

Legumes and Soil Quality



United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Soil Quality Institute
411 S. Donahue Dr.
Auburn, AL 36832
334-844-4741
X-177

Technical
Note No. 6

March 1998

This is the sixth in a series of Soil Quality-Agronomy technical notes on the effects of land management on soil quality. This information is general and covers broad application.



Introduction

The ability of legumes to fix atmospheric nitrogen is perhaps the most notable aspect that sets them apart from other plants. In addition, legumes can provide a wide range of important soil quality benefits.

Nitrogen Fixation

Legume plant and seed tissue is relatively high in protein. This can be directly attributed to a legume's ability to supply most of its own nitrogen needs with the help of symbiotic *Rhizobia* bacteria living in their roots.

Inoculated with the proper strain of *Rhizobia* bacteria, legumes can supply up to 90% of their own nitrogen (N). Shortly after a legume seed germinates in the presence of *Rhizobia* bacteria in the soil, the bacteria penetrate the root hairs and move into the root itself. The bacteria multiply, causing a swelling of the root to form pale pink nodules.

Nitrogen gas present in the soil air is then bound by the bacteria which feed on carbohydrates manufactured by the above-ground plant during photosynthesis. The bacteria produce ammonia (NH₃) from the hydrogen acquired from the plant's carbohydrates and nitrogen from the air. The ammonia then provides a source of nitrogen for the plant to grow. This symbiotic relationship between bacteria and legume allows them both to flourish and produce a high-protein seed or forage crop. Even though legumes can fix nitrogen from the atmosphere, they can take up large quantities of soil nitrogen if it is available.

Generally speaking, the higher the protein content of a plant the more nitrogen it will return to the soil. Nitrogen is an important element for the formation of soil organic matter.

Nitrogen release from a legume crop occurs as the above-ground plant residues, roots and nodules gradually decompose. Soil microorganisms decompose the relatively nitrogen-rich organic material and release the nitrogen to the soil when they die. Usually about two-thirds of the nitrogen fixed by a legume crop becomes available the next growing season after a legume in a rotation.

In a perennial grass and legume mixture, legumes not only supply their own N, but approximately 36% of the N needs of the grass plants growing alongside them. The total amount of N fixed and released by a legume can be estimated from the amount of seed produced by an annual legume as follows:

| |
|--|
| $\text{Bushels of seed/acre} \times 1.0 = \text{lbs. of N/acre}$ <p style="text-align: center;">or,</p> $\text{Pounds of seed/acre} \times .017 = \text{lbs. of N/acre}$ |
|--|

For perennial or biennial legumes such as alfalfa or sweetclover, 40 to 70 pounds of N are produced per ton of forage if the crop is left unharvested. If the crop is harvested as forage, the remaining stubble and roots will return 5 to 15 pounds of nitrogen to the soil as a function of each ton of forage removed. Tillage is not necessary to release legume-N into the soil. A study involving no-till corn after legumes demonstrated that the N benefits following a legume were the same whether the legume was killed with herbicide or with tillage.

Soil Quality Benefits of Legumes

Soil quality benefits of legumes include: increasing soil organic matter, improving soil porosity, recycling nutrients, improving soil structure, decreasing soil pH, diversifying the microscopic life in the soil, and breaking disease build-up and weed problems of grass-type crops.

Soil Organic Matter

As mentioned previously, legumes are high in protein, and therefore, nitrogen-rich. Because most crop residues contain much more carbon than nitrogen, and bacteria in the soil need both, the nitrogen supplied by legumes facilitates the decomposition of crop residues in the soil and their conversion to soil-building organic matter.

Soil Porosity

Several legumes have aggressive taproots reaching 6 to 8 feet deep and a half inch in diameter that open pathways deep into the soil. Nitrogen-rich legume residues encourage earthworms and the burrows they create. The root channels and earthworm burrows increase soil porosity, promoting air movement and water percolation deep into the soil.

Recycle Nutrients

Because perennial and biennial legumes root deeply in the soil, they have the ability to recycle crop nutrients that are deep in the soil profile. This results in a more efficient use of applied fertilizer and prevents nutrients (particularly nitrate nitrogen) from being lost due to leaching below the root zone of shallower-rooted crops in the rotation.

Improve Soil Structure

Research in both the United States and Canada indicate improved soil physical

properties following legumes. The improvements are attributed to increases in more stable soil aggregates. The protein, glomalin, symbiotically along the roots of legumes and other plants, serves as a “glue” that binds soil together into stable aggregates. This aggregate stability increases pore space and tilth, reducing both soil erodibility and crusting.

Lower Soil pH

Because inoculated, nodulated legumes acquire their N from the air as diatomic N rather than from the soil as nitrate, their net effect is to lower the pH of the soil. In greenhouse studies, alfalfa and soybeans lowered the pH in a Nicollet clay loam soil by one whole pH unit. Legumes could lower the pH and promote increased plant-soil-microbial activity on soils with a pH above the range for optimum crop growth and development.

Biological Diversity

Legumes contribute to an increased diversity of soil flora and fauna lending a greater stability to the total life of the soil. Legumes also foster production of a greater total biomass in the soil by providing additional N. Soil microbes use the increased N to break down carbon-rich residues of crops like wheat or corn.

Break Pest Cycles

Legumes provide an excellent break in a crop rotation that reduces the build-up of grassy weed problems, insects, and diseases. A three year interval between the same type (grassy, broadleaf, cool-season, warm season) crop is usually sufficient to greatly reduce weed, insect, and disease pressure.

Conclusion

All totaled, the soil quality benefits of legumes have been shown to be greater than the sum of their parts. Research in Saskatchewan and Minnesota, have shown yield increases of spring small grains of 7 to 14% after alfalfa. This yield increase is in addition to what can be attributed to improvements in moisture and nutrients measured in the soil. The Minnesota research attributes these yield increases to 'rotation effects' including improved soil physical

properties, depression of phytotoxic substances, addition of growth promoting substances, and decreased disease pressure.

Legumes can provide a multitude of benefits to both the soil and other crops grown in combination with them or following them in a rotation. Locally adapted legumes can be used in almost any conservation situation to improve soil quality.

References:

- Bowren, K.E., V.O. Biederbeck, H.A. Bjorge, S.A. Brandt, B.P. Goplen, J.L. Henry, H. Ukrainetz, T. Wright, and L.A. McLean. 1995. Soil Improvement With Legumes. 24 pp. Saskatchewan Agriculture and Food. (Internet site; www.gov.sk.ca)
- Ebelhar, S.A., W.W. Frye, and R.L. Blevins. 1984. Nitrogen from legume cover crops for no-tillage corn. pp. 51-55. *Agronomy Journal*, vol. 76, January-February 1984.
- Graber, L.F., and J.M. Sund. 1975. *Laboratory Manual for Students of Agronomy*, 10th edition. 246 pp. Kendall/Hunt Publishing Co., Dubuque, IA.
- Heichel, G.H., and K.I. Henjum. 1991. Dinitrogen fixation, nitrogen transfer, and productivity of forage legume-grass communities.. *Crop Science* 31:202-208.
- Nyatsanga, Titus, and W.H. Pierre. 1973. Effect of Nitrogen Fixation by Legumes on Soil Acidity. *Agronomy Journal* 65: 936-940.
- O'Leary, Mike, George Rehm, and Michael Schmitt, 1990. Providing Proper N Credit for Legumes. University of Minnesota Extension Service, Clean Water Series. (Internet site; www.mes.umn.edu)
- Wright, Sara E., and Abha Upadhyaya. 1997. Extraction of an abundant and unusual protein from soil and comparison with hyphal protein of arbuscular mycorrhizal fungi.. *Soil Science* 161(9):575-586.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326W, Whitten Building, 14th and Independence Avenue, SW, Washington, D.C. 20250-9410 or call (202) 720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.