# Increasing Soybean Productivity

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# Increasing Soybean Productivity while Improving Soil Quality and Mitigating Climate Change

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Soybeans are in high demand around the world. This is a great market opportunity for American producers but it is also a challenge. How do we grow more soybeans without harming our soil and environmental quality and reducing future food production? How do we grow soybeans sustainably on marginal land better suited to grass?

We are researching management systems that include no-tillage, multi-purpose cover crops and gypsum soil amendment for higher soybean yields. These soybean production systems are expected to increase soybean yields even when soybeans are grown on marginal lands or under intensified growing conditions. These methods maintain sustainable environmental practices that enhance overall "ecosystem services" by reducing soil erosion and greenhouse gas emissions and by improving soil and water quality.

This project is supported by the United Soybean Board to help improve the environmental footprint of the entire U.S. soybean industry, including raising awareness among farmers on why sustainability is important. The project began in October 2011.

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Field experiments are being conducted at four locations across different soil types and weather: Hoytville in northwest Ohio; Piketon in south central Ohio; Farmland in east central Indiana; and Auburn in east central Alabama.

The tests include: (1) continuous soybeans compared to a soybean/corn rotation; (2) cover crops versus no cover crop; and (3) FGD gypsum surface-applied at 1,000 and 2,000 pounds per acre per year compared to no gypsum. (FGD gypsum is a high quality by-product from the flue gas desulfurization process in coal-fired power plants.) A high-oil soybean variety suitable for soydiesel production is also included in the experiment.

Selecting best management practices that produce high soybean yields and maintain soil quality is the key for sustainable production systems. Soybeans produce much less residue than other crops such as corn. Growing soybeans continuously or even including soybeans in rotation causes a decline in soil organic matter and overall soil quality. This decline can be counteracted by using continuous no-tillage, cover crops, and soil amendments such as gypsum ($CaSO_4 \cdot 2H_2O$). [i]

### Cover crops and continuous no-till

Because soybeans produce so little residue, cover crops are an essential component in maintaining and building soil quality. Converting from conventional tillage to continuous no-till is a good strategy to reduce farming costs and improve functional capacity of agricultural soil for enhanced ecosystem services. With no-till, crop residues accumulate on the surface, reducing air and water exchange between the soil surface and the atmosphere. As a result, soil temperatures are lower, evaporation is reduced (soil retains moisture longer), and less nitrogen and phosphorus are lost to waterways.[ii]

**Oilseed radish can grow to 2 to 3 inches diameter and go 12 to 24 inches deep.**


**Soybeans following cereal rye cover crop**

Potential benefits include:

- greater accumulation of soil organic matter and associated nutrients;
- reduced greenhouse gas emissions;
- increased soil aggregate formation and stability;
- increased fungal dominance in soil food webs;
- and improved water infiltration and drainage.

The result is enhanced soil quality to support higher crop yields.[iii]

Despite success with no-till soybeans, farmers still face some barriers as they transition to continuous no-till: lower crop yields, soil c ompaction, weed pressure, stratification of nutrients, and immobilization of N and P. Cover crops are a key component to shorten the transition period and create a long-term economically and environmentally sustainable system.[iv]

Based on Ohio State University research, continuous no-till with cover crops decreases reactive P and N losses by 55% to 85% via surface runoff and infiltration compared to conventional tillage. Plus, cover crops provide substantial amounts of fixed N (from legumes), recycle biomass N and P for succeeding crops, increase yields, reduce greenhouse gas emissions, increase soil organic matter, and improve overall soil quality.[v]

Cover crops that produce allelopathic (weed-inhibiting) chemicals are valuable for assisting or replacing herbicides for weed management. Cereal rye and oilseed radish provide allelopathic benefits. In field trials using radish and rye planted in the fall as cover crops and soybeans drilled into standing cover crops, only rye provided season-long weed suppression. Cereal rye is a popular cover crop in the Midwest because of its winter-hardiness and exceptional ability to scavenge N and P from the soil. Oilseed radish can grow to 2 to 3 inches diameter and go 12 to 24 inches deep. Freezing temperatures kill the radish, leaving holes in the ground which greatly increases infiltration and aeration. The deep rooting of both cover crops helps break up compacted soils.[vi]

Including oilseed radish and cereal rye in a continuous no-till system will: minimize surface runoff, leaching, and soil erosion; recycle biomass carbon, N, and P (reducing rates for N and P fertilization); accumulate soil organic matter; enhance soil quality; and increase crop yields.[vii]

## FGD Gypsum

Gypsum is one of the earliest forms of fertilizer used in the United States, having been applied to agricultural soils for more than 250 years. Gypsum can help improve crop yields and overall soil quality.[viii]

For many years, crops received more than enough sulfur from rainfall, mainly from the burning of coal by power plants. In 1979 about 31 pounds of sulfur per acre were deposited onto Ohio soils. By 2007, only 16 pounds of sulfur per acre were deposited.[ix]

Concerns about air quality have resulted in federal legislation requiring coal-fired power plants to reduce the emission of sulfur dioxide ($SO_2$), which resulted in the development of sulfur removal systems. The by-product of this process is flue gas desulfurization (FGD) gypsum. This FGD gypsum is typically greater than 95% pure gypsum.

Other factors have led to less sulfur in soils: use of highly concentrated fertilizers containing little or no sulfur; and intensive cropping systems with increased yields that result in more sulfur removal from the soil every year. This decrease is leading to more frequent reports of sulfur deficiencies in crops.[x]

Benefits of gypsum as a soil amendment for soybean production may include:

(1) reducing surface crusting and thus increased water infiltration and soil aeration;
(2) serving as a source of calcium and sulfur for plants;
(3) improving nitrogen fertilizer use efficiency for the corn crop that would follow soybeans in rotation;
(4) ameliorating the effect of subsurface acidity, not by changing soil pH but by dislodging aluminum from soil exchange sites and also by chelating soluble aluminum with sulfate to create a less

toxic form of aluminum sulfate; and

(5) improving crop productivity on high sodium or magnesium soils.

Overall, these lead to a healthier and more extensive root system meaning that fertilizer use efficiency and water uptake are improved.[xi]

Gypsum helps eliminate surface crusting by reducing the chemical dispersion of the clay caused by low electrolyte rain water. Both the rate of crust development and final strength will be affected by gypsum additions leading to improved seedling emergence. Surface crust strength is largely dependent on clay and moisture content.[xii]

**Environment**

Additionally, gypsum soil amendment also benefits the environment by:

(1) enhancing the ability to practice no-tillage on heavy clay soils where no-tillage normally does not do so well — this can also sequester carbon;

(2) increasing soil drainage and preventing surface sealing thus mitigating the production of nitrous oxide and methane by the reduction of reactive nitrogen (nitrate) and dissolved organic carbon under poorly drained conditions — note that one molecule of nitrous oxide is equivalent to 310 of carbon dioxide and one molecule of methane is equivalent to 27 molecules of carbon dioxide with potential as a greenhouse gas;

(3) improving soil aggregate stability, water infiltration, and reducing water runoff, and thus, erosion, which is important on more fragile, sloping lands when soybeans are produced;

(4) reducing loss of reactive phosphorus from farmland, benefiting fragile lakes, such as Lake Erie and Ohio's Grand Lake St. Marys, and coastal regions of the Gulf of Mexico and the Chesapeake Bay where soluble nutrient loadings are a concern. The calcium in gypsum binds with phosphorus to form a calcium phosphate precipitate [$Ca_3(PO_4)_2$]. Excess P has resulted in eutrophication (excessive levels of blue-green algae) in lakes which led to millions of dollars of losses from recreational uses and added costs for municipal water treatment plants.[xiii]

**Economics**

Use of FGD gypsum as a soil amendment also offers economic benefits to crop producers. Data from a four-year experiment conducted by The Ohio State University showed that when gypsum was used to grow corn at a reduced nitrogen fertilizer application rate of 150 pounds nitrogen per acre, the difference between gypsum treated and untreated plots was 26 bushels per acre in favor of the gypsum treatment. Soybeans can withstand saturated soil conditions much longer when the soil has been treated with gypsum. The economic benefits of gypsum on soybean production have not, however, been fully documented.[xiv]

If climate change forecasts are accurate, more drastic variations in weather will result in swings between excessive rainfall and drought. Continuous no-till will help maintain high soybean production by improving soil drainage during excessively wet years and maintaining more water in the soil profile during drought years. No-tillage does this by creating macropores that helps soil quickly get rid of excess water and by maintaining a mulch layer that reduces evaporation and thus increases water supply to crops during times of drought.[xv]

**Summary**

With cover crops and/or gypsum, soybean productivity can be increased by combining continuous no-tillage practices and rotation with corn on more fragile lands and with continuous soybean production on higher quality soil. These management practices will promote ecosystem services of improved soil and water quality, minimized weed pressures, enhanced carbon sequestration, and reduced greenhouse gas emissions.

## References


[i] Using Cover Crops to Convert to No-till, by Jim Hoorman, Alan Sundermeier, Rafiq Islam and Randall Reeder. 2009. Crops and Soils 42 (6), Nov-Dec., p 9.

[ii] Using Cover Crops to Convert to No-till, by Jim Hoorman, Alan Sundermeier, Rafiq Islam and Randall Reeder. 2009. Crops and Soils 42 (6), Nov-Dec., p 9.

[iii] Using Cover Crops to Convert to No-till, by Jim Hoorman, Alan Sundermeier, Rafiq Islam and Randall Reeder. 2009. Crops and Soils 42 (6), Nov-Dec., p 10.

[iv] Using Cover Crops to Convert to No-till, by Jim Hoorman, Alan Sundermeier, Rafiq Islam and Randall Reeder. 2009. Crops and Soils 42 (6), Nov-Dec., p 11.

[v] Using Cover Crops to Convert to No-till, by Jim Hoorman, Alan Sundermeier, Rafiq Islam and Randall Reeder. 2009. Crops and Soils 42 (6), Nov-Dec., p 12. [ii]

[vi] Using Cover Crops to Convert to No-till, by Jim Hoorman, Alan Sundermeier, Rafiq Islam and Randall Reeder. 2009. Crops and Soils 42 (6), Nov-Dec., p 12.

[vii] Using Cover Crops to Convert to No-till, by Jim Hoorman, Alan Sundermeier, Rafiq Islam and Randall Reeder. 2009. Crops and Soils 42 (6), Nov-Dec., p 12.

[viii] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 10) http://ohioline.osu.edu/b945/b945.pdf

[ix] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 8) http://ohioline.osu.edu/b945/b945.pdf

[x] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 8) http://ohioline.osu.edu/b945/b945.pdf

[xi] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 14) http://ohioline.osu.edu/b945/b945.pdf

[xii] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 10) http://ohioline.osu.edu/b945/b945.pdf

[xiii] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 14) http://ohioline.osu.edu/b945/b945.pdf

[xiv] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 24) http://ohioline.osu.edu/b945/b945.pdf

[xv] Gypsum as an Agricultural Amendment, by Liming Chen and Warren Dick. 2011. Ohio State University Extension Bulletin 945. (page 5) http://ohioline.osu.edu/b945/b945.pdf