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Research Institute of Organic Agriculture Switzerland

Joint Bachelor Course on Organic Agriculture 2014

Lecture 7: Organic plant production I: Soil tillage and weed control, fertilization, crop rotation, variety choice in arable crops.

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### **Definition of Organic Production**

A production system that is managed ... to respond to site-specific conditions by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity.

Site-specific: understand each farm as a unique individual

Our Common Goal: Change this  $\implies$  to this:





# Reducing tillage in organic production systems

Reduced tillage goals

- > Enhance soil quality (tilth)
- > Conserve organic matter and moisture
- > Minimize soil disturbance
  - > Minimize weed germination
  - > Reduce compaction and erosion
- > Reduce fuel and equipment use
  - > Minimize hand weeding
- > Maintain yields

Key feature in organic RT

- > Cover crops intensively cultivated
- Seeding and rates, timing of seeding, methods of seeding, methods of killing
- Complex rotations and diversified operations/systems (crops and planting schemes)
  - > Integration of animals

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# Soil tillage: with or without ploughin

Advantage of ploughing

- Good aeration enhanced microbial activity
- > Efficient weed reduction (root spreading weeds)
- Clean integration of harvest residues
- > Expanded root zone
- > Homogeneous soil enrichment of nutrients

Disadvantage of ploughing

- > Energy demand (40% of production)
- > High work load
- > Humus depletion
- > Embedding of organic material
- > Harm to soil fauna
- > Risk of slurry seal coating and incrustation
- Disruptive transition of top soil and lower soil (plough sole)

# Reducing tillage in organic production systems

### Advantage

- > Increased humus
- > High biological activity
- > More earthworms
- > Stable soil structure
- > High infiltration
- > Less erosion
- Less costs/work load

### Disadvantage

- Problems in low precipitation regions
- > Late mineralization
- > Weed problem



### Organic options to reduce tillage

- Annual Strategies: Frequency, intensity, spatially
- > Multi-year Strategies: Rotation
- > Different Systems: Hybrid mulch system
- > Permanent Beds

### > Conventional tillage

- > Primary, secondary tillage
- > Seedbed preparation
- > 2-4 field tillage passes
- > 'Clean Field'

### > Permanent No-till

- > No tillage passes
- > Residue minimally disturbed
- Maximize protection against erosion and crusting







# **Organic farming ideals**

species and genetic diversity on farm

closed nutrient cycles - farm based fertiliser, biological N fixation

adapted varieties intact self-regulation – promotion of beneficial organisms, symbiota, living soil

refrain from synthetic fertilizers

refrain from GMOs

soil fertility

refrain from synthetic pesticides

conservation of resources, sustainable

Messmer, M., FiBL, 2013

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### **Organic farming ideals: Ecological balance**

- > Maintain healthy, living soil
- > Provide sufficient NPK
- > Use cultural and biological pest controls
- > Utilize least-toxic pest sprays (avoidance before usage)
- > Evaluate off-farm impacts of all practices
- > Cycling of Resources
- > Recycle on-farm nutrient resources
  - > Cover crops and green manures
  - > Animal manures
  - > Other on-farm residues
- > Use of ecosystem structures/functions
  - > E.g. Deep-rooted crops
- > Prevent nutrient loss by runoff/ erosion



This cover crop of crimson clover and winter barley fixes N, retrieves subsoil nutrients, and prevents soil erosion.

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### Organic crop production: organic nutrient supply

Supply via:

- > Applying animal manure
- > Green manure/fallowing
- > Compost animal manure, plant residues, or other organic "wastes"
- > Crop rotation
  - > Growing properly inoculated legumes in the rotation
  - > Rotating high and low nutrient demand crops
  - > Rotating deep and shallow rooted crops
- > Applying acceptable organic crop nutrient products
- > Summer fallowing using conservation tillage
- > Test manures and composts to determine application rates
  - > N, P, K & other nutrients can vary significantly
- Build <u>fertility on-farm</u>, using imported composts and manures to supplement



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### **Organic crop production: Compost**

- Stable, humus-like material produced from aerobic decomposition of organic wastes.
  - > Minimizes pathogens

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- Made from plant and animal materials
- Homogeneous with initial residues indistinguishable upon completion
- No application restrictions if produced to NOP standards (or if containing no manures)



# Organic crop production: Green manuring/fallowing

- > Green manure
  - Increases soil aggregation, as well as nutrient supplying and waterholding capacity
- > Green fallowing
  - > Frequently grown to supply N to the soil
  - > Protecting the soil from wind and water erosion
  - > Carefully incorporated
- > Growth of annual legume determined by available moisture
  - > Limited moisture early termination of annual legume
  - Adequate moisture, crop terminated at full bloom stage to optimize biomass and N fixation

### **Organic crop production: Green manure**

- > Benefit of green manuring legumes
  - > Increase soil N levels of N
  - > N availabilty for plants
- > Mycorrhizal crops for green manuring
  - Microbes (arbuscular mycorrhizal fungi) colonize roots and produce structures for bi-directional nutrient exchange (increase resilience to diseases, stress)
  - > Highly relevant for nutrient cycles
- Mycorrhizal crops; Lentil, pea, bean, wheat, barley, corn, sunflower and flax

# **Organic crop production: Green manure**

- > Reducing tillage (during summer fallow)
- > Varying crop root depths
  - > Nutrients supply
  - Deeply rooted plants (alfalfa) extract nutrients from soil depths not accessed by the shallower roots
- > Short-term solution to nutrient supply
  - But in long-term nutrients deplete deeper in soil, because grain or forage is harvested and exported, nutrients from external sources (manure and organically approved products)
- > Organic compatibility guides on farm decision making

# **Crop rotation**

- > Minimize risk of diseases and pests
- > Cultivation pauses for specific crops
- > Nutrient supply / humus
  - > N-fixation
  - > P / K mobilisation from soil
  - > Build up humus level

 $\rightarrow$  annual to several years' mixed crop of green fields and vegetables in



### **Crop Rotation: Organic Options**

- > Rotating crops helps to control
  - Disease organisms, weed species, nematode populations, insect populations
  - > Utilize nutrients in the soil
- > Organic farming systems are often highly diverse
  - Joint nutrient household
- Cover Crops: Prevent erosion, add organic matter, fix N (legumes), take up surplus N (grasses), suppress weed



An eight-year rotation of eight vegetable and seven cover crops at an organic farm in Vermont.



A cover crop of sorghum-sudan grass and sunnhemp in a field trial at Virginia Tech's Kentland Agricultural Research Farm.

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# **Organic crop production: Crop rotation**

Growing legumes in crop rotation production

- > If properly inoculated with rhizobia
  - > Fix 50 to 90 % of required N from air which they require
  - > Legume residue has higher N level, breaks down much faster than non-legume residue
    - > Resulting in faster cycling of N to subsequent crops

Logumo	Available N /	
Legume	increase (lb./ac.)	
Lentil	9	
Field pea	22	
Faba bean	36	

Increase in available N of Dark Brown soils due to residue of one annual legume crop From: Slinkard, Crop Development Centre, Saskatoon

Plant-N derived from atmosphere				
Legume	(%)	(lb./ac.)		
Alfalfa	80	267		
Sweetclover	90	223		
Faba bean	90	267		
Field pea	80	178		
Lentil	80	134		
Soybean	50	134		
Chickpea	70	108		
Field bean	50	62		



## **Organic crop production: Crop Rotation**

- > Perennial legumes (alfalfa)
  - > Supply substantial amounts of N to subsequent crops
  - > Alfalfa produces about as much root material as it does top growth (large share renews annually)
  - Substantial amount of N-rich organic matter remains in soil after harvest because of roots
- > High soil N levels can inhibit N fixation by legumes
  - > Legumes will preferentially use soil N before they fix atmospheric N

# **Organic crop production: Crop Rotation**

- > Efficient resource use
  - > Rotating High and Low Nutrient Demand Crops
  - Solution Serving non-legume crops on animal manured, green manured or summer allowed fields
  - Solution Serving Legumes on fields with low levels of N allowing the N-fixing benefit of the legumes
- > Phosphorus nutrition is very important for high N fixation in legumes
- > Crop specific nutrient demand
  - > Rotating high and low nutrient demand crops for balanced nutrient household

# Cover Crops and organic crop production

- Cover crops enhance quantity of soil organisms
- > Add diversity to system
- Add food resources for beneficial insects – pollen and nectar
- Habitat for predators
- > Compete with weeds

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- > Protect soil (sun,wind)
- Soil fertility and nutrient retention



Hairy Vetch



Buckwheat

Mustard Photos: T. Pisani Gareau

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### **Organic crop production: variety choice**



Maize field



Salad SNF/SCOPES

Source: Photo, Fetahu,, 2012



Common bean Nitrogen Fixation



Wheat

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### **Organic crop production: Crop Rotation**

> The Bean and Pea Family: Beans, peas, clovers, vetches



- Plant Families Not Susceptible to *Phytophthora capsici* Family: Poaceae (Gramineae)
- > FOR HARVEST OR GREEN MANURE
- > The Cereals: Rye, wheat, corn, sudangrass, Sorghum



Source: Michelle I. Agricultural Agent. Rutgers Cooperative Extension of Gloucester County. PPT. Fetahu 2014.22

# **Organic crop production: Basic weed ecology**

- > Weeds are nature's way of keeping bare ground covered and increasing biodiversity
- > Dynamic system involving the interaction of weeds, crops, humans and environment
- > Factors affecting weed ecology are identical to those affecting crop ecology:
  - Light, temperature, water, pH, nutrients, organic matter, insects and diseases, etc



www.css.cornell.edu/WeedEco/WeedDatabase/index2.html

# Weed regulation in organic farming



# **Organic crop production: Weeds control**

### Weeds control through

- > Crop rotation
- > Cover cropping
- Optimum crop and nutrient management
- Timely cultivation
- Mulching



Pepper cultivation with in-row irrigation, and timely cultivation followed by controlled weeds, by cultivators.



Plastic mulch with in-row drip irrigation, and timely cultivation followed by hay mulch in alleys controlled weeds in this vigorous pepper crop.

Pepper, production, Fetahu, 2012.

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# **Organic crop production: Intercropping**

When 2 or more crops grow together, each must have adequate space to maximize cooperation and minimize competition between the crops.

- > spatial arrangement, plant density, maturity dates of the crops, and plant architecture
- > Row intercropping (2 or more crops at the same time with at least one crop planted in rows)
- Strip intercropping (2 or more crops together in strips wide enough to permit separate crop production using machines but close enough for the crops to interact)
- > Mixed intercropping (2 or more crops together in no distinct row arrangement)
- > Relay intercropping (2nd crop into a standing crop at a time when standing crop in reproductive stage but before harvesting)

## **Organic crop production: Plant Density**

- > Optimized plant density
  - > seeding rate of each crop below full rate
  - > if full rates of each crop planted, overcrowding will minimize yield
- > Reducing the seeding rates
  - > crops yield well within the mixture
  - > challenge: knowing how to balance seeding rates
  - > E.g., growing corn and cowpeas, best to plant peas near normal rate and reduce corn-seeding drastically (by 80% or more)
  - > If you wanted equal yields from both peas and corn, then the seeding rates would be adjusted to produce those equal yields.

# **Organic Crop production: Maturity Dates**

- > Intercrops with staggered maturity dates (or development periods)
  - > benefiting from variations in peak resource demand of nutrients, water, and sunlight
  - > reduces competition between crops with different maturity dates
- Corn-Bean planting
- > Aggressively climbing bean hampers corn growing, lowering yield
- > Timing the planting of bean mitigates competition in crucial stage, therefore corn be harvested before bean begins to climb.
  - corn planted at low plant population allowing enough sunlight to reach beans.
  - > corn close to maturity, so young legumes do not compete
  - > when corn is mature, beans or peas use corn stalks to climb on
  - > corn and beans harvest together in autumn.
- > Selecting crops or varieties with different maturity dates can also assist staggered harvesting and separation of grain commodities.

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# **Organic crop production: Plant architecture**

- Plant architecture is commonly used strategically to allow > one member of the mix to capture sunlight that would not otherwise be available by the others.
- Widely spaced corn plants growing above an understory > of beans and pumpkins would be a classic example.



Intercropping; Photo, orig. Fetahu, 2012

### **Traditional Corn-Bean-Squash Mixed Intercrops**

- Throughout the world, a common intercrop of maize, beans, and squash is traditionally grown.
- Grown together, these three crops optimize available resources.
- > The corn towers high over the other two crops while the beans climb up the corn stalks.
- The squash plants sprawl along the ground, capturing light that filters down through the canopy and shading the ground.
- The shading discourages weeds from growing.
  This mixture was compared to the individual crops grown separately.

### **Organic crop production: Impact of weed pressure**

Weeds compete with crops for water, nutrients and sunlight. In high enough pressure weeds can reduce yields, reduce crop quality, increase irrigation needs and harbor insects (both beneficial and pestiferous) and diseases.

Complete elimination of weeds is unnecessary, as they can protect the soil surface from heavy rain, add organic matter, help to recycle nutrients, provide habitat for beneficial insects and other impacts.



### **Organic crop Production: Organic weed management**

Practice	Effect	
Tillage	Kills growing weeds; damages perennial roots & rhizomes; buries seeds too deeply to emerge; brings weed seeds to surface.	
Post-planting cultivation	Removes weeds from the crop.	
Stale seedbed	Flushes weeds from the soil before planting.	
Organic fertility sources	Favor crops over faster-growing weeds due to slow release of nutrients.	
Drip irrigation	Directs water to the crops rather than to weeds.	
Mulch	Smothers weeds: delays emergence of weeds	
Using transplants	Competitive advantage to crop	
Competitive cultivars	Improves competitive ability of crop against weeds.	
Increase plant density	Suppress weeds by shading	
Rapid cleanup after harvest	Prevents seed set by residual weeds.	
Cover crops	Suppress weeds, improves soil health	

Source: Organic weed management practices" Crop Rotations on Organic Farms, Mohler & Johnson, 2009

### Organic crop production: Mulch

- Prevent seeds from germinating by blocking light, can smother out some weeds
- > Conserve water, minimal soil disruption
- Use local resources: straw, fabric, wood, newspaper, plastic
- > Be careful of weed seeds in straw or hay
  - Avoid hay, unless you know its free of weeds
- > Especially good for perennial systems
  - blueberries, blackberries, flowers, trees
- > Living mulches
  - constant cover of clover on orchard floor
     Hyte





Hybrid Mulch Approach Plastic intact for 2-3 years Cover crop managed between rows

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### Organic crop production: onion production with mulch

### **Mulch No-Till**

### Cover Crop Ridge-Till





Reduced Tillage Crops Research - Plant Science plantscience.psu.edu/research/projects/.../reduced-tillage-crops-research.p...

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### **Organic Crop Production: Cover Crops**

An organic advantage

- Herbicides are not used for weed control >
- Cover crop options are not restricted by herbicide carryover >
- Tight rotations limit cover crop niches >
- Cover cropping may entail foregone income >
- Sandy soils and warm climates burn up cover crop > residues quickly



# **Organic crop production: Weed and Cover Crops**

- Smother weeds by outcompeting for light, water, nutrients
- Release allelopathic chemicals that suppress weed germination
- May reduce weed emergence by 75-90%
- > Common cover crops
  - E.g. Sudangrass, buckwheat, annual rye grass, sesbania, many more

Source: Managing Cover Crops Profitably, 3<sup>rd</sup> ed. SARE <u>www.sare.org/publications/covercrops/covercrops.pdf</u> crops profitably. 3<sup>rd</sup> ed. SARE







### Organic crop production: Weed and crop rotation

- Weeds tend to infest crops with similar life cycles
- > Change crop ecology
  - shallow/deep roots, cold/warm season, row/drilled crops, foliage density, and heavy/light feeders
- Change cultural practices
  - cultivation, mowing, fertilization, herbicide application, and planting/harvest dates



# Organic crop production: Weed and crop rotation

10 Year Rotation Scheme , Source: Alex and Betsy Hitt, Chapel Hill NC; http://www.ssawg.org/hitt.html

Y R	Spring	Summer	Fall
1	Tomatos & leeks		Oat-crimson cl
2	Flowers-cool seas.	Sudangrass-soyb.	Oat-crimson cl.
3	Spring lettuce	Flowers, summer	Rye-hairy vetch
4	Squash		Fall planted flowers
5	Flowers-overwintered	Sudangrass-soyb.	Rye-hairy vetch
6	Peppers		Wheat-crimson cl
7	Flowers -summer		Oat-crimson clover
8	Mixed spring veg	cowpeas	Fall planted flowers
9	Flowers-overwintered	Sudangrass-soyb.	Oat-crimson clover
10	Flowers-summer		Wheat-hairy vetch

# Cultivation

- Should be shallow to lessen disturbance to weed seed bank
- Better for perennial and biennial control than annual weed control
  - > Exhaust root system by depleting storage reserves
  - Requires 6-8 timely treatments in yr 1, then 3-5 the following year

Thoroughly clean equipment before moving it between fields to prevent weed transport





# **Control Tactics**

Knock the weeds out at critical times.

- Utilize biological processes to enhance weed control
- Bring existing weeds under control before planting weed-sensitive crops and long-term perennial crops



No-till organic farm; weed-free bed of weed-sensitive onion crop.



Cultivation during vegetation!

# **Organic crop production: Weed management**

- > Develop a weed management strategy that is designed for the needs of your farm.
- Using multiple approaches ("many hammers") to manage weeds will yield greater impact than relying on a few practices.
- > Big Hammers
  - > Competitive crops
  - > Rotation
  - > Cover Crops
  - > Mulches
  - Weed predators
  - > Livestock/grazers
  - Cultivation tools
  - > Rollers/roller-crimper
  - > Growers Observation

- > Little Hammers
  - > Solarization
  - > Organic herbicides
  - Bioherbicides
  - > Soil microorganisms
  - > Crop-weed interactions

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