/acre into early crops such as onions or spring lettuce. Lettuce is overseeded a week or two after planting but before leaves open up to trap sweet clover seeds, while onions are overseeded near harvest. The Nordells walk up and down every other row with a hand-crank broadcast seeder. They harvest the cash crop, then let the clover grow through summer. Yellow blossom sweet clover (one of the best cover crop choices for warm-season nitrogen production) puts down a deep taproot before winter if seeded in June or July, observes Eric. Note: the clover alone will not suppress weeds. It works on their farm because of their successful management efforts over a decade to suppress overall weed pressure by crop rotation and varied cover crops.

  The following spring, the sweet clover grows until it is about knee-high in mid-May. Then the Nordells clip it just before it buds. They let the regrowth bloom to attract pollinators and beneficial insects to the field, before clipping it again in July. In early- to mid-July, the Nordells moldboard plow the sweet clover to kill it. They then leave the ground in bare fallow, working it with a spring tooth harrow to hit perennial weeds at the weakest point of their life cycle. Harrowing every two to three weeks brings weed roots and rhizomes to the soil surface, where they bake in the summer sun. The harrowing also kills flushes of annual weeds before they can set seed.

  After five years in this weed-killing rotation, the Nordells have been able to cut back on harrowing. In mid-August, the Nordells plant a second, overwintering cover crop. In this rotation, they seed a mix of rye and hairy vetch. They broadcast and lightly incorporate about 80 lbs rye and 30 lbs vetch per acre. The rye establishes quickly, putting on good growth both above and below the surface, while the vetch fixes nitrogen. Another combination is yellow, red and white clover in a 2:2:1 ratio by volume. Rye and vetch are a popular combination to manage nitrogen. The rye takes up excess N from the soil, preventing leaching. The vetch fixes additional nitrogen, which it releases after it is killed the following spring prior to planting the next cash crop. With the August seeding, the Nordells'

rye/vetch mixture produces most of its biomass in fall. The Nordells plow the rye/vetch mix after it greens up in late March to early April, working shallowly so as not to turn up as many weed seeds. They forego maximum biomass and N for earlier planting of their cash crop—tomatoes, peppers, summer broccoli or leeks—around the end of May.

- ***Spring fallow – Pumpkins – Fall/winter cover.*** This method lets you grow a marketable crop. First, allow weeds/Quackgrass to grow in the spring until six- to eight-inches tall. At this point, the Quackgrass begins transferring energy resources away from its roots and into producing a seed stalk and head. While it is vulnerable, moldboard plow and disk the area lightly. A series of cultivations with a spring tine harrow (field digger) will knock back regrowth, bring rhizomes up to the surface to dry out, and can also drag rhizomes to the edge of the field. Pumpkins are then transplanted into the field. Cultivate again as necessary before the pumpkins begin to vine. The pumpkin vines will quickly form a closed canopy and suppress weed growth. You may want to consider a closer spacing than normal (four to five feet between rows rather than six feet) to be assured of a quick-forming, dense canopy. As the pumpkin vines die back in the fall, a late fall cover crop (oats and peas, rye or rye and vetch) can be overseeded. This method requires a sufficiently long growing season to achieve a decent pumpkin harvest (the transplants may not go into the field as early given the series of cultivations prior to planting), but it has been used successfully in southern Wisconsin.

Mulching

Another non-chemical means of removing weeds is mulching heavily for a year. Note: this method is more feasible and appropriate for smaller scale gardens. First, apply a thick layer of organic mulch (hay, leaves, even fresh manure). Then, top this with some kind of material that will block out light (black plastic, layered newspaper or old tin roofing). Leave this on for one full year. An exception is plastic. This should be removed before winter or else it will begin to break apart. After the spring thaw, remove the covering and pull back the mulch. Check to see if any roots or rhizomes survived their year of darkness. The soil should be ready for planting, but if not, cover the garden plot back up for another year.

Plan only a fall garden

If you are unable to cultivate the ground during the preceding season, a garden is still possible, albeit more difficult. One consideration would be to not push for a spring crop. Rather, give yourself time to get the land adequately ready and plan for a summer or, better yet, a fall garden. On a small scale, almost anything is possible. One can plant into spring-plowed sod within three weeks. However, yields are usually compromised and weed pressure can be significant.

Check in with your county extension office to see if they have information on cover crops. And don't be afraid to ask neighboring farmers for advice. Many will offer it whether you ask for it or not! Remember to ***start small, be realistic and enjoy the work***. Good luck!

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[1] Adapted from *Weed Ending Secrets*, Rodale Press Inc., Emmaus, PA, 1994.

[2] Adapted from *Managing Cover Crops Profitably*, Second Edition, by the Sustainable Agriculture Network, reprinted 2000, SAN, Beltsville, MD, pp. 34-42. Complete text: www.sare.org/handbook/mccp2/index.htm. To order: http://www.sare.org/htdocs/pubs/ToOrder.html

Cover Crop Fact Sheet

SUSTAINABLE FARMING ASSOCIATION • SFA-MN.ORG

Prepared by Kent Solberg, SFA Livestock & Grazing Specialist

- **Cover crops are** a "tool" that can provide substantial benefits to improving soil health, productivity and farm profitability.
- **Cover crops are not** a "silver bullet" but work best in combination with diverse crop rotations, no-till, and livestock integrated into the cropping enterprise through planned grazing.
- **Complex cover crop blends**, or "biological primers," typically consist of eight or more plant species in the mix.
- **Biological primers** have demonstrated their effectiveness in jump-starting the biological systems in many soil types and farm applications.
- **The more diverse** the complex cover crop mix, the better the response from soil microbes and the higher level of drought tolerance.
- **Biological primers** are customized to meet the needs and goals of a particular field and farm operation.
- **Previous crop history** and future cropping plans for a particular field are essential in determining a specific cover crop blend.
- **A sound crop rotation** must include representatives from each of the four major crop types: cool-season grasses, cool-season broadleaves, warm-season grasses and warm-season broadleaves (see table below for examples).
- **Drill boxes** are filled only one-third full when planting complex cover crop blends to minimize small seed from sifting to the bottom of the seed box.
- **Complex cover crop blends** may be mechanically harvested as forage; however, the greatest biological and economic impact typically occurs when grazing livestock harvest approximately one-third of the cover crop and trample the remainder to protect soil and feed microbes.
- **Aim for 120-145 percent of full seeding rate** per acre in cover crop blends.
- **Be aware of herbicide rotation restrictions** when considering cover crops.

RESOURCES

SFA soil health portal:
sfa-mn.org/soil-health-grazing

Wisconsin Extension herbicide rotation restriction brochure:
tinyurl.com/zcg9qum

YouTube: Search "Innovative No-till" and "Slake and Infiltration Test"

Burleigh County (N.D.):
bcscd.com

Cover Crop Chart:
mandan.ars.nrcs

Midwest Cover Crop Council

SmartMix Calculator™:
greencoverseed.com

EXAMPLES OF MAJOR CROP TYPES

Cool-season grasses: Oats • Barley • Wheat • Annual rye • Cereal rye • Triticale
Cool-season broadleaves: Field pea • Red clover • Hairy vetch • Common vetch • Turnip • Daikon radish
Warm-season grasses: Sorghum-sudan • Millets • Corn
Warm-season broadleaves: Soybean • Cowpea • Sunflower • Buckwheat

COVER CROP COMPARISON CHART

Species	N fixer	N scaven-ger	Biomass (adds OM)	Weed Sup-pression	Bene-ficial Insects	Seed (lb) per 1,000 ft^2	Seed (lb) per acre	Seed Cost ($) per 1,000$ft^2$	Seed Cost per acre	Reference cultivar	Reference Seed Source
Winter Rye		x	x	x		4	60 - 120	10	$		
Oat		x	x	x		4	110 - 140	11	$$		
Sorghum sudan-grass		x	x	x		1	40 - 50	13	$$		
Hairy vetch	x				x	1	25 - 40	10	$$		
Chickling vetch	x				x	2	70	6	$		
Sunn hemp	x		x			1	40	8	$$	8118	Fedco Seeds
Field pea	x		x	x	x	3	120	12	$$$	4010 organic field pea	Johnny's Selected Seeds
Red clover	x			x	x	1/2	5 - 15	5	$	mammoth red organic	Johnny's Selected Seeds
Crimson clover	x				x	2/3	22 - 30	6	$		
Fava beane	x					5	200	20	$$$	WW4403	Territorial Seed Co
Cowpea	x			x	x	5	100	17	$$	iron & clay	Johnny's Selected Seeds
Soybean	x					4	150	13	$$$	viking 2265 organic	Johnny's Selected Seeds
Tillage radish		x	x	x		1/2	8-10	6	$		
Buckwheat		x	x	x	x	2-3	50-90	7-10	$-$$		
Oilseed rape		x		x	x	1	5-15	6	$		

	Seeding Rate (lbs/acre)			Seeds/lb	Seeding Date	Seeding Depth	Total N (lb/A/yr)	P & K Scavenger	Erosion Control	Weed Control	Quick Growth	Grazing
	Drill	Broadcast/Aerial	In Mix									
Winter Rye	50-100	120-150	25-75	18,000	Aug.-Nov.	1"	-	VG	E	E	E	E
Oats	64-96	96-128	48-64	16,000	Aug.-Sept.	1 - 2"	-	F	VG	E	E	E
Annual/Italian Ryegrass	15-20	20-30	4-5	227,000	Aug.-Sept.	¼ - ½"	-	G	VG	VG	E	E
Tillage Radish	6-8	8-10	3-4	25,000	Aug.-Sept.	¼ - ½"	-	VG	VG	E	VG	E
Purple Top Turnips	4-6	6-8	1-2	220,000	July-Aug.	¼ - ½"	-	-	F	G	G	E
Forage Rape	4-8	8-10	1-2	145,000	July-Aug.	¼ - ½"	-	VG	VG	VG	VG	E
Mustard	15-20	20-25	2-4	180,000	Aug.-Sept.	¼ - ¾"	-	G	VG	VG	VG	P
Phacelia	7-12	Not Rec.	3-5	220,000	Aug.-Sept.	¼"	-	-	VG	VG	E	-
Nitrogen Producing Cover Crop Legumes												
Hairy Vetch	25-35	30-40	15-20	16,000	Aug.-Oct.	½ - 1"	70-200	G	G	G	F	F
Winter Peas	50-100	Not Rec.	25-50	2000	Aug.-Sept.	1 - 2"	70-150	F	VG	F	VG	VG
Crimson Clover	12-25	25-30	2-5	150,000	Aug.-Sept.	¼ - ½"	55-130	G	VG	VG	G	VG
Field Peas	100-200	Not Rec.	50-100	2000	Aug.-Sept.	2 - 3"	70-150	F	VG	F	VG	E
Cowpeas	50-100	Not Rec.	20-30	3000	June-Aug.	½ - 1"	100-150	G	E	E	VG	G
Lentils	40-50	50-75	10-20	15,000	Aug.-Sept.	1 - 1½"	20-30	VG	F	G	F	E
Lupin	50-90	Not Rec.	20-40	4000	March-May	¼ - ¾"	100-200	E	G	F	VG	G
Chickling Vetch	60-70	Not Rec.	20-30	2600	March-May	1 - 1½"	80-100	F	VG	G	F	E
Sunn Hemp	15-20	Not Rec.	4-8	11,000	June-Aug.	½ - 1"	100-140	F	VG	E	E	P
Balansa Clover	5-8	6-9	2-3	500,000	July-Sept.	¼"	50-100	F	VG	E	VG	E
Common Vetch	50-60	60-75	20-40	7,000	Aug.-Sept.	½ - 1"	50-120	-	G	G	F	G
Cover Crop Mixes												
Viking NitroMax CC1 Fall Radish + Field Peas + Oats	75-125	90-150	-	-	Aug.-Sept.	½ - 1"	50-75	G	VG	E	E	E
Viking ValueMax CC2 Fall Radish + Crimson Clover + Annual Ryegrass + Rape	15-20	20-25	-	-	Aug.-Sept.	¼ - ½"	30-65	VG	VG	E	E	VG
Viking WinterMax CC3 Winter Rye + Hairy Vetch + Fall Radish	40-50	50-75	-	-	Aug.-Sept.	½ - 1"	50-75	G	VG	E	E	E
Viking BioMax CC4 Fall Radish + Annual Ryegrass	15-20	20-25	-	-	Aug.-Sept.	¼ - ½"	-	VG	VG	E	VG	E
Viking AerialMax CC5 Winter Rye + Forage Rape + Common Vetch + Lentils	60-70	75-80	-	-	Aug.-Sept.	½"	20-40	VG	E	E	VG	E
Viking SummerMax CC6 Sorghum/Sudan + Japapanese Millet + Sunn Hemnp + Buckwheat + Soybeans	50-75	75-80	-	-	May-Aug.	½ - 1"	50-100	VG	E	E	E	G
Viking MultiMax CC7 Berseem Clover, Crimson Clover, Purple Top Turnips, Dwarf Essex Rape, Lentils, Annual Ryegrass	15-20	20-25	-	-	Aug.-Sept.	¼ - ½"	30-65	G	VG	VG	VG	E
Viking SpringMax CC8 Oats + Mustard	60-75	75-80	-	-	Feb.-April	¼ - ¾"	-	F	VG	VG	E	P
Plowdown Blend CC9 Mammoth Red Clover + Alfalfa + YB Sweet Clover + Alsike Clover	12-15	15-20	-	-	Feb.-May	¼ - ½"	50-100	E	G	G	P	VG

E = Excellent VG = Very Good G = Good F = Fair P = Poor

When Broadcasting/Aerial Seeding : Increase seeding rate by 25-30%
When Seeding for Forage : Increase seeding rate by 50%

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Farm Seed Comparison Chart

Type	Sowing Season	Min. Germ. Temp.	Hardiness Zone	Growth Rate	Sow Per 1,000 sq. ft.	Sow Per Acre	Seeding Depth	Nitrogen Fixation	Bees and Beneficial Insects	Compaction Control	Erosion control (Cover Crop)	Weed Suppression	Pest Management	Green Manure	Forage	Biomass (Organic Matter)
Alfalfa, Summer	Early Spring to late Summer	45°F/7°C	Frost sensitive	Fast	1/2 Lb.	15-25 Lb.	1/4-1/2"	Yes	Yes	X		X			X	X
Barley	Early Spring to Summer	38°F/3°C	7	Fast	2 Lb.	80-125 Lb.	3/4-2"				X	X		X		X
Buckwheat	Spring to Summer	50°F/10°C	Frost sensitive	Fast	2-3 Lb.	50-90 Lb.	1/2-1 1/2"		Yes			X		X		
Clover, Crimson	Anytime	45°F/7°C	7	Medium	2/3 Lb.	22-30 Lb.	1/4-1/2"	Yes	Yes		X	X		X	X	
Clover, Mammoth Red	Anytime	41°F/5°C	4	Fast	1/4 Lb.	5-15 Lb.	1/4-1/2"	Yes	Yes	X	X	X		X	X	
Clover, Medium Red	Anytime	41°F/5°C	4	Medium	1/2 Lb.	5-15 Lb.	1/4-1/2"	Yes	Yes	X	X	X		X	X	
Clover, New Zealand White	Spring to Summer	40°F/4°C	4	Slow	1/4 Lb.	5-15 Lb.	1/4-1/2"	Yes	2nd year		X	X		X	X	
Clover, Sweet	Spring to Summer	42°F/6°C	4	Medium	1/2 Lb.	10-20 Lb.	1/4-1"	Yes	2nd year	X	X	X		X	X	X
Cowpeas	Spring to Summer	58°F/14°C	Frost sensitive	Fast	2 Lb.	70-120 Lb.	1-1 1/2"	Yes						X		
Mangels	Spring to Summer	41°F/5°C	Frost sensitive	Medium	1/4 Lb.	10 Lb.	1/2-1 1/2"								X	
Manure Mix, Fall Green	Summer to Fall	45°F/7°C	See mix components	Medium	1 1/2 Lb.	50 Lb.	1/2-1 1/2"	Yes	Yes			X		X		X
Manure Mix, Spring Green	Spring to Summer	38°F/3°C	See mix components	Medium	5 Lb.	200 Lb.	1/2-1 1/2"	Yes				X		X		X
Millet, Pearl	Summer	60°F/16°C	Frost sensitive	Fast	1/4 Lb.	6-10 Lb.	1/2-1"				X	X		X		X
Mustards	Spring to Summer	40°F/4°C	7	Fast	1 Lb.	15-20 Lb.	1/4-3/4"		Yes		X	X	X	X	X	X
Oats, Common	Spring to Summer	38°F/3°C	8	Medium	4 Lb.	110-140 Lb.	1/2-1 1/2"				X	X		X		X
Oats, Hulless	Spring	38°F/3°C	8	Medium	4 Lb.	110-140 Lb.	1/2-1 1/2"				X	X		X		X
Peas, Field	Spring or Fall	41°F/5°C	7	Fast	3 Lb.	120 Lb.	1 1/2-3"	Yes				X		X		X
Radish, Oilseed	Late Summer	45°F/7°C	6	Fast	1 Lb.	10-20 Lb.	1/4-1/2"			X	X	X				
Rape, Dwarf Essex	Spring to Summer	41°F/5°C	7	Fast	1 Lb.	5-15 Lb	1/4-3/4"						X		X	
Rye, Winter	Anytime (Fall for grain)	34°F/1°C	3	Medium	4 Lb.	60-120 Lb.	3/4-2"				X	X		X		X
Ryegrass	Anytime	40°F/4°C	6	Fast	1 Lb.	20-30 Lb.	0-1/2"				X	X		X		X
Soybeans	Spring to Summer	60°F/16°C	Frost sensitive	Fast	4 Lb.	150 Lb.	1"	Yes								
Sudangrass	Early Summer	65°F/18°C	Frost sensitive	Fast	1 Lb.	30-40 Lb.	1/2-1 1/2"			X	X	X		X	X	X
Sunflower	Spring	70°F/21°C	Frost sensitive	Medium	1,500 seeds	20,000 seeds	1/2-1"		Yes							X
Turnips	Spring or late Summer	45°F/7°C	6	Fast	1/4 Lb.	8 Lb.	1/2"								X	
Vetch, Chickling	Spring to Summer	45°F/7°C	8	Medium	2 Lb.	70 Lb.	1"	Yes			X			X		
Vetch, Hairy	Anytime	60°F/16°C	4	Slow	1 Lb.	25-40 Lb.	1/2-1 1/2"	Yes	2nd year		X			X		
Wheat, Spring	Early spring	38°F/3°C	7	Fast	4 Lb.	60-150 Lb.	1/2-1 1/2"				X	X				


Spring Green Manure Mix


Fall Green Manure Mix


Ryegrass


Oilseed Radish


Sudangrass


Mighty Mustard® Pacific Gold


Barley (Conlon)


Royal Hybrid Sunflower


Winter Rye (Common)


Spring Wheat (Glenn)


Buckwheat (Common)


Hulless Oats (Streaker)


Oats (Common)


Chickling Vetch


Hairy Vetch

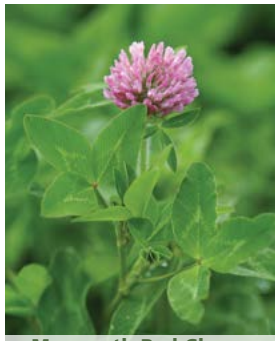

Summer Alfalfa


Cowpeas (Iron & Clay)


Field Peas (Maxum)


Soybeans (Viking 2265)


Crimson Clover


Mammoth Red Clover


Sweet Clover


Medium Red Clover


New Zealand White Clover


Hybrid Pearl Millet


Dwarf Essex Rape


Purple Top Forage Turnips


Mammoth Red Mangels

COVER CROP N CALCULATION

What cover crop did you plant?

How much plant material is in a given area (lb/ac)?	(C x 43,560) / (A x B)	_____ (D)
How many places did you collect a square of plant material from?		_____ (A)
How big was the square, in ft^2?		_____ (B)
How much did all of the plant material weigh combined, once dry?		_____ (C)
How much nitrogen in is in that material (lb N/ac)?	D x given percent from the table below	_____ (E)
How quickly will the material decompose and be available for plants?		
Will you leave it on the surface?	E x 0.4	_____ (F)
Or will you incorporate (till) it?	E x 0.5	_____ (G)
Do you need extra nitrogen?	H - F or H - G	_____
How much N does your crop need?		_____ (H)

COVER CROP	EXAMPLES	%N
Legumes	Hairy vetch Clovers Pea Sunn hemp	4% at flowering 3% is seeds are maturing
Non-legume grasses	Rye Oat Sorghum sudangrass	3% at flowering 2% is seeds are maturing
Non-legume broadleaves	Buckwheat Tillage radish Canola	Similar or a little less than grasses

CALCULATING MINERALIZABLE SOIL N FROM SOM

What % SOM does your soil test say you have?		= _____(A)
lb/ac of SOM	(A) x 2,000,000	= _____(B)
lb N/ac from SOM	(B) x 0.07	= _____(C)
lb mineralized N/ac/yr	(C) x 0.02	=_____