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Crop Rotation

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A basic tenet of agronomy courses has been the benefit of crop rotation. Modern cotton production runs counter to much of that teaching. In many parts of the Cotton Belt, monoculture and continuous cotton have maximized both short term and long term profitability.Now, with the flexibility provisions of the 1990 farm bill, should growers reevaluate their crop rotation? This issue will focus on specific benefits and detriments of rotation.

Cotton Monoculture

Monoculture — cotton grown year after year over a large area — describes much of cotton's history. This system has evolved because of its profitability.

Effect on Cotton Yields

Compared to other crops, cotton's yield response to crop rotations is relatively small. Long term rotation research, initiated at the turn of the century in Alabama, stressed growing legumes in rotation to provide the nitrogen needed for cotton production. Current (1978 to 1987) cotton yields in this ongoing study indicate an 11% increase in cotton yield with legume-cotton rotations compared to continuous cotton. These yield increases seem rather small when compared to 95 years of continuous cotton.

In the mid 1970's, declines in cotton yields Beltwide were attributed to the absence of crop rotation. However, another Alabama study (initiated in 1979) comparing continuous cotton with 1-year rotations of corn, soybeans or double crop wheat-soybeans has shown only small yield benefits since its inception. The largest lint yield increase (average 6%) resulted with the wheat-soybean rotation.

These long term studies reveal that although yield responses to rotation have not been dramatic, cotton responses to rotation can be larger where disease and nematodes build in the soil.

Reasons for Cotton Monoculture

Income Generation: The prime reason for continuous cotton is income generation. Many field crops simply do not generate as much income as cotton. USDA figures indicate that on average cotton returns $168 per acre above variable costs (excluding program benefits and no return to land or management) while soybeans, corn, milo, rice and wheat return $130, $95, $56, $51 and $47 per acre. Where cotton can be grown, it is the dominant crop. In areas with limited prime cotton soils, any rotation out of cotton will force cotton on to poorer soils or reduced acreage — both of which decrease profitability.

Pest Management: Cotton monoculture often leads to weed and insect suppression. Many pest problems come from adjoining rotational crops or non-cropped areas:

- Whiteflies from vegetables
- Boll weevils that overwinter in adjacent habitats
- Resistant spider mites from seed alfalfa or almond orchards
- Organophosphate resistant aphids from dormant treatments of orchards
- Lygus bugs and flea hoppers from alfalfa, safflower, weedy or non-crop areas
- European corn borer and corn earworm (bollworm) from nearby corn fields
- Weed seeds build up in low-input, non-cultivated crops such as soybeans.

Nutritional Efficiency: Cotton's nutritional needs are less than several other crops due to cotton's deep root system, mycorrhizal associations and warm season growth. When other crops are grown in rotation with cotton, the soil level of the stable nutrients (P, K and micronutrients) must be high enough to satisfy the requirements of these other crops. Cotton fields rotated with alfalfa, corn, vegetables or wheat, require higher soil levels of P than continuous cotton grown on that same field. Likewise, soybeans can tolerate lower fertility levels of K. Regardless of whether rotational crops need a higher or lower level of soil fertility, these different requirements create inefficiencies in fertility programs.

Cotton can achieve high fertilizer efficiencies without inputs from rotational crops. Cottons nutritional efficiency in the U.S. was recently reviewed by Walt Wallingford of the Potash and Phosphate In-

stitute. The average production of lint per pound of N fertilizer applied was 9.4 lbs in 1990, for each lb of P_2O_5 29 lbs of lint and for each lb of K_2O 43 lbs of lint. Cotton's fertilizer efficiency is higher now than at any other time, according to detailed fertilizer records that have been kept since 1964. These high efficiencies have come about by increased yields along with producer commitment to wise, efficient usage of fertilizers, and not by use of green manure rotational crops.

Herbicide Carryover: Bladex and Zorial are two of the herbicides used on cotton which can carryover and cause injury to rotational crops. Some herbicides used on other crops, such as Scepter on soybeans, can injure cotton the following year.

Problems associated with Monoculture Cotton

Diseases and nematodes: When cotton yields decline following continuous cotton, disease or nematodes is usually the culprit. Soilborne diseases such as Verticillium wilt, cotton black root rot and nematodes build their population with each consecutive year of susceptible hosts.

Weeds resistant to common cotton herbicides are a problem with continuous cotton. Nightshades, velvet leaf, cocklebur and strains of goosegrass are resistant to the dinitroaniline herbicides and unfortunately fill the void left in many cotton fields by the excellent control of grasses and other annual weeds. Cocklebur resistance to MSMA and DSMA also has been reported in a few Mid-South fields.

Some vegetable growers use cotton in rotation to gain access to herbicides unavailable to vegetables. Cotton provides the opportunity to clean up these vegetable fields.

Soil organic matter content will be lower in fields continuously cropped to cotton compared to those with grain corn in the rotation.

Pink bollworm While some insect pests are aggravated by rotation others are suppressed with rotations. The pink bollworm only can survive on cotton squares and bolls, thus large scale rotation out of cotton has a dramatic impact on this pest.

Crop diversity has historically led to economic stability and risk reduction. When several profitable crops can be grown, producers can weather downturns in cotton yields or price.

Rotation to Address Specific Problems

Rotation is not new. Virgil, the Roman poet who lived in 30 B.C., praised the use of crop rotation. Crop rotation is an efficient and economical weapon for controlling plant diseases. Farmers who practice monoculture must be constantly on guard against disease outbreak because the continuous presence of a host may permit pathogens to build up to high levels. In general, most rotations will have a positive effect to reduce the following diseases: Verticillium wilt, Phymatrotrichum root rot, black root rot (Thielaviopsis), Ascochyta blight, bacterial blight and nematodes.

As a general rule, rotations with crops that are most distantly related will provide the greatest pest suppression. For example: rotating cotton, a dicot (broadleaf), with monocots (wheat, barley, corn, milo, rice, sugarcane, onion and garlic), is superior to a rotation that includes only dicots (beans, vegetables, alfalfa). And rotations with close relatives of upland cotton (pima cotton and okra) provide the least suppression of pests.

Cotton Nematodes

Crop rotation is one of the oldest and most important methods of managing nematodes that feed on roots of annual plants. In cotton, the effectiveness of a rotation system will depend upon the type of nematodes present (above the threshold level), the type of rotational crop used and the length of the rotation. Realizing that nematodes cannot be eliminated, the overall goal is to keep the population density as low as possible.

Root-knot nematode can be managed with rotation, if the field is not infested with the Fusarium wilt fungus. One year out of cotton to any of the following crops can reduce nematode populations for cotton during the next two years: winter grain, nematode resistant beans, summer fallow (dry OK, wet better).

Rotation not only has a positive effect on nematode populations themselves, but also on the diseases with which the nematodes interact. This is true with the vascular wilts, several root rots, and the seedling disease complex. For example, if the reniform nematode population is high at planting, the seedling disease complex is much more severe. Reducing the populations by rotation will generally reduce the nematode and disease problem. Rotational studies conducted in the Mississippi Delta indicate that a 1-year rotation system for the control of the reniform nematode in cotton is beneficial. The studies included rotating cotton with milo, a reniform resistant soybean variety or wheat-fallow. The greatest reduction in reniform nematode population occurred using milo.

Verticillium Wilt

This disease is caused by a soil fungus *Verticillium dahliae* that survives in the soil as tough knots of hardened fungus (microsclerotia or propagules). Microsclerotia germinate and grow only a short distance in the soil to invade a nearby cotton root. This fungus survives on predominately broadleaf plants.

When host plants are grown for consecutive years, the number of propagules increases exponentially. The subsequent multitude of disease organisms increases the chance that a cotton root will be infected earlier in the season resulting in earlier plant injury or death.

Although the numbers of fungal propagules increases rapidly with consecutive years, the fungus only declines slowly due to its tough — resistant to degradation — microsclerotia. Just like pigweed or cocklebur seeds, once a field has become infested with a high level of Verticillium microsclerotia it will remain infested for many years despite rotation to non-host crops — with the exception of rice. The long term flooding associated with rice culture will destroy many cotton soil pathogens including *V. dahliae* and *Thielaviopis basicola*. However, the long term flooding with rice can also cause P availability problems in acid soils, when these soils are drained the oxidation of soil iron causes a tie-up of available soil P. Production of other crops that are not hosts to *V. dahliae* (barley, wheat, cornand milo) allow a gradual decline in microsclerotia and prevents their buildup. However, rotation to these non-host crops can fail to control Verticillium wilt if broadleaf weeds are present. Most broadleaf weeds are host of *V. dahliae* and allow production of additional microsclerotia.

Rotations with susceptible crops such as tomatoes build inoculum levels. Where Verticillium wilt is a severe problem (the San Joaquin Valley, West Texas and New Mexico), rotations that include a non-host crop every other year maintain the disease at low enough levels that Vert-sensitive varieties can be successfully grown. The high tolerance level of some Acala varieties allows cotton to be grown continuously, although the risk of severe yield loss increases dramatically if a cool early August promotes plant infection and subsequent premature crop termination.

Seedling Disease

In general, the seedling disease organisms that infect cotton have broad host ranges and can survive or buildup on most broadleaf crops. Thus, rotations that do not include monocots generally fail to suppress seedling disease. Specific rotations have been researched to suppress seedling diseases. Research in Arkansas has demonstrated the benefits of planting a hairy vetch cover crop for the control of cotton black root rot caused by *Thielaviopsis basicola.* California research has demonstrated the benefit of onion or garlic rotation (both monocots) for suppression of *T. basicola* seedling disease. Apparently in both of these cases a chemical is released that antagonizes *T. basicola.*

Other rotations with legume cover crops tend to increase the incidence of seeding disease, and if included in a rotation should be followed by a monocot crop prior to planting cotton.

Weed Control

Many of our tough cotton weeds can be controlled with herbicides used on other crops, such as corn. In addition, the ground shading with a vigorous corn crop will further suppress weeds that would tower over cotton. The various weeds have been controlled successfully with the following rotational crops and herbicide programs.

Weed	Rotational Crop	Herbicide
nutgrass	alfalfa, corn	Eptam, Lasso
nightshades, velvetleaf, cocklebur	corn, milo	Atrazine
morning glory	wheat	phenoxy

Organic Matter / Tilth

In the Alabama long term rotation studies, the continuous cotton fields presently contain 1% soil organic matter compared to the 3-year rotation of wheat-beans-corn-cotton which contains 2.5% organic matter. This difference results from the corn component of the rotation and translates into large differences in soil tilth, infiltration, crusting and compaction.

The following figure represents typical residue levels from different crops. To maintain high organic matter in cotton fields is not practical; either the field needs to be flooded to retard decomposition or annual additions of residue need to be made to compensate for the warm, wet weather's promotion of decay.

Residue from Various Crops

Crop	Tons per acre
Corn	3
Wheat	1.8
Cotton	1.0
Soybeans	1.1

Dry Fallow Rotation

A dry fallow rotation can be successful in controlling many noxious perennial weeds (field bindweed, bermudagrass, johnsongrass, nutgrass). In addition, dry fallow and winter crop rotations free up water for increased irrigation on other cotton fields.

Cover Crop Rotations

Cover crop rotations (planting a winter cereal or legume in the fall and then cotton next spring) is a technique that has been successfully developed primarily for erosion control and conservation compliance. This technology provides some of the benefits of rotation and at the same time maintains fields in cotton production. In Oklahoma, wheat is seeded

into the cotton prior to harvest, then grazed during the winter and planted into cotton in the next spring. In California, a barley cover crop resulted in a 10% increase in cotton lint due to improved soil tilth and suppression of disease. In Tennessee, a wheat cover crop is planted after cotton harvest to protect the highly erodible soils from winter rains.

About the Authors

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Should Cotton Fields Be Rotated?

YES

- Where soilborne diseases and nematodes and resistant weeds build up on continuous cotton, rotation may be the most economic control strategy.
- When profitable crops can be grown in rotation with cotton, diversification increases economic stability.

NO

- Certain farms are limited by their acres of prime cotton land. And distinct regions or soils of the cotton belt allow diseases and nematodes to be managed without rotation.Benefits of Specific Rotations

Rotation Crops and the Degree of Control they Provide to Various Soil Problems

CROP	Root Knot nematode	Reniform nematode	Verticillium wilt	Seedling disease	Thielaviopsis basicola	Organic Matter
Wheat + summer fallow	Good	Good	Good	Good	Some	Some
Soybeans or blackeyes (nematode resistant variety)	Some	Good	Minimal	Minimal	Some	Minimal
Corn	Good	Good	Good	Good	Good	Good
Milo	Good	Good plus	Good	Good	Good	Some
Alfalfa	Good	-	Some	Good	Some	Good
Onions or Garlic	Minimal	-	-	-	Good	Minimal
Fallow	Some	Some plus	Some	Some	Some	Minimal