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Cooperative Extension Service

Remediation of the Fragipan Using Annual Ryegrass

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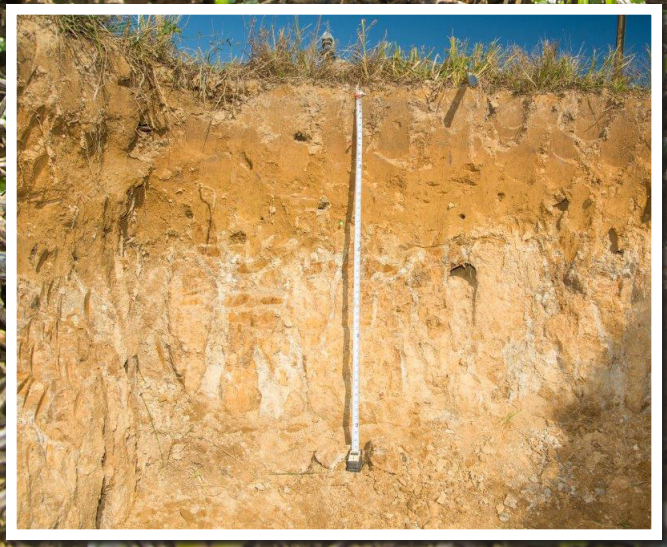

The fragipan is a naturally occurring restrictive soil horizon that virtually stops water movement and root growth through the soil. It commonly is located 18-32 inches below the surface of most of Kentucky's fragipan soils (Figure 1). The dense nature of this layer is due to the cementation and binding of the soil particles with a silicate rich amorphous aluminosilicate in association with iron. The binding agents seal the pores and pack soil particles close together (Figure 2). The fragipan is found in 2.7 million acres in Kentucky (Figure 3) and about 50 million acres in the United States (Figure 4).

The fragipan acts as a barrier similar to solid bedrock with negative effects on plant growth and rooting. Crop yields on fragipan soils are limited due to 1) limited water holding capacity and nutrient availability due to shallow soil depth and 2) water saturated soil conditions during wet periods that reduce soil oxygen, delays planting and other management operations and increases potential for soil compaction and denitrification losses of nitrate-N.

Fragipan characteristics such as hardness and density can vary within states and between states. Fragipan soils also vary in the depth to the fragipan and the thickness of the fragipan. These different characteristics are expected to affect the ease or difficulty with which a fragipan soil can be remediated.

If the cementing agents that created the fragipan can be dissolved the released soil particles can begin to function as a soil again with improved soil characteristics which previously limited yields.

Figure 1. A fragipan soil (Zanesville silt loam) with the lighter colored fragipan beginning 20 inches below the soil surface.

Figure 2. Cross section of the fragipan. The dark brownish areas are cemented and restrict root penetration or water movement.

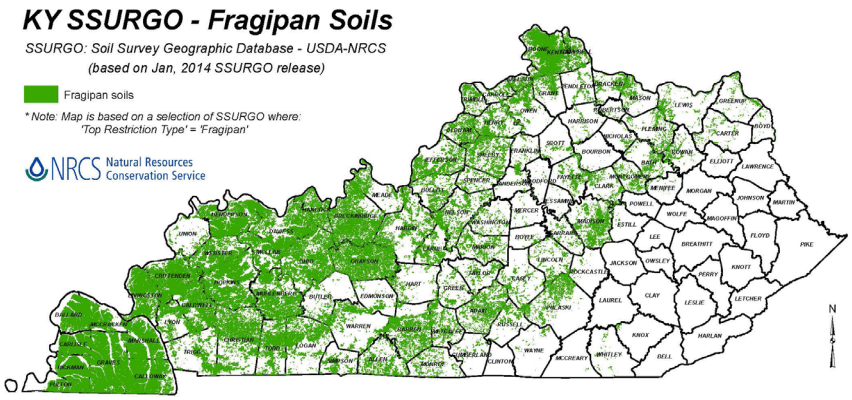

Figure 3. The location of fragipan soils (green) in Kentucky.

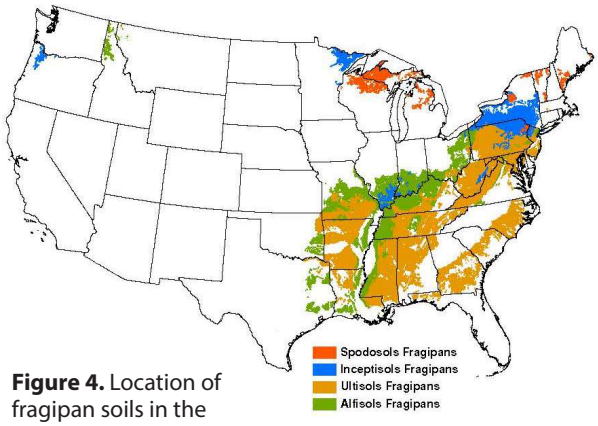

Figure 4. Location of fragipan soils in the United States.

Remediating the Fragipan

Laboratory, greenhouse and field experiments were conducted by scientists at the University of Kentucky to determine the potential of different chemicals and plants to dissolve fragipan binding agents. A number of them have shown promise but the one that showed the greatest promise in a number of laboratory and greenhouse tests and in the field, at this time, is annual ryegrass. The seven years of testing with annual ryegrass degraded the fragipan and increased yields more effectively than any other chemical or plant alternative and has shown good potential as a practical remedy.

What Fragipan Degradation Means in the Field

The effect of annual ryegrass on the fragipan degradation was examined in several fields that had a history of annual ryegrass used as a cover crop or forage crop. All fields used for this comparison had an adjoining control field of the same soil type and topography that had no history of annual ryegrass growth.

Table 1 shows results from five field trials with annual ryegrass grown over a 5- to 10-year period as a cover crop in a grain crop rotation compared to a no-till crop residue cover or as a hay and grazing crop compared to fescue. The depth of the soil to the point where the fragipan showed no signs of degradation was termed the depth to the unaltered fragipan. The depth to the unaltered fragipan increased with the growth of annual ryegrass in each case, with increases ranging from 3 to 14 inches and averaging 6.8 inches.

Table 1. Effect of annual ryegrass on the degradation of the fragipan grown on fields in Kentucky and Indiana.

Location	Treatment	Depth of Unaltered Fragipan (inches)	Notes
Todd County, Kentucky	Fescue sod	26.0	Annual ryegrass grown as a cover crop. Five of last 10 years in a corn and soybean rotation on a Sadler soil. Three replications with about 100 feet between ryegrass and control site.
	Ryegrass	31.5	
	Change in depth	5.5	
Logan County, Kentucky	Fescue sod	21.0	Annual ryegrass grown for hay and grazing. Five of last 10 years. Three replications with 75 feet between ryegrass and control site.
	Ryegrass	26.3	
	Change in depth	5.3	
Dubois County, Indiana	Fescue sod	18.3	Annual ryegrass grown 6 of last 6 years as a forage (grazing and hay). Double cropped with corn silage. Four replications with about 200 feet between ryegrass and control site.
	Ryegrass	31.3	
	Change in depth	14.0	
Dubois County, Indiana (SIPRF)	Fescue sod	25.0	Annual ryegrass grown in a mixture with radishes and spring oats as a forage, double cropped with sorghum or millet 10 of last 10 years with about 200 feet between ryegrass and control site. Five replications.
	Ryegrass	31.0	
	Change in depth	6.0	
Caldwell County, Kentucky	No-tillage cover	21.0	Annual ryegrass grown as a cover crop 5 of last 5 years in a corn and soybean rotation on a Zanesville soil. Six replications with a side by side comparison.
	Ryegrass	24.0	
	Change in depth	3.0	

Although the depth to the unaltered fragipan increased in each case, the rate of increase in depth to unaltered fragipan was somewhat unpredictable. Some of the factors that might have affected the rate of increase were:

- The number of times annual ryegrass was grown on a field
- The fragipan density and degree of cementation
- The stage of growth of the annual ryegrass before termination
- If annual ryegrass is grown as a single species or in a mixture

We assume the two most important factors that affected the increase in depth to unaltered fragipan were the fragipan density and degree of cementation and the number of times annual ryegrass was grown.

Yield Responses to Changing the Fragipan

As the cementing agent in the fragipan is dissolved, the freed soil particles begin to act as a productive soil making the soil deeper. This should increase the yields of these soils as the depth increases.

Six years of published research (see resources) completed in the 1970s and 80s on fragipan soils in Western Kentucky and Tennessee, indicated that for each inch of soil above the fragipan, corn yields increased an average of 2 to 2.3 bushels/ac (2 to 2.5 percent) and soybean 1.1 bushels/ac (4 percent). The yield increase varied greatly from year to year as the many things that affect yield, changed from year to year. The yield change ranged from a plus 5 bu/ac for each added inch to a one-year negative of 2 bu/ac.

The yield comparisons that we presently have from field trials with and without annual ryegrass on fragipan soils are of rather short duration (3 to 6 years). It appears that little or no yield gain is common in the first two years. Yield gains after this become more consistent and significant. In 2018, yield comparisons from six field trials were harvested. The yield gains found when using annual ryegrass as a cover crop ranged from 3.1 percent to 13 percent with an average of 6.4 percent. Five of the sites had an annual ryegrass cover crop for three years and one for six years.

The only long-term data demonstrating the ability of annual ryegrass to degrade fragipans was collected from a field owned by Ralph (Junior) Upton in Hamilton County Illinois. Annual ryegrass was grown as a cover crop alone or in a mixture for 15 years on a fragipan soil type (Bluford silt loam). Corn yields in the field with the ryegrass cover crop were compared to the yearly average corn yields for Hamilton County (Figure 5). The trend line indicates that yields on his fragipan soil with ryegrass cover crops begin 15 to 20 bu/ac below the county average and after 15 years were over 40 bu/ac. above the county average. This sloping, somewhat eroded field was compared to all the soils and different management practices in that county. This data demonstrates that the long-term use of an annual ryegrass cover crop may positively influence fragipan soils and increase productivity and yields over a long period of time. This is the only long-term data we are aware of at this time. Although this is not a scientifically controlled trial it does suggest that the extra effort for this practice may be justified.

Finding a Solution in the Laboratory

Soil slaking is the breakdown of soil clods and is related to the soil's structural stability. Slaking laboratory experiments allowed researchers to determine if a plant, chemical, or other products might show promise as a treatment that would dissolve the cement between the particles. Naturally cemented fragipan clods were placed in a solution of each plant extract, chemical, or other product (Figure 6). Thirty days later the size and distribution of the remaining aggregates were determined (Figure 7). As the binding agent is dissolved, the fragipan clod begins to fall apart. The greater the dissolution of the binding agent, the smaller the remaining aggregates. Among many different materials tested, extracts from annual ryegrass was one of the few that

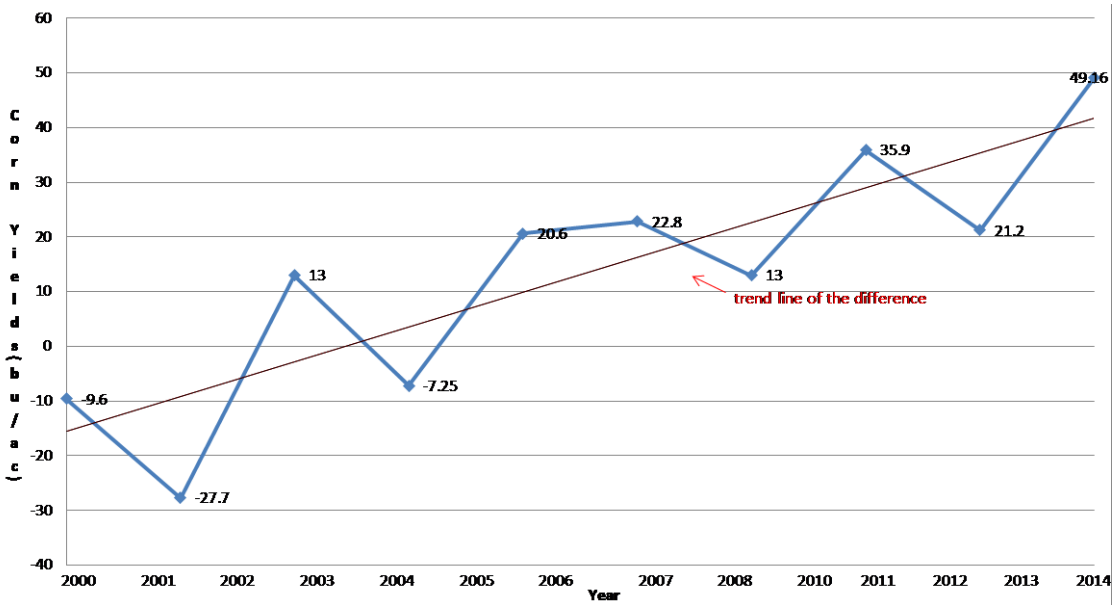

Figure 5. Differences between corn yields on Upton's Ryegrass cover crop field compared to the Hamilton County, Illinois, average yield over a 15-year period.

demonstrated a significant ability to dissolve the cementing agents binding the fragipan particles. The above ground foliage and the roots of annual ryegrass were tested separately, and both found to have similar effectiveness.

Ten varieties of annual ryegrass have been tested to identify possible differences among varieties in dissolving the cement binding agent. All annual ryegrass varieties effectively broke apart the fragipan. Five of the varieties had a greater effect on dissolving the binding agent as measured in the laboratory. They were Bounty, Marshall, Bruiser, Centurion and Bardelta suggesting these varieties may contain a higher concentration of the chemical or chemicals that dissolve the cementing agent.

Degrading the Fragipan in Greenhouse Experiments

Complete intact soil profiles in transparent plastic tubes were used in the greenhouse experiments (Figure 8). Different plants were grown in them and the most promising treatments were applied to the surface soil as they would be in the field. The top of the fragipan was marked on the tube when the core was taken. Rooting patterns and any changes to the fragipan from those roots or applied treatments were observed.

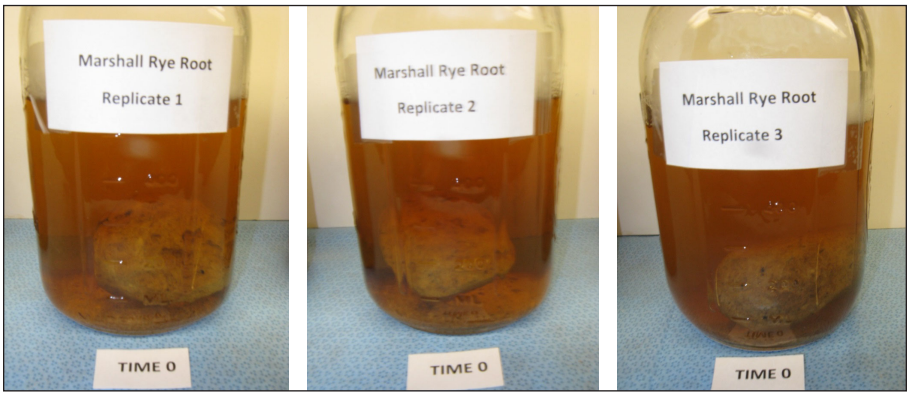

Figure 6. The beginning of the Slaking Trial, in which naturally occurring cemented fragipan clods are placed in a solution of a plant extract, chemical, or other product.

Annual ryegrass was grown in a rotation with soybeans or corn similar to cover crop conditions. It was grown to a height of 9 to 12 inches in about three months before being killed with glyphosate. Annual ryegrass roots reached the fragipan at 18 to 24 inches within five to six weeks after planting and top growth reached about 4 to 5 inches at this time. Extensive rooting reached the fragipan in about 2 to 2.5 months. No changes in the fragipan were observed with the first cycle of an annual ryegrass cover crop but differences became apparent during the second cover crop cycle. The binding agent was dissolved in zones in the upper part of the fragipan (Figure 9).

Figure 7. The remaining aggregates produced from the single fragipan clod after 30 days in a solution of annual ryegrass extract.

These zones became bleached in color and some of the massive structure turned to loose, friable and powdery particles. Deeper areas remained unchanged.

The more often annual ryegrass was grown the more the fragipan was degraded and the degradation became more extensive and deeper. When annual ryegrass was grown 6 times in a rotation with soybeans the depth of the newly formed productive soil increased about 7 inches when compared to the unaltered fragipan (Figure 10). The bulk density was also decreased, the porosity was increased, and the bonding strength of the fragipan soil was decreased thus allowing more extensive root growth.

Figure 8. Complete soil profiles in transparent tubes allow for visual verification of different treatments added to break apart the fragipan.

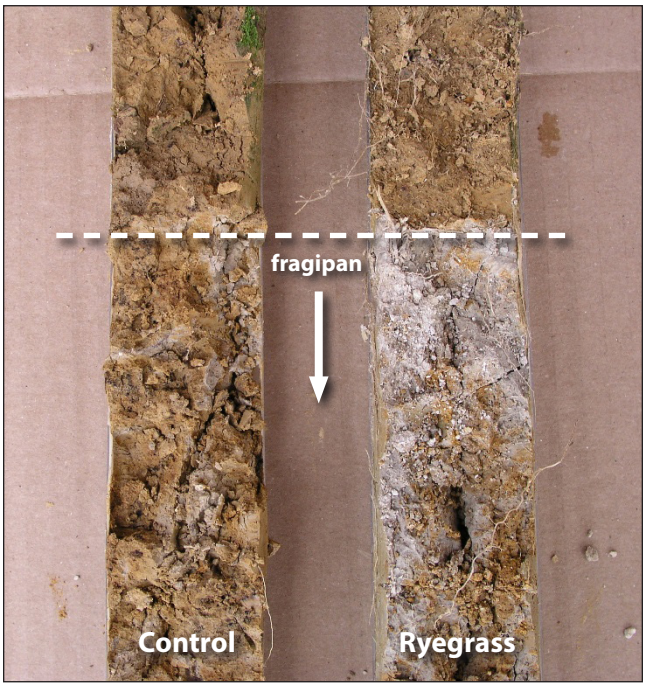

Figure 9. The core on the right had two annual ryegrass cover crops grown on this soil profile. Zones in the upper part of the fragipan became bleached and powdery. The core on the left is the control fragipan profile.

Growing Ryegrass to Degrade the Fragipan

Annual ryegrass is a cool season grass that has an extensive root system and robust growth. It makes an excellent cover crop and is also a high-quality forage crop. Whether being grown for a cover crop or forage, annual ryegrass can reduce soil erosion, capture excessive nutrients and build soil organic matter, all while remediating the fragipan. It is fortunate that a plant with such good qualities is also one that contains the right chemistry needed to degrade the fragipan. These chemical substances are present in both the roots and the above ground plant foliage. Although it is not proven, the roots are assumed to be the most effective part of the plant in degrading the fragipan since they are in contact with the fragipan and exert both physical and chemical action. Increases in annual ryegrass root and top growth are assumed to increase the quantity of chemical compounds released in the soil.

The annual ryegrass roots must reach the fragipan to maximize the remediation effect. When annual ryegrass achieves a shoot growth of 7 to 10 inches in height, roots should reach 3 feet or more, enough to directly contact and interact with the fragipan. Annual ryegrass as short as 4 inches in shoot growth will have roots 24 inches deep or deeper in the fall. However, the root volume is minimal at this time and the expected fragipan remediation would be minimal at this point.

Planting Date

Annual ryegrass establishes and grows faster in warm temperatures (above 55 degrees F). September is the ideal planting date for annual ryegrass and should allow for at least 6 inches of shoot growth before winter. September plantings should allow for earlier spring termination of annual ryegrass cover crops and also allow for maximum forage production.

Planting the first or second week of October, most years, can give good stands but the root and shoot growth are reduced going into winter. October plantings might require later termination of annual ryegrass in the spring to allow for adequate root and shoot growth to help remediate the fragipan.

Cutting or grazing annual ryegrass will slow root development. Greenhouse studies indicate that removing shoot growth reduces root growth until shoot growth recovers.

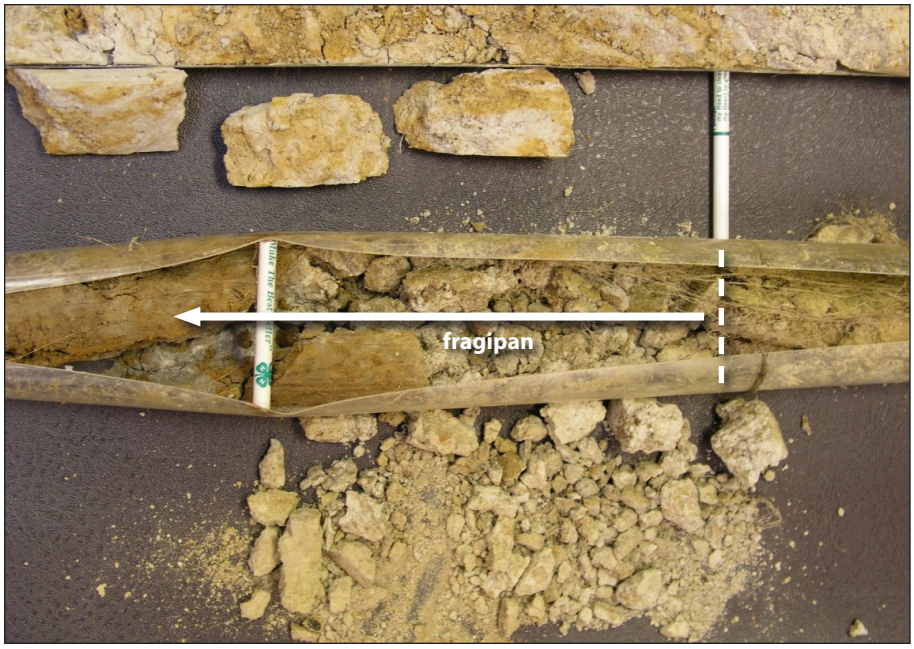

Figure 10. The altered fragipan (lower profile) after annual ryegrass is grown six times in an annual ryegrass/soybean rotation. The upper profile is the control.

Planting Method

No-till drills are the best method for planting annual ryegrass. Seeding rates of 10 to 15 pounds per acre at a depth of ¼ to ½ inch are ideal. Some farmers have been successful using coated seed mixed with fall applied fertilizer and broadcasting the mixture soon after corn or soybean harvest. Some have used pneumatic spreaders to broadcast uncoated seed soon after harvest. These methods are reported to be successful with or without a light disking. In more northern areas, annual ryegrass is sometimes broadcast into standing corn or soybeans. Broadcasting annual ryegrass seed is dependent on late season rains to successfully germinate the seeds. Higher seeding rates may be necessary to offset the risk of seeding failure.

Corn and Soybean Rotation

Shorter season corn and soybean varieties also help with earlier planting of annual ryegrass and may allow for an earlier kill in the spring.

Nitrogen and Annual Ryegrass

Annual ryegrass grown after soybeans needs little or no nitrogen to stimulate the foliage and root growth. However, the additional nitrogen can be quite beneficial to annual ryegrass when planted after high-yielding corn or summers with excessive rainfalls. When the annual ryegrass shows symptoms of nitrogen deficiency (yellowing and slow growth) 30 to 40 pounds of nitrogen per acre will significantly increase the foliage and root growth.

Annual Ryegrass Varieties

There are differences in varieties of annual ryegrass. Select a variety that is capable of good growth and is not susceptible to winter kill. The University of Kentucky variety test is an excellent place for help http://forages.ca.uky.edu/variety_trials. A variety that has excellent root development and a high concentration of the chemical substances that degrade the fragipan is preferred. There is some but limited information on these two items. The concentration of effective chemical compounds in annual ryegrass varies that have been tested was addressed earlier in this publication. Only ten varieties were tested though. There are also varieties bred for high rooting volume but there is limited public information on this subject.

The different methods of killing the ryegrass cover crop is covered by a number of publications. Desiccation of the ryegrass before planting removes the green bridge and reduces some possible disease and vole problems. Additional information can be found in a number of publications. The publication "Annual Ryegrass as a Cover Crop" in the References section is an excellent resource.

Conclusion

Laboratory and greenhouse experiments and field trials using annual ryegrass have led to several preliminary conclusions.

- Lab results indicate that annual ryegrass produces chemicals that dissolve the fragipan cementing agents and turn portions of the dense fragipan back into productive soil particles with a more favorable structure.
- Greenhouse and Field trials indicated that annual ryegrass degradation of the fragipan might occur as a cumulative process over multiple seasons.
- Annual ryegrass breaks down the fragipan in an uneven manner. Numerous observations seem to indicate that parts of the fragipan are less cemented, allowing some root growth. The effect of the ryegrass begins in these areas with weaker cementation and expands to more resistant areas over multiple growing seasons.

Acknowledgements

The authors want to thank Ralph (Junior) Upton and the late Mike Plumer for their kind assistance on this project. They learned the benefit of annual ryegrass as a cover crop on a fragipan soil using a different method and were willing to share their experience.

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Cover photos:

Main: No-till ryegrass seeded into a harvested soybean field.
Steve Patton, Agricultural Communications

Top: No-till ryegrass cover crop in late March.
Dottie Call, Plant and Soil Sciences

Bottom: Fragipan beginning 24 inches below the soil surface.
Steve Patton, Agricultural Communications

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