



**THE OHIO STATE UNIVERSITY**

COLLEGE OF FOOD, AGRICULTURAL,  
AND ENVIRONMENTAL SCIENCES

[extension.osu.edu](http://extension.osu.edu)

[agmr.osu.edu](http://agmr.osu.edu)

[fabe.osu.edu](http://fabe.osu.edu)

## USING COVER CROPS TO CONVERT TO NO-TILL

SAG-11

Date: 11/23/2009

**James J. Hoorman, Extension Educator, Cover Crops and Water Quality, Ohio State University Extension**  
**Rafiq Islam, Soil and Water Specialist, Ohio State University Extension, South Centers at Piketon**  
**Alan Sundermeier, Extension Educator, Agricultural and Natural Resources, Ohio State University Extension**  
**Randall Reeder, Extension Agricultural Engineer, Food, Agricultural, and Biological Engineering, Ohio State University Extension**

**No-till versus Tillage**—In the Midwest, about three-fourths of all soybeans and wheat are planted without prior tillage. But before corn is planted at least three-fourths of the fields are tilled in the fall and possibly tilled again in the spring. Farmers are tilling ahead of corn planting because they perceive a yield increase with tillage that is more than enough to cover the added direct costs for machinery, fuel, and labor. Typically, soybeans are no-tilled into corn stalks followed by soybean residue being tilled for corn planting the next year. No-tilling one year (for soybeans), then tilling the next (for corn), is not a true no-till system.

In many situations, corn yields drop slightly after switching to no-till. In Ohio, 10 to 20 percent of corn acres are no-tilled. So the question becomes, *Why does this occur?* Since corn is a grass, it requires more nutrients (especially nitrogen) and water and corn responds well to tillage. Farmers typically see a 5 to 10 percent bushel yield decrease for the first 5 to 7 years after they convert from conventional tilled to no-till. The corn crop benefits from tilled soils due to the release of nutrients from soil organic matter. Tilling the soil injects oxygen into the soil, which stimulates bacteria and other microbes to decompose the organic residues and releases nutrients. Every one percent soil organic matter holds 1,000 pounds of nitrogen. However, continuous tillage oxidizes or burns up soil organic matter and soil productivity declines with time. Thus, tillage results in poor soil structure and declining soil productivity.

Long-term research reveals that 7 to 9 years of continuous no-till produces higher yields than conventional tilled fields because it takes 7 to 9 years to improve soil health by getting the microbes and soil fauna back into balance, and start to restore the nutrients lost by tillage. In those transition years, the soil is converting and storing more nitrogen as microbe numbers and soil organic matter levels increase in the soil. For the first several years after converting to no-till, there is competition for nitrogen as soil productivity increases and more nitrogen is stored in the soil in the form of organic matter and humus. See OSU Extension fact sheet "Understanding Soil Ecology and Nutrient Recycling."

Cover crops have the ability to "jump-start" no-till, perhaps eliminating any yield decrease. Cover crops can be an important part of a continuous no-till system designed to maintain short-term yields and eventually increase corn yields in the long run. Cover crops recycle nitrogen in the soil, help to build soil organic matter, and improve soil structure and improve water infiltration to improve no-till corn yields. Long-term cover crops can boost yields while improving soil quality and providing environmental and economic benefits. Growing

cover crops is helping farmers adapt faster to a continuous no-till system, one that provides long-term economic and environmental benefits that are impossible to obtain by no-tilling one year at a time.

## Ecosystem Functionality

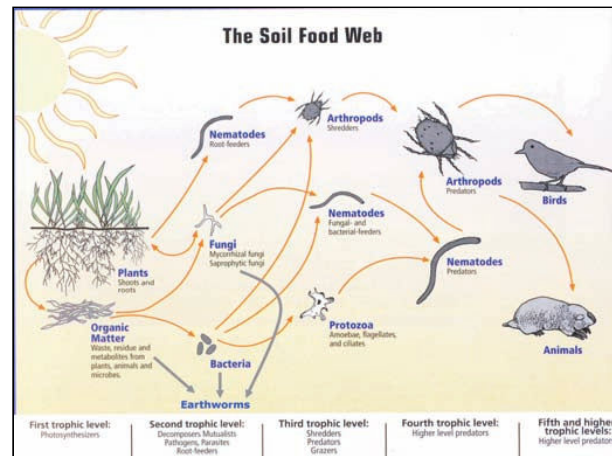
Our agricultural landscape is only green for about 6 months during the year with no living cover for the other 6 months. Corn and soybeans are planted in the spring and harvested in the fall. Fall tillage prepares the seed bed for the following crop but leaves the soil exposed and fallow. The result is a soil surface devoid of plant life for 6 months and a decrease in "ecosystem functionality." In a typical corn-soybean rotation, there are active living roots only a third of the time (Magdoff and van Es, 2001). Typically there are 1,000 to 2,000 times more microbes (especially bacteria and fungus) associated with living roots because the roots provide active carbon and exudates to feed the microbes (Schaetzl and Anderson, 2006).

Ecosystem functionality means that an ecosystem can sustain processes and be resilient enough to return to its previous state after environmental disturbance. Functionality depends on the quantity and quality of a system's biodiversity. An important characteristic of ecosystem functionality is that it develops and responds dynamically to constantly occurring environmental changes. Tillage is a constant disrupter and biodiversity in the soil decreases as tillage increases.

Tillage releases carbon to the atmosphere by oxidizing the soil organic (carbon based) residues and in the process releases nitrogen. Nitrate leaching typically occurs after the crop is harvested in the fall, winter, and early spring months because after the microbes release the nutrients, there are no live plants to recycle the excess nutrients. Tillage also increases soil erosion and phosphorus losses (phosphorus attaches to clay soil particles) to surface water. Excess nitrogen and phosphorus in the water cause hypoxia and eutrophication in surface waters. Ecosystem functionality decreases because the soil biodiversity decreases and there is less recycling of nutrients in the soil. That explains why the nitrogen use efficiency for commercial N and P fertilizer is only 30 to 40 percent for N and 50 percent for P. By improving ecosystem functionality, farmers can increase their N and P nutrient use efficiency, decrease their fertilizer bill, and improve the environment by decreasing N and P losses to surface water.

In the last hundred years, tillage has decreased soil organic levels by 60 to 70 percent with 30 to 40 percent soil organic carbon stocks remaining. Carbon stocks (30 to 40 percent) correlate directly with nitrogen use efficiency (30 to 40 percent) and the two are directly related to each other. To increase nitrogen and other nutrients in the soil, farmers need to increase carbon or organic matter. Carbon is the glue that binds the soil, stores nutrients, and keeps nutrients recycling.

Ecosystem functionality decreases as the soil carbon content decreases because carbon is the food for microbes and the storehouse for many nutrients. Most soil nitrogen (>90%) and available phosphorus (50 to 75 percent) is stored in the organic form. Nitrogen use efficiency for corn is directly related to the amount of soil organic carbon in the soil. The soil carbon holding capacity is 2.5 times the amount of carbon dioxide in the atmosphere, so the soil has a tremendous ability to store carbon. Ultimately, a loss in soil ecosystem functionality reduces the quality of life for the farmer, land owners, our rural communities, and our society.



Ecosystem functionality is dependent on a healthy soil food web. Each species has a certain role and function in the soil.

## Continuous Living Cover and No-till

An agricultural system that combines a continuous living cover (cover crops) with continuous long-term no-till is a system that more closely mimics natural systems and should restore ecosystem functionality. A thick layer of plant residue on the soil surface protects the soil from the impact of rain drops, moderates soil temperatures, and conserves soil moisture. Soil microorganisms and plants together produce polysaccharides, and glomalin (a glycoprotein) which acts like glue to bind soil particles and improve soil structure. Living roots increase pore space for increased water infiltration, soil permeability, and increased water holding capacity and recycle soil nutrients (nitrogen and phosphorus) in the soil profile.



No-till corn planted into cowpeas as a cover crop with no additional commercial N fertilizer. *Photo by Dr. Rafiq Islam.*

In natural systems, the land is not extensively tilled and a continuous living cover protects the soil from rain drop impact (less erosion). By growing a cover crop in the winter, carbon inputs are added to the soil, keeping nutrients recycling within the system. Nitrogen is directly linked to carbon so less carbon losses means more nitrogen stays in the soil rather than being lost through leaching or runoff. Soil nutrients (N and P) are recycled within the natural system. Plant roots and soil residues protect the soil and keep the soil from eroding and reduce P losses resulting in less hypoxia and eutrophication. Microbial diversity and microbe numbers increase with continuous living covers so that pests (disease, insects, and weeds) can be more effectively moderated. The solution lies in changing agricultural practices to promote greater nutrient efficiency to recycle carbon, nitrogen, and phosphorus in the soil. Improved soil productivity, soil structure, and nutrient efficiency should increase crop yields and farmer profitability.

## Nitrogen Recycling

Legume cover crops (cowpeas, Austrian winter pea, etc.) can provide nitrogen to the following crop. Legume cover crops fix nitrogen from the air, adding up to 50 to 150 pounds per acre of this essential nutrient. Non-legume cover crops recycle leftover nitrogen from the soil, storing it in roots and aboveground plant material, where a portion will be available to the following crop. Every pound of nitrogen stored is a pound of nitrogen prevented from leaching out of the top soil into streams (see OSU Extension fact sheet on Homegrown Nitrogen and Crop Rotations with Cover Crops).

Cover crops can replace nitrogen fertilizer, but not in every situation. After cereal rye, there may not be enough early nitrogen available for the new crop and after a legume, the N will likely not be available until later in the growing season depending upon when the crop decomposes. It all depends upon the carbon to nitrogen ratio.

A C:N ratio less than 20 allows the organic materials to decompose quickly while a C:N ratio greater than 30 requires additional nitrogen and slows down decomposition. Microbes will tie up soil nitrogen if a high carbon-based material with low nitrogen content



Cowpeas may supply 120–150 pounds of N to no-



(cereal rye or wheat straw) is added to the soil. Eventually the soil nitrogen is released but in the short-term the nitrogen is tied up. A low C:N ratio means more nitrogen is available quickly for microbes and plants to convert nitrogen to amino acids and protein.

Microbes generally take up nitrogen faster than plants, so if nitrogen is limiting, the plant will suffer. In no-till corn, corn is sometimes yellow from a lack of nitrogen because as the soil carbon content is increasing, the microbes are using the limited nitrogen stocks before the corn plant. A typical soil C:N ratio is 10 to 12 so nitrogen is available to plant roots. If the soil C:N ratio is too high, adding nitrogen to the soil will allow the microbes to decompose the carbon residues and will decrease the C:N ratio and more nitrogen will become available to the plant.

For cereal rye and annual ryegrass before corn, plan to kill it 3 to 4 weeks before planting (when it is young and lush and the C:N ratio is lower). If it cannot be killed until about 2 weeks before planting, apply nitrogen (as liquid fertilizer or dry fertilizer). Cereal rye and annual ryegrass provide good rooting and soil structure and absorb nitrogen, which can be recycled for the following corn crop but depending upon the C:N ratio, may tie up nitrogen short-term, hurting corn yields.

Cereal rye or annual ryegrass management is different for soybeans. Soybeans can be successfully no-till drilled into a standing cereal rye cover, even 7 feet tall. The cereal rye gets flattened, helping to smother potential weed growth, and is fairly easy to kill with herbicides (Roundup®) after planting. Annual ryegrass will reach 3–4 feet tall but should not be allowed to go to seed. Since soybeans are legumes and make their own nitrogen, the carbon content or C:N ratio of cereal rye and annual ryegrass does not hurt the soybean growth or yield.

No-till corn generates 14 percent less CO<sub>2</sub> losses than intensive tillage. Among the advantages are: less fuel used; soil quality and structure improves; better drainage, which can lead to earlier planting. Potential disadvantages include more weeds, more herbicides (to initially kill the cover crops), slower soil drying in spring at least initially (until soils are better aerated), and more N required in the transitional years until soil compaction is reduced and or drainage is improved. The nitrogen may be provided, at least in part, by manure or cover crops.

## Reduced Soil Erosion and Phosphorus Retention

Using a continuous living cover with no-till greatly reduces soil erosion and the loss of phosphorus with runoff. Remember that 50 to 75 percent of the available P in soil is organic and our P efficiency is only about 50 percent with tillage. Since the majority of the phosphorus (P) in the soil is attached to clay particles and organic matter, protecting the soil from rain drops results in less sediment erosion and keeps the P on the soil, rather than as runoff to surface water. Over 90 percent of P runoff is associated with phosphorus attached to the soil when soil phosphorus levels are below 100 pounds per acre Bray P1. Phosphorus in the soil is quickly tied up by clay particles so tillage incorporates P into the soil and binds P quickly.

till corn. No-till corn (background) planted into cowpeas with no additional commercial fertilizer. Note dark green color indicating good N fertilization. Cowpeas (foreground) drilled into wheat stubble 7 days after planting. *Photo by Dr. Rafiq Islam.*



Cereal ryegrass rolled before planting soybeans. Some farmers drill soybeans directly into the cereal rye then spray the cereal rye after the soybeans emerge. The cereal rye helps to control weeds and hold soil moisture going into the summer.

In no-till, as the crop residues decompose, they release soluble P, which can flow to surface waters. Growing a living crop with no-till or adding a cover crop allows the soluble P to be absorbed and recycled back into the soil system.

In long-term no-till systems with a continuous living cover (cover crops), P is efficiently recycled on the soil surface so less P fertilizer is needed. A continuous living cover protects the soil from soil erosion, where a majority of the P is lost. With tillage, the P is incorporated into the soil and binds to the soil, but since the soil is not protected, soil erosion may increase sediment and P losses to surface water. When soil erodes, the nutrient-rich portion or the organic matter is the first portion to erode off in sediment because it is less dense than soil particles, floats, and can easily be washed away from the soil surface into surface water.

## Soil Temperature

Living cover crops can significantly alter soil temperatures. Cover crops decreased the amplitude of day and night temperatures more than average temperatures resulting in less variability. Cover crop mulches protect the soil from cold nights and slow down cooling. This may be a benefit in hot regions, but may slow growth in cooler regions. Winter cover crops moderate temperatures in the winter. Standing crops have higher soil temperatures than flat crops. Row cleaners help manage residues and improve soil temperatures in no-till fields. Corn responds to warmer soil temperatures so strip tilling in a 10 inch band by moving the top soil residue may increase stand establishment and corn growth initially when converting from conventional till age to no-till.



No-till soybeans drilled into a cover crop. Cereal rye and annual ryegrass used as a grass cover crops before soybeans, a legume grain crop. *Photo by Dr. João Moraes Sá.*

Long-term no-till farmers who use cover crops say that their soils are not cold. There are three reasons why this occurs. **First**, in the transition from conventional till age to no-till, soils tend to be compacted, keeping the soil wet and saturated. Water holds the heat and cold longer than air, which acts like an insulation. Thus, cold soils tend to be wet and insulated from the atmosphere by residue on the soil surface. Cover crops in a no-till rotation allow rainfall and precipitation to infiltrate the soil (soils are more porous) and allow more air into the soil to warm up the soil faster. Grass cover crops can typically penetrate 12 inches of soil compaction per year, so it may take several years to remove soil compaction that is several feet deep.

**Second**, in long-term no-till with cover crops, as organic residues are added to the soil surface, the soil color changes from light yellow and brown to dark brown and black as organic residues decompose. Dark brown and black organic residues absorb sunlight and heat, warming the soil. This process may take several years to occur.

**Third**, as even more organic residues accumulate on the soil surface, the intensity of the biologic activity on the soil surface increases. Biologically active organic matter like compost piles give off heat as the microbial decomposition intensifies, warming the soil. In order for this last sequence to occur, a thick layer of residue needs to accumulate on the soil surface. Long-term no-tillers and no-till farmers using cover crops say that the improved soil porosity and dark organic residues promote soil warming.

## ***Cold versus Warm No-till Soils***

1. Compaction and poor drainage create cold soils because water holds both the heat and cold more than air. Cover crops improve drainage and aeration in no-till soil so they warm up faster in the spring.
  2. Surface residue decomposes, turning black, and absorbs heat.
  3. Thick surface residue increases microbial activity and creates heat, like in the center of a compost pile.
- 

## **Controlled Traffic and Compaction**

Soil compaction is a biological problem. Surface and subsoil tillage may physically break up hard pans and soil compaction temporarily but they are not a permanent fix. Good soil structure requires the production of glomalin, formed from polysaccharides produced by plants and fungus in the soil. The plant roots provide the sugar and the fungi provide the protein to form glomalin, a glycoprotein.

Glomalin coats microaggregate soil particles, forming macroaggregates, which improves soil structure and allow soil air and water to infiltrate and move through the soil. Tillage destroys macroaggregates by oxidizing the glomalin. Both cover crops and fungus microorganisms are needed to improve soil structure and decrease long-term soil compaction in the soil. (See OSU Extension fact sheet: "The Biology of Soil Compaction.")

No-till corn (either in rotation or continuous) offers an opportunity for controlled traffic to manage compaction and provide other savings. Using auto-steering to maintain exact traffic patterns means that earlier planting and more timely harvest are possible because tracks are firm, resulting in higher grain yields. Precise steering means no overlap, which reduces costs of all inputs, including fuel and labor. Using auto-steering with a cover crop and no-till in a controlled system offers the opportunity to manage soil compaction so that it does not hurt crop yields.

## Water Infiltration

As a plant grows, the roots create channels and fissures in the soil called macropores. These macropores allow air and water to infiltrate and move in the soil. These macropores also allow water to be stored. A pound of soil organic matter has the ability to hold 18 to 20 pounds of water. The organic residues stabilize the soil and hold soil moisture. A bare soil that has been tilled has the ability to hold 1.5–1.7 inches of water, while a continuously vegetated soil has the ability to hold 4.2–4.5 inches of water. Organic matter improves water infiltration, soil structure, and macropores in the soil. Living plants, plant roots, organic matter, and the polysaccharides in the soil (glomalin) stabilize the soil and allow the soil to retain more water than a tilled soil.

Cover crops produce more vegetative biomass than volunteer plants, transpire water, increase water infiltration, and decrease surface runoff and runoff velocity. If the velocity of runoff water is doubled in a stream, the carrying capacity of water or the stream competence to transport soil sediment and nutrients increases by a factor of 26 or 64 times. So 64 times more sediment and nutrients are lost with moving water when the velocity is doubled (Walker et al., 2006). Cover crops protect soil aggregates from the impact of rain drops by reducing soil aggregate breakdown. By slowing down wind speeds at ground level and decreasing the velocity of water in runoff, cover crops greatly reduce wind and water erosion.

Cover crops decrease soil erosion by 90 percent, decrease sediment transport by 75 percent, reduce pathogen loads by 60 percent, and reduce nutrient and pesticide loads by 50 percent to our streams, rivers, and lakes. As the price of fuel and fertilizer increases, planting cover crops becomes more and more economical as a way to build SOM and store and recycle nutrients in the soil. See the OSU Extension fact sheet on "Using Cover Crops to Improve Soil and Water Quality."

## Summary

Agricultural systems that mimic the natural world tend to be more efficient, sustainable, and profitable. Using a continuous long-term no-till system with cover crops or a continuous living cover is an agricultural system that closely mimics the natural world and restores ecosystem functionality. In no-till, a thick layer of residue protects the soil from the impact of raindrops and reduces soil erosion. Soil temperatures are moderated by this residue and soil moisture is retained in the soil profile. Water infiltration is improved and runoff is minimized. Soil nutrients are efficiently stored and recycled in the soil by growing plants or cover crops, allowing carbon to be recycled in the soil and storing nitrogen and phosphorus. Soil pests like weeds, insects, and diseases are controlled because there is a biological diversity, which generally prevents or moderates large increases in one species over another. Growing a continuously living cover with no-till promotes healthy growing crops and reduces the problems most farmers have in growing crops with tillage (hard soil, cloddy soils, soil compaction, runoff, soil erosion, nutrient losses, annual weeds, insects, soil diseases). Tillage creates problems with soil compaction, water infiltration, soil structure, and nutrient recycling.

However, converting to no-till requires a transition period because the biological diversity has been diminished with tillage. Natural systems are fragile and once they have been disturbed it takes time to restore the ecosystem functionality. As the carbon is decomposed and released to the atmosphere, the capacity to store nutrients in the soil is diminished. The fastest way to build soil organic matter levels is to grow plants continuously using long-term no-till so that the residues are not decomposed. Continuous no-till plus a cover crop mimics natural cycles and promotes nutrient recycling and improved soil structure to improve crop production.

## Making No-till Corn Successful

No-till corn production has struggled to be successful in the Midwestern United States. No-till farmers say it takes 7 to 9 years to transition from conventional farming to long-term no-till. Using a cover crop with continuous long-term no-till shortens the time period to 2 to 4 years. No-till corn yields are typically reduced 10 to 20 percent during those transition years.

This occurs for several reasons. First, initially fewer nutrients are being released from the residues deposited on the soil surface. Tillage allows surface residues to decompose faster, releasing nutrients, but it also destroys organic matter, resulting in less storage of soil nutrients.

Second, in biologically active soils, the microbial biomass is increasing in size and population, accumulating N as amino acids and proteins and P as DNA in microbes. This initially deprives no-till corn of nitrogen and soil nutrients until the soil system becomes stable.

Third, the soil is building humus organic matter, which requires N to decompose and stabilize the organic molecule. Every one percent SOM requires 1,000 pounds of N, so if the N is being tied up and N is not available, the soil microbes will utilize N before the corn. Fourth, soil compaction from the previous tillage causes denitrification from saturated/water-logged fields, losing 40 to 60 percent of the available N in the soil.

So to reverse this process, first cover crops are grown to reduce soil compaction and improve the recycling of C and N in the soil. Second, as the microbial and humus organic matter levels build up, N and P are more efficiently recycled in the soil to the corn and no-till corn yields increase, outperforming conventional tilled soils. Third, as water infiltration increases and soils are better aerated, denitrification and N losses decrease, increasing the storage and recycling of N in crop residues and organic matter (humus) and resulting in more soil nutrients (N, P, and S) for the corn crop. See OSU Extension fact sheet: "Understanding Soil Ecology and Nutrient Recycling."

### Reasons Why No-till Corn Struggles

1. Surface residue ties up nutrients and slows down decomposition and release of nutrients.
2. Soil microbes tie up soil nutrients, especially N.
3. Long-term soil organic matter ties up nutrients, especially N.
4. Compaction and poor drainage causes denitrification and loss of N.
5. Cold wet soils limit germination and planting.

Conventional



Soil compaction

No-till plus Cover Crop



Improved root and soil structure

*Diagram by James J. Hooman.*

*Illustrated by Danita Lazenby.*

### Successful No-till Plus Cover Crops

1. Reduces soil compaction.
2. Improves C, N, P recycling.
3. Reduced N Losses from denitrification.
4. Increased nutrient storage in soil from increased SOM

## Acknowledgments

This fact sheet was produced in conjunction with the Midwest Cover Crops Council (MCCC). The authors wish to thank Danita Lazenby (illustrations). Outside reviewer: Mark Fritz, Ohio Department of Agriculture.

## References



- Magdoff, F. and H. van Es. 2001. *Building Soils for Better Crops*, 2nd Edition. Beltsville, MD: Sustainable Agriculture Network. [sare.org/publications/soils.htm](http://sare.org/publications/soils.htm).
- *Managing Cover Crops Profitably*, 3rd Edition, Sustainable Agriculture Network, Handbook Series Book 9, Ed. Andy Clark. Beltsville, MD: United Book Press, 2007.
- Schaetzl, R., and S. Anderson. 2006. Chapter 6: Basic concepts: soil organisms. In *Soils: Genesis and Morphology*. Cambridge University Press, p. 96.
- Tisdal, J.M., and J.M. Oades. Organic matter and water-stable aggregates in soils. *Journal of Soil Sci*, 33 (1982): 141–163.
- *USDA-NRCS Engineering Field Handbook*, Chapter 2, Hydrology.
- Walker, D., D. Baumgartner, K. Fritzsimmmons, and C.P. Gerber. 2006. Chapter 18: Surface Water Pollution, In *Environment & Pollution Science*. Eds. I.L. Pepper, C.P. Gerber, and M.L. Brusseau, p. 283.
- Widman, N., R. Glaze, B. Miller, A. Sundermeier, and R. Reeder, No-till Corn Production, Ohio State University Extension, Food, Agricultural and Biological Engineering, AEX 501-01.

## Related OSU Extension Fact Sheets

- Crop Rotations with Cover Crops
- Understanding Soil Ecology and Nutrient Recycling
- Homegrown Nitrogen
- The Biology of Soil Compaction
- Using Cover Crops to Improve Soil and Water Quality

## Ohioline

<http://ohioline.osu.edu>

Ohio State University Extension embraces human diversity and is committed to ensuring that all research and related educational programs are available to clientele on a nondiscriminatory basis without regard to age, ancestry, color, disability, gender identity or expression, genetic information, HIV/AIDS status, military status, national origin, race, religion, sex, sexual orientation, or veteran status. This statement is in accordance with United States Civil Rights Laws and the USDA.

Roger Rennekamp, Associate Dean and Director, Ohio State University Extension

For Deaf and Hard of Hearing, contact Ohio State University Extension using your preferred communication (e-mail, relay services, or video relay services). Phone 1-800-750-0750 between 8 a.m. and 5 p.m. EST Monday through Friday. Inform the operator to dial 614-292-6181.

Copyright © 2009, The Ohio State University