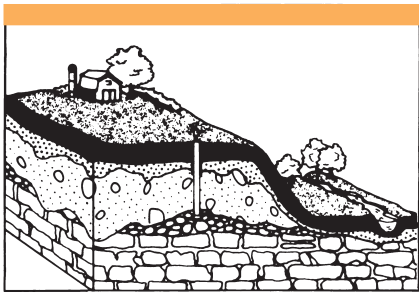

Soil Facts

Nutrient Removal by Crops in North Carolina

Studying nutrient removal by plants is one of the methods used to develop fertility recommendations. Tests are designed to examine patterns of nutrient uptake in response to different levels of fertilizer application. Information on nutrient removal alone is not adequate for making fertility recommendations because it does not take into account the ability of the soils to retain and supply nutrients. It can, however, show variations in nutrient needs among different crops. In addition, it can indicate the rates at which reserves of soil nutrients will be depleted.

Plant growth and development depends on many factors, including adequate nutrition. The exact amount of fertilizer necessary varies with the potential yield, growth, and the concentration of nutrients that are available from soil reserves and decaying organic matter. These interacting factors make it difficult to develop reliable recommendations for fertility. Sound recommendations require well-planned, long-term experiments that can show responses for a wide range of environmental, soil, and growth conditions.

Nutrients in plants that are left in the field will partially resupply nutrient reserves in the soil as they decompose. Estimates of nutrient depletion, therefore, should take into account only the nutrients removed with the harvested portion of the plant. The table on page 2 shows the mean concentration of various nutrients that are removed by each crop for the yield level indicated. Values are not reported for boron, molybdenum, iron, or chlorine because they were omitted from the references used. This does not mean they are not removed nor that they are unimportant. A brief discussion of each nutrient precedes the table.

Nitrogen

Nitrogen is a part of all plant and animal proteins and a component of DNA and RNA. Crop uptake of nitrogen is relatively inefficient and often results in average nitrogen losses of 50 percent because of leaching, volatilization, or denitrification. Consequently, crop removal values reflect a minimum amount of nitrogen required because they do not account for nitrogen losses.

Legumes produce most of their own nitrogen through a symbiotic, or beneficial, relationship with bacteria (Rhizobium species) that infect their roots. These bacteria have the ability to convert atmospheric nitrogen into forms that can be used by plants. Therefore, legumes with active nitrogen-fixing bacteria do not need additional sources of nitrogen. If fertilizer nitrogen is added to a legume, bacterial production of nitrogen decreases. Current research suggests that legumes may be less efficient than nonlegume crops in recovering nitrogen applied as fertilizers.

Nitrogen can accumulate under some conditions in North Carolina soils. However, the rate of accumulation and the length of availability is extremely unpredictable and as such is not included in standard soil analysis. Sources of soil nitrogen include commercial fertilizers, animal manures, legume residues, and other forms of decaying organic matter. For more information on nitrogen refer to Extension publication AG-439-2 *Nitrogen Management and Water Quality*.

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Table 1. Estimated Nutrient Removal Rates of Crops

Crop		Yield per acre	N	P_2O_5	K_2O	Ca	Mg	S	Cu	Mn	Zn
			-----	-----	-----	-----	lbs	-----	-----	-----	-----
Grains											
Barley	(grain)	40 bu	35	15	10	1	2	3	0.03	0.03	0.06
	(straw)	1 ton	15	5	30	8	2	4	0.01	0.32	0.05
Corn	(grain)	150 bu	135	66	40	2	8	10	0.06	0.09	0.15
	(stover)	4.5 tons	100	37	145	26	20	14	0.05	1.50	0.30
Oats	(grain)	80 bu	50	20	15	2	3	5	0.03	0.12	0.05
	(straw)	2 tons	25	15	80	8	8	9	0.03	—	0.29
Rye	(grain)	30 bu	35	10	10	2	3	7	0.02	0.22	0.03
	(straw)	1.5 tons	15	8	25	8	2	3	0.01	0.14	0.07
Sorghum	(grain)	60 bu	50	27	15	4	5	5	0.01	0.04	0.04
	(stover)	3 tons	65	20	95	29	18	—	—	—	—
Wheat	(grain)	40 bu	50	20	15	1	6	3	0.03	0.09	0.14
	(straw)	1.5 tons	20	5	35	6	3	5	0.01	0.16	0.05
Hay											
Alfalfa		4 tons	180	59	180	112	21	19	0.06	0.44	0.42
Bluegrass		2 tons	60	29	60	16	7	5	0.02	0.30	0.08
Coastal Bermuda		8 tons	400	92	345	48	32	32	0.02	0.64	0.48
Cowpea		2 tons	120	25	80	55	15	13	—	0.65	—
Fescue		3.5 tons	135	65	185	—	13	20	—	—	—
Orchardgrass		6 tons	300	100	375	—	25	35	—	—	—
Red Clover		2.5 tons	100	25	100	69	17	7	0.04	0.54	0.36
Ryegrass		5 tons	215	85	240	—	40	—	—	—	—
Sorghum-Sudan		8 tons	319	122	467	—	47	—	—	—	—
Soybean		2 tons	90	20	50	40	18	10	0.04	0.46	0.15
Timothy		2.5 tons	60	25	95	18	6	5	0.03	0.31	0.20
Fruits and Vegetables											
Apples		500 bu	30	10	45	8	5	10	0.03	0.03	0.03
Beans, dry		30 bu	75	25	25	2	2	5	0.02	0.03	0.06
Bell Peppers		250 cwt	137	52	217	—	43	—	—	—	—
Broccoli†		1 cwt	.58	0.18	0.44	—	—	—	—	—	—
Cabbage		15 tons	98	27	98	15	6	33	.03	.08	0.06
Cucumbers		10 tons	90	28	174	—	25	—	—	—	—
Eggplant‡		16 tons	207	46	34	—	—	—	—	—	—
Lettuce‡		7 tons	61	19	116	13	4	—	—	—	—
Melons	(cantaloupe)†	10 cwt	1.5	0.84	3.84	—	—	—	—	—	—
	(honeydew)†	10 cwt	1.06	0.44	3.61	—	—	—	—	—	—
	(watermelon)‡	6 tons	50	14	89	63	13	—	—	—	—

Table 1. *(continued)*

Crop		Yield per acre	N	P_2O_5	K_2O	Ca	Mg	S	Cu	Mn	Zn
			------	------	------	------	-lbs-	------	------	------	------
Okra‡		8 tons	179	65	139	24	24	—	—	—	—
Onions		12 tons	28	12.5	25	6.9	1	11	0.02	0.05	0.19
Peaches		600 bu	35	20	65	4	8	2	—	—	0.01
Peas		25 cwt	164	35	105	—	18	10	—	—	—
Potatoes	(white)	30,000 lbs	90	45	158	5	7	7	0.06	0.14	0.08
	(vines)	—	61	20	54	—	12	7	—	—	—
Potatoes	(sweet)	500 bu	67	57.5	160	7	7	10	0.03	0.10	0.05
	(vines)	—	30	4	280	—	5	—	—	—	—
Snap Beans		4 tons	138	33	163	—	17	—	—	—	—
Spinach		5 tons	50	10	30	12	5	4	0.02	0.10	0.10
Squash	(summer)**	10 tons	32	12	56	—	—	—	—	—	—
	(winter)*	6 tons	12	10	58	—	—	—	—	—	—
Sweet Corn		90 cwt	140	47	136	—	20	11	—	—	—
Tomatoes		20 tons	120	20	160	7	11	14	0.07	0.13	0.16
Turnips		15 tons	45	20	90	12	6	—	—	—	—
Other Crops											
Cotton	(seed & lint)	2,600 lbs	63	25	31	4	7	5	0.18	0.33	0.96
	(stalks, leaves, & burs)	3,000 lbs	57	16	72	56	16	15	0.05	0.06	0.75
Peanuts	(nuts)	4,000 lbs	140	22	35	6	5	10	0.04	0.3	0.25
	(vines)	5,000 lbs	100	17	150	88	20	11	0.12	0.15	—
Soybeans	(beans)	50 bu	188	40	74	19	10	23	0.05	0.06	0.05
	(leaves, stems, & pods)	6,100 lbs	89	16	74	30	9	12	—	—	—
Tobacco, flue-cured											
	(leaves)	3,000 lbs	85	15	155	75	15	12	0.03	0.55	0.07
	(stalks)	3,600 lbs	41	11	102	—	9	7	—	—	—
Tobacco, burley											
	(leaves)	4,000 lbs	145	17	150	—	18	24	—	—	—

(—) symbol means the information was not available in the reference used.
†USDA, NRCS. 2007. The PLANTS Database (http://plants.usda.gov, 19 November 2007). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.
‡Wichmann, W. (ed.), 2007. World Fertilizer Use Manual (http://www.fertilizer.org/ifa/publicat/html/pubman/manual.htm, 19 November 2007). BASF AG, Germany.
*Schulthers, J.R., 1995. Growing Pumpkins and Winter Squash (http://www.ces.ncsu.edu/depts/hort/hil/hil-24.html).
**Smith, R.C., 2000. Vegetable Maturity Dates, Yield and Storage, H-912. (http://www.ag.ndsu.edu/pubs/plantsci/hortcrop/h912w.htm).
Other reference sources include: The Fertilizer Institute, Potash and Phosphate Institute, Alabama CES circular ANR-449, Tisdale and Nelson's *Soil Fertility and Fertilizers*, Mortvedt, Giordano and Lindsay's *Micronutrients in Agriculture*, and IMC's *Efficient Fertilizer Use — Fertilizing for Profit*.

Phosphorus

Phosphorus is involved in the energy dynamics of plants. Without it, plants could not convert solar energy into the chemical energy needed for the synthesis of sugars, starches, and proteins. Phosphorus moves very slowly in mineral soils and thus tends to build up over time when the amount of phosphorus added in fertilizer and organic matter exceeds the amount removed in the harvested portions of crops. Because phosphorus is relatively immobile in soil, it is important that plant roots have a close and adequate supply. Factors that inhibit root growth therefore can affect uptake of phosphorus.

Much of the phosphorus added to soil is "fixed" by chemical reactions with iron, aluminum, and calcium and becomes unavailable for uptake by crops. The quantity of phosphorus available to plants is much smaller than the total quantity of phosphorus in the soil. This amount can be determined only through soil tests. The quantity of available phosphorus in soils is the fraction that is affected by plant uptake.

Potassium

Potassium is involved in photosynthesis, sugar transport, water and nutrient movement, protein synthesis, and starch formation. Potassium helps to improve disease resistance, tolerance to water stress, winter hardiness, tolerance to plant pests, and uptake efficiency of other nutrients.

Potassium removal by crops under good growing conditions is usually high, and is often three to four times that of phosphorus and equal to that of nitrogen. In many cases where levels of soluble potassium in the soil are high, plants tend to take up more potassium than they need. This is called luxury consumption because the excess potassium does not increase yields.

Potassium is also mobile in soils, depending on soil texture. Movement is greatest in course-textured sands, followed by fine sands and then clay soils. Accumulation of potassium also depends upon soil texture. The greatest accumulation generally occurs in clay soils, followed by loam and coarse-textured sands.

Calcium and Magnesium

Calcium is a constituent of the cell wall and keeps the cell membranes stable. Visual evidence of calcium deficiencies generally occurs in growing points of the plant at the fruit, stem, leaf, and root tips.

Magnesium is an essential part of the chlorophyll molecule where photosynthesis occurs. Magnesium is also involved in energy metabolism in the plant and is required for protein formation.

Depletion of calcium and magnesium reserves in the soil by crop removal is rarely a problem in limed soils because of the large quantity of these nutrients that are present in liming materials. However, some crops, such as peanuts, may require more calcium than the crops can remove.

Sulfur

Sulfur is a component of some amino acids that are important in building proteins. Sulfur is required by plants in about the same quantity as phosphorus.

Sulfur, just as nitrogen, is mobile in soils and can be lost by leaching. Leaching is greatest in coarse-textured soils under high rainfall conditions and least in limed clay soils that are low in aluminum and iron. In North Carolina, most of the sulfur in surface soils is associated with organic matter. About 10 pounds of sulfur per acre are deposited annually by rainfall in North Carolina. Values for crop removal may be useful guides for sulfur fertilization on coarse-textured, sandy soils with clay subsoils at depths greater than 15 inches.

Micronutrients

Micronutrients are called "micro" only because they are needed in very small quantities by plants. Without them, however, no plant could survive and function normally. The micronutrients are involved in different plant processes and can react differently in the soil.

Copper. Copper is involved in plant enzyme systems, protein synthesis, seed formation, chlorophyll formation and nitrogen metabolism. Copper moves very little in soils and thus can accumulate when application rates exceed utilization. Copper is also held tightly by organic matter.

Zinc. Zinc is involved in starch formation, protein synthesis, root development, growth hormones, and enzyme systems. As with copper, zinc is relatively immobile in soils and tends to accumulate.

Manganese. Manganese is involved in chlorophyll formation, nitrate assimilation, enzyme systems, and iron metabolism. Manganese deficiency is generally caused by a high soil pH but can also be induced by an imbalance with other elements such as calcium, magnesium, and ferrous iron. Manganese availability in limed soils is decreased with increasing levels of organic matter.

Boron. Boron is involved in sugar and starch balance and translocation, pollination and seed production, cell division, nitrogen and phosphorus metabolism, and protein formation. Boron, just as nitrogen and sulfur, is highly mobile and is not readily retained by sandy surface soils. Because of this mobility, boron must be added annually for crops sensitive to boron deficiencies. Removal of boron by crops is a reasonable estimate of need. Leaching loss of boron is typically several times greater than crop removal. Boron fertilizer is required for cotton, peanuts, reseeding clovers, and alfalfa, and vegetable crops often require boron fertilization on sandy soils.

Molybdenum. Molybdenum is involved in protein synthesis, legume nitrogen fixation, enzyme systems, and nitrogen metabolism. Deficiencies of molybdenum generally occur on acidic soils that contain high levels of iron and aluminum oxides. Estimates of molybdenum removal by crops may serve as a general fertilization guide. However, availability of soil reserves of molybdenum to the plant are largely regulated by soil pH.

Iron. Iron is important in chlorophyll and protein formation, enzyme systems, respiration, photo-synthesis, and energy transfer. Iron deficiency, which is not very common in North Carolina, is believed to be caused by an imbalance of metallic ions, such as copper and manganese, excessive amounts of phosphorus in soils, and a combination of high pH, high lime, cool temperatures and high levels of carbonate in the root zone.

Chlorine. Chlorine is involved in photosynthesis, water-use efficiency, crop maturity, disease control and sugar translocation. While chloride leaches quite readily in coarse-textured soils, deficiencies are not very common.

Summary

Estimates of crop nutrient removal rates are useful in comparing the nutrient demands of different crops. These values, however, do not take into account the quality and availability of nutrient reserves already in the soil. Because of this limitation, soil testing should still be the cornerstone of all fertility programs. Removal rates can be used in conjunction with soil testing to estimate nutrient reserves.

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NORTH CAROLINA COOPERATIVE EXTENSION SERVICE

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