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1. Soil organic matter: How it is measured

Most producers and landowners have at least some idea of soil organic matter, and of its importance in soil health. Organic matter provides several benefits to crops and soils, including:

* Supplies all or part of most essential nutrients for plant growth.
* Improves soil physical condition.
* Increases water infiltration rates and water holding capacity.
* Reduces erosion potential.

The only real drawback to higher levels of organic matter on soils in the Central Plains is that organic matter can tie up certain herbicides, requiring higher rates of application on soils with high organic matter.

Organic matter consists of the remains of plants and animals in various degrees of decay. This includes everything from fresh organic residue readily decomposed by soil microbes to fractions that are very resistant to further decomposition.

A soil testing lab determines only “stable” organic matter. The lab intentionally omits fresh organic residue from its organic matter determination. Soil sampling instructions call for pushing residue cover aside when taking a soil sample. Also, in processing the soil sample in the lab, the samples are dried, crushed, and sieved. This removes any large particles of crop residue.

Measuring soil organic matter in the lab is usually done indirectly, by measuring either the total nitrogen or total carbon of the soil sample. Because there is less variation of carbon content in organic materials than nitrogen, organic matter is usually based on determining total carbon. Total carbon is then converted to organic matter by assuming a certain percent carbon in organic matter.

Carbon determination can be by wet digestion with chromic acid oxidation of easily oxidized material or dry combustion measuring carbon dioxide evolved or loss of sample weight. The chromic acid method was the method most used in early soil test labs, but many labs have now converted to dry combustion methods because of waste disposal restrictions for chromic acid. All methods have been cross-compared and reported organic matter contents are similar for the wet and dry procedures.

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2. Trends in soil organic matter: Past, present, and future

Breaking of native sod to put land into crop production has generally resulted in lowering soil organic matter levels because tillage has increased microbial decomposition of the existing organic matter and there has been increased removal of organic material in the form of grain and/or forage. In many cases there also has been greater erosion on the cultivated land.

Estimates of soil organic matter losses from breaking native sod for cultivated crop production range from 25 to greater than 50% over a 30 to 40 year period on land converted in the early 1900's. The greatest decrease occurred in the first 10 years and where grain crops were grown continuously without rotation with green manure crops. These observations come from an era of low crop yields and maximum tillage for seedbed preparation with few soil conservation practices.

K-State agronomists were concerned about soil organic matter losses even in the early 1900s. A 1918 Kansas Experiment Station bulletin (No. 220) on soil fertility, authored by L.E. Call and R.I. Throckmorton, mentions the importance of organic matter for crop production. The authors encouraged the use of crop rotations and manure to maintain organic matter levels. Their observation of the importance of organic matter is still valid today.

With substantially higher yields today through better cultural practices -- including better hybrids/varieties, proper fertilization, better erosion control practices, and minimum or no-till planting practices -- organic matter levels are being maintained or slightly increased in many fields. However, organic matter levels have not returned to pre-cultivated levels, and in many cases returning to pre-cultivations may not be possible.

It is difficult to build organic matter levels because of the amount of organic residue required to result in an increase, but lowering of soil organic matter levels can happen quickly through soil erosion. Organic matter levels decrease markedly with soil depth.

Thus, removing topsoil through either wind or water erosion results in a lower organic matter soil.

One approach to assessing soil organic matter changes over time is to consider a balance sheet approach of deposits and withdrawals. The deposits being the amount of crop residue, manure, etc. returned to the soil; and the withdrawals being erosion losses, microbial decomposition of the existing soil organic matter, and removal in grain and forage. In the native prairie system little withdrawal occurs, thus organic matter levels reflect the residue returned to the soil.

Crop residue amounts returned to the soil can be quite different depending on crop species, yield level, and whether just the grain or the total plant is removed. Estimated residue amounts from grain production would be 100 pounds per bushel of wheat, 60 pounds per bushel of corn or grain sorghum, and 45 pounds per bushel of soybeans. These residue amounts were used by NRCS in estimating reside cover for conservation compliance for the 1985 Farm Bill. Thus a 50-bushel wheat crop would produce 5,000 pounds per acre of wheat straw and chaff, which would undergo considerable reduction in amount during the process of microbial decomposition before it becomes stable organic matter.

Cultural and climatic conditions play a role in decomposition rate and the final amount of organic matter produced. Research results show a range of 5 to 15 pounds of fresh residue is needed to produce a pound of organic matter. If we assume 10 pounds of wheat residue is needed to produce a pound of organic matter, then our 5,000 pounds of wheat straw would add 500 pounds of organic matter to the soil. This estimate of organic matter addition does not include roots, which would contribute another 300 pounds of organic matter, assuming the root system is about 30% of the total plant weight. The total organic matter addition from a 50-bushel wheat crop would be 800 pounds per acre.

However, at the same time there would be some decomposition of the existing organic matter. Estimates of 1.0 to 3.0% loss of existing organic matter have been reported, through normal microbial activity. This rate depends on many factors, including tillage, soil temperature, soil moisture levels, soil pH, and others.

A soil with 2% organic matter would have 40,000 pounds of organic matter per acre in the surface two million pounds of soil (a 6 to 7 inch depth depending on soil bulk density). Thus, a 1.5% loss of the 40,000 pounds of organic matter in that soil would be 600 pounds of organic matter loss. So our 50-bushel wheat crop would result in a 200 pound net gain per acre in organic matter (in this example). If the soil started out the year with 40,000 pounds of organic matter per acre (or 2.00%), it might end up the year with 40,200 pounds per acre (or 2.01%) – not a very fast rate of increase!

Although this increase is small for one year, over a 10- or 20-year period this becomes a significant increase. It's certainly better than a decrease in organic matter. As mentioned above, tillage systems and other factors affect the actual increase or decrease in soil organic matter from a given cropping system. Maintaining current organic matter or gradually increasing matter should be the goal of all farmers.

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3. Estimating crop response to fertilizer P at different soil test P levels

When a routine soil sample is analyzed by the K-State soil testing lab, the lab report will include a list of P fertilizer and other nutrient and lime recommendations. The soil test report does not state, however:

a. How frequently a producer might expect to get a yield response to P fertilizer at different soil test P (STP) levels, or
b. The relative size of the yield increase a producer might get at different STP levels.

In reviewing the K-State fertilizer recommendations recently, the soil fertility group, led by Dale Leikam, summarized the results from phosphorus response experiments with corn, grain sorghum, and wheat conducted in Kansas. A soil test correlation graph was developed from this data (the relationship between crop yield with no fertilizer added and soil test level), which can be found in the new Fertilizer Recommendation bulletin, MF2586. The data set used had 256 points, across a range of STP levels. The correlation graph is simply a mathematical line fit to the 256 points to represent that relationship between soil test P levels and percent yield in those experiments when no P was applied. Most of the STP levels in this data set were below 20 ppm, which is what we normally would consider to be the responsive range.

By looking at the percent yield with no fertilizer as compared to the yield with fertilizer in this data set, one can quickly determine how frequently crops responded to P at different soil test levels, and how large the response was. The results of that simple analysis are summarized in the table below. Since crop and fertilizer prices can vary widely from year to year, agronomists have traditionally considered a 5% yield increase the amount necessary to be economical. At STP levels less than 5 ppm, the responses ranged from 20 to 620%, with an average of 71%, and all of the experiments showed a yield response to P of greater than 5% (the economic threshhold).

Soil Test P Level (ppm)	Frequency of Fertilizer Response	Percent Yield Increase	
		Average	Range
<5	95-100%	71%	20-620%
5-10	80-90%	28%	0-185%
10-15	50-70%	8%	0-100%
15-20	30-50%	8%	0-40%
>20	<30%	2%	0-13%

Thus when the STP level is less than 5 ppm, extremely low, it is almost a certainty that producers will get an economic yield response from applying the recommended P fertilizer rate (in the absence of other yield-limiting factors, such as hail, insects, disease, weeds, extreme drought, etc.). If the farmer were to get the average 71% increase, 30 bushel wheat without P fertilizer would become 50 bushel wheat with P fertilizer.

As soil test levels went up in these studies, the frequency of response and the size of the response, when it occurs, went down. At STP levels of 15-20 ppm, a response to fertilizer was only seen a third of the time in this data set (23 of 69 experimental points), and the average yield response at this STP level was only about 8%. A yield response of only 8%, a third of the time, may not be economical with today's crop and fertilizer prices, even with a recommendation of only 15 pounds per acre. With $3 wheat and $0.35 -$0.40 phosphorus it's probably little more than a breakeven proposition in many cases.

At STP levels above 20 ppm, the number of data points was very limited, but the frequency of response was less than 30% and the average size of the yield increase was only 2%. Clearly this small increase would not be economical at today's crop and fertilizer prices. K-State does not recommend P at these STP levels, except for the purpose of maintaining soil test levels. Keep in mind that with no fertilizer applied, crop removal will lower STP levels. A 50-bushel wheat crop removes about 20 pounds of P_2O_5, and would lower STP about 1 ppm.

Several factors other than STP level can affect both the frequency and relative size of the response one obtains to P fertilizer, such as planting date, soil temperature, application method, and so forth.

P response for corn, grain sorghum, and wheat tends to be greatest:

* When the corn and sorghum are planted early into cold soils,
* When wheat is planted late into rapidly cooling soils,
* In no-till or other reduced tillage systems,
* When the P is applied with the seed as a starter, or in a band near the seed, and
* When other soil nutrients are not limiting.

One other special situation where P responses can be very large is in acid soils, with high levels of soluble aluminum. On those soils, producers generally stand a very high chance of getting an economic response, and a greater magnitude of yield response, to fertilizer P placed with the seed for wheat and grain sorghum.

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4. No-tilling wheat into chemfallow ground

Wheat planting is one of the most difficult aspects of a no-till cropping system in western Kansas. Most cropping systems in western Kansas include a fallow period at some point. A wheat/sorghum-or-corn/fallow system is common, but some producers are also using variations on that, usually involving two consecutive years of wheat and/or sorghum or corn. In most cases, a fallow period is typically maintained as the bridge between the row crop and wheat. This is commonly a tillage-based fallow system, although there is also some chemfallow being used prior to wheat.

Tillage is often used prior to wheat planting primarily because the soil can become hard and dry some years during the fallow period. We have conducted a multi-year test since 1991 at the Southwest Research-Extension Center at Tribune, comparing total no-till, reduced-till, and conventional till in a wheat-sorghum-fallow system. In reduced-till, the sorghum has been no-tilled and the ground is worked before wheat planting since 2001.

Wheat yields have been higher in the total no-till chemfallow system than in the reduced-till or conventional-till system. Many years, the chemfallow ground has been hard and dry at the time of wheat planting, and wheat stands in the no-till plots have been less than stands in the plots that were tilled prior to planting. But the reduced stand does not carry through to reduced yields. Just the opposite.

We have been planting the wheat with a single-disc, John Deere 750 no-till drill, using a seeding rate of 55 pounds per acre. We try to plant about 2.5 inches deep. Sometimes this requires additional weight to be added to the drill when the ground is particularly hard.

We have found that the available soil moisture in the soil profile at planting time for both wheat and grain sorghum is similar for no-till and reduced-till wheat. But there is a difference in moisture distribution throughout the soil. In the no-till plots, the upper layers of the soil get drier when there is a prolonged dry period prior to planting than where the ground has been worked. At the same time, the deeper layers of soil have more moisture in the no-till plots than in the reduced-till plots. As a result, wheat (and grain sorghum) in no-till is able to tolerate late-season stress better than reduced-till. Both no-till and reduced-till plots had more available soil moisture at planting time than conventional-till.

In previous years, we have tried using a cover crop, or “green fallow,” instead of chemfallow ahead of wheat planting, using hairy vetch, sweet clover, and several other legumes. The cover crops used up soil moisture and reduced wheat yields by about 25 percent depending upon how long they were allowed to grow.

The best wheat yields in this research usually have come from the total no-till system using chemfallow. Initial wheat stands in the no-till plots often seem poor compared to plots where the ground has been worked. But the no-till wheat evidently takes advantage of the deep moisture in no-till soils and yields better than reduced-till wheat at the end of the season.

On average, from 1991 through 2004, wheat yields were 8 bu/a higher for no-till (38 bushels per acre) with chemfallow than for conventional-till (30 bushels per acre). Wheat yields for reduced-till were 5 bushels per acre greater than conventional-till during that period.

Grain sorghum yields responded to total no-till even more than wheat yields in this study. Sorghum under the conventional-till system averaged 36 bushels per acre from 1991-2004, compared with 58 bushels for the reduced-till system and 70 bushels for the total no-till system.

In this study, both wheat and grain sorghum benefited when a total no-till system was used. Water infiltration rates measured in-season in the wheat crop were about twice as great in the total no-till system as in reduced-till or conventional-till. Soil aggregate size was greater and aggregate stability was greater in the no-till plots.

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