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The Nature And Value of Residual Soil Fertility

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What nutrients does a particular soil have before fertilizer is added? To answer this question, agronomists refer to residual soil fertility, the level of available plant nutrients which a soil can provide without additional fertilization.
A high residual level can occur for several reasons:
•Prolonged application of fertilizers beyond crop needs.
•Naturally high levels of plant nutrients in soils. For example, soils in the Inner Bluegrass region are high in phosphate because they were formed from highly phosphatic limestones.

Residual soil fertility can also be low for several reasons:
•Prolonged cropping without adequate fertilization.
•Naturally low levels of plant nutrients in soils. For example, low phosphorus levels are often found on unfertilized soils formed from low phosphate parent materials.

In any case, knowing the residual fertility level of soil is important to determine if fertilizers are necessary for economically optimum crop production.

Composition
Residual soil fertility consists of "residual pools" of
•nutrients in the organic matter,
•exchangeable nutrients,
•slowly soluble chemical compounds,
•nutrients in the soil mineral fraction.

Plant availability of residual fertility is affected by many factors, including
•the release of plant nutrients from the soil's mineral and organic fractions by dissolution and decomposition,
•past fertilization practices,
•past cropping history.

Soil Testing as an Indicator
The science of soil testing has been developed through long-term research to:
•more accurately measure residual levels of available soil nutrients (soil test levels);
•more precisely relate crop response to available nutrients;
•determine fertilizer needs.

Figure 1 shows how residual soil fertility affects crop yield. When fertilizer is added to soil with very low or low residual fertility, larger yield increases can be expected. In contrast, little or no fertilizer is needed for maximum crop yields after residual soil fertility has been built to, or exists at, the upper medium or high levels.
Soil testing methods usually measure two things about each nutrient:
•all of the plant available form, (exists in the soil solution around soil particles and comprises a very small part (.01 to 1%) of the total in the soil).
•portions of the organic, exchangeable and slowly soluble forms.

Residual soil fertility is commonly defined as the amount of nutrient reported in the soil test plus some variable amount expected to become available during the crop season from the nutrient's organic, exchangeable and slowly soluble forms. The residual forms are reservoirs which can replenish the plant available form during the growing season, as plant uptake removes nutrients from the soil solution.
The chemical solutions used in soil testing extract variable amounts of the residual forms, depending on the nutrient. Most of the residual forms extracted can easily become plant available and thus can directly influence how much nutrient exists in the plant available form. Because of this relationship, soil test results are often used to measure residual soil fertility.

Adjusting Residual Fertility

Changes in residual soil fertility occur as nutrients are added or removed from the soil. Nutrients can be added by
•crop residues,
•manures,
•agricultural lime,
•fertilizers.

Nutrients can be removed by
•harvested crops,
•soil erosion,
•leaching.

When additions are greater than removals, the residual fertility increases, and likewise, when removals exceed additions, residual fertility decreases.

Increasing Residual Fertility
Residual soil fertility is increased as a result of prolonged application of a nutrient from any source that exceeds nutrient removed in cropping. Or, it can be increased by a single large application of nutrients from fertilizer, manure or lime. In these cases, the extra nutrients become part of the residual forms, resulting in increases in soil test values. However, soil test levels do not change on a pound-for-pound basis when extra fertilizer is added. Several factors influence how these soil test levels change:
•soil type,
•clay type,
•relative level of the soil test when the large addition occurred. (When soil test values are low, it takes more fertilizer to raise the values per unit of added fertilizer than when soil test values are high.)
•how deeply the applied lime or fertilizer material is mixed.

Table 1 illustrates this relationship for a Belknap silt loam in western Kentucky. Different soil types have somewhat different numerical values for each soil test value but the general relationship (decreased amounts of excess nutrient required for increasing soil test values) is the same.

Table 1. - Amounts of excess addition over removal required to change soil test P or K (lb nutrient/lb soil test) at a given soil test, Belknap silt loam.

Soil test P	**P_2O_5 Required**	**Soil test K**	**K_2O Required**
lb/A	**lb P_2O_5/lb P**	**lb/A**	**lb K_2O/lb K**
10	14.5	100	6.4
20	10.3	150	5.4
30	8.4	200	4.7
40	7.3	250	4.2
50	6.5	300	3.8

Adding organic matter (manures or crop residues) to soil can also increase residual fertility. However, the crop can benefit from this source only as it is released when the organic matter decomposes. The rate and amount of nutrient release depends on residue type, temperature, soil moisture, soil type, aeration, soil pH and tillage method. Most increases occur quite slowly over years and some equilibrium is reached after several years depending on changes in the soil management factors. For example, no-till allows more accumulation of crop residue on the surface compared to conventional tillage. Thus no-till temporarily reduces release of some nutrients for a few years. After equilibrium is established, (nutrient addition equals nutrient release), greater amounts of plant available nutrients are released. Soil test values from these soils that are built to a high level of residual fertility can often support several years of cropping without fertilizer application.

Recommendations
Sample and retest soils high in residual fertility every 3 to 4 years. Doing so is especially important for cropping rotations that remove large quantities of potassium (tobacco, corn silage, alfalfa and other forages) or when soil test P and K levels are not more than 25% above the values needed for no additional phosphate and potash fertilizer.

Reducing Residual Fertility

Residual fertility decreases when net nutrient removal occurs. This situation may happen when no additional nutrients are applied or when few crop residues are returned to a soil. For nutrients determined by soil test, it follows that a high soil test value decreases faster than a low soil test value. Table 1 shows that lesser amounts of P_2O_5 and K_2O are required to increase the soil test when values are higher, so the soil test decreases at a faster rate at high values. Example: With 60 lb P_2O_5/ac removal, soil test P would decrease about 9 lb/ac at 50 (60 divided by 6.5) but only about 4 lb/ac at 10 (60 divided by 14.5).
The residual fertility in organic form can be drastically reduced when you switch from a more reduced tillage method to a conventional tillage method (moldboard plowing, disking or chiseling). Such a change results in greater residue incorporation, or breaking of larger residue into smaller pieces, which temporarily speeds decomposition rate. More nutrients become plant available, thus reducing the organic residual pool.

Periodic Large Nutrient Applications
Fertilizers and manures are sometimes applied in large amounts once every 2 or 3 years and agricultural lime may be applied only every 3 to 5 years. This practice causes nutrients to build up during the year of application, and some undecomposed or undissolved nutrients carry over to compensate for crop removal before another application. If the excess nutrients exceed crop removal, then residual fertility is increased.
In succeeding years when no fertilizer is applied, the higher amounts from the first year are then reduced by crop removal in succeeding years and the residual soil test values decrease. With such immobile nutrients as phosphorus, zinc and molybdenum, a large application may have a residual effect for up to 10 years. Use of crop residues and manures can also add to residual levels because they do not completely decompose in a single crop season, but carry over some nutrients for succeeding years.

How Residual Fertility Affects Choice of Application Methods
At Low Residual Fertility
At low residual fertility (low soil test values) banding is more effective than broadcasting. However, with medium to high residual fertility, the methods are about equal.

Why
At these low levels, proportionately more of the applied nutrients become fixed into less available forms than in soils with high residual fertility. This effect is particularly evident when nutrients are broadcast applied. Because of this situation, banding of fertilizers increases fertilizer efficiency at low residual fertility levels of the immobile nutrients and application rates can often be reduced from those recommended for broadcasting.

Examples
At low residual levels of P and K, banded fertilizer can be from 1.5 to 3 times more effective than broadcast. Tobacco leaf yields have responded economically to banding of potassium containing fertilizers up to a medium to high residual level in the soil.

Temperature Effect
Some crops, like early planted corn and late-fall seeded small grains, may show higher banding efficiencies when soil and air temperatures are cool for long periods after seeding. However, at medium or above residual levels there is little difference in crop use between the two methods if soil temperatures are normal during early crop growth.

At High Residual Fertility
When residual fertility levels are high (high soil test values), it is generally immaterial when fertilizer is applied (except N sources) in relation to crop growth, or what method is used for nutrient application since there will likely be no crop response anyway.

Recommendations
Using soil test results for most nutrients is the best guide to determine when nutrients are needed and the rate necessary to provide for an economic growth response.

Economics of Residual Fertility
From an economic standpoint, apply nutrients to a soil only if they will result in a profitable yield increase. When soils have high residual fertility, either naturally or due to buildup from prolonged use of excessive fertilizer, in most years yields will not increase with further addition of those nutrients. These soils can be cropped for several years without any further nutrient addition before residual fertility drops to responsive levels.
Fertility recommendations made by the Kentucky Cooperative Extension Service are based on the principles found in

this publication.

Patterns of Residual Fertility in Kentucky

Residual fertility of Kentucky soils is quite variable. However, residual fertility has increased strongly during the past 25 years as fertilizer use increased. Tables 2 and 3 show the distribution of soil samples by residual fertility level according to the crop for which the field was to be used for 1975 and 1985.

Table 2 -Percent of phosphorus soil test values in each category in 1975 and 1985 for soils to be planted to important crops in Kentucky.

	Crop Year	Soil P test category[1]					No. Samples
		VL	L	M	H	VH	
		% of samples found in each group					
Burley tobacco	1975	9	7	12	7	65	4365
	1985	2	6	12	8	72	7461
Corn	1975	33	17	21	7	23	3940
	1985	3	20	33	13	31	9869
Soybeans	1975	43	22	20	6	9	1341
	1985	3	21	35	15	26	3322
Alfalfa	1975	25	14	22	9	30	909
	1985	4	20	23	11	42	4506
Grass-legume forage	1975	58	12	12	4	14	6464
	1985	14	33	20	8	25	5744

[1]*Bray no. 1-VL << 15 lb/acre, L = 15-30, M = 30-60, H = 60-80, VH > 80.*

Table 3. Percent of potassium soil test values in each category in 1975 and 1985 for soils to be planted to important crops in Kentucky.

	Crop Year	Soil K test category[1]				No. Samples
		VL	L	M	H	
		% of samples found in each group				
Burley tobacco	1975	9	25	47	17	4365
	1985	6	20	45	29	7463
Corn	1975	25	46	24	5	3940
	1985	12	34	43	11	9869
Soybeans	1975	30	49	18	3	1341
	1985	10	36	44	10	3322
Alfalfa	1975	20	39	33	8	909
	1985	12	30	42	16	4507
Grass-legume forage	1975	30	44	21	5	6464
	1985	16	34	37	13	5742

[1]*NH 4 OAC-VL<<75lb/acre,L=75-165,M=165-250,H>250.*

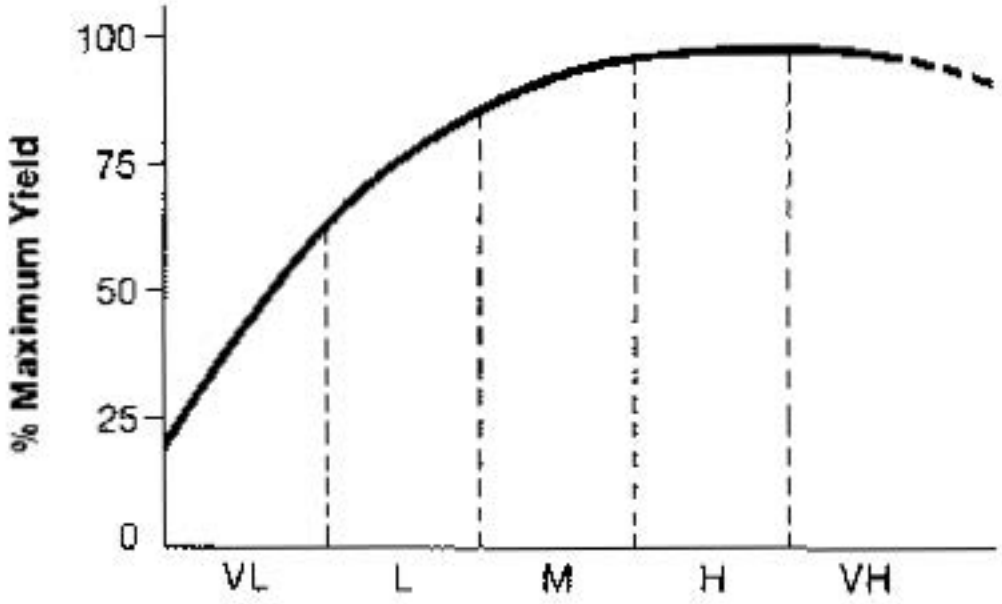

Figure 1. — Residual Soil Fertility (Soil Test Levels) Effects on Relative Yield.