



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 (N) is a part of all plant and animal proteins and a compo-

nent 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 and Water Quality*.

Table 1. Estimated Nutrient Removal Rates of Crops

| Crop | Yield | N | P ₂ O ₅ | K ₂ O | 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 | 53 | 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 | 25 | 15 | 4 | 5 | 5 | 0.01 | 0.04 | 0.04 |
| | (stover) | 3 tons | 65 | 20 | 95 | 29 | 18 | — | — | — | — |
| Wheat | (grain) | 40 bu | 50 | 25 | 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 | 40 | 180 | 112 | 21 | 19 | 0.06 | 0.44 | 0.42 |
| Bluegrass | | 2 tons | 60 | 20 | 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 |
| Bean, Dry | | 30 bu | 75 | 25 | 25 | 2 | 2 | 5 | 0.02 | 0.03 | 0.06 |
| Bell Peppers | | 180 cwt | 137 | 52 | 217 | — | 43 | — | — | — | — |
| Cabbage | | 20 tons | 130 | 35 | 130 | 20 | 8 | 44 | 0.04 | 0.10 | 0.08 |
| Onions | | 7.5 tons | 45 | 20 | 40 | 11 | 2 | 18 | 0.03 | 0.08 | 0.31 |
| 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 | 48 | 158 | 5 | 7 | 7 | 0.06 | 0.14 | 0.08 |
| | (vines) | — | 61 | 20 | 54 | — | 12 | 7 | — | — | — |
| Potatoes (sweet) | | 300 bu | 40 | 18 | 96 | 4 | 4 | 6 | 0.02 | 0.06 | 0.03 |
| | (vines) | — | 30 | 4 | 24 | — | 5 | — | — | — | — |
| Snap Beans | | 4 tons | 138 | 33 | 163 | — | 17 | — | — | — | — |
| Spinach | | 5 tons | 50 | 15 | 30 | 12 | 5 | 4 | 0.02 | 0.10 | 0.10 |
| Sweet Corn | | 90 cwt | 140 | 47 | 136 | — | 20 | 11 | — | — | — |
| Tomatoes | | 20 tons | 120 | 40 | 160 | 7 | 11 | 14 | 0.07 | 0.13 | 0.16 |
| Turnips | | 10 tons | 45 | 20 | 90 | 12 | 6 | — | — | — | — |

Nutrient Removal by Crops in North Carolina

Table 1 (continued)

| Crop | Yield | N | P ₂ O ₅ | K ₂ O | Ca | Mg lbs | S | Cu | Mn | Zn |
|---------------------------------|-----------|-----|-------------------------------|------------------|----|-----------|----|------|------|------|
| | | | | | | | | | | |
| Other Crops | | | | | | | | | | |
| Cotton (seed & lint) | 2,600 lbs | 63 | 25 | 31 | 4 | 7 | 5 | 0.18 | 0.33 | 0.96 |
| Cotton (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 | 41 | 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 | 14 | 150 | — | 18 | 24 | — | — | — |

(—) symbol means the information was not available in the reference used.

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 (P) 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 removal.

Potassium

Potassium (K) 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 con-

sumption because the excess potassium does not increase yields.

Potassium is also mobile in soils, depending on soil texture. Movement is greatest in coarse-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 (Ca) 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 (Mg) 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 (S) 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 (Cu) is involved in plant enzyme systems, protein synthesis, seed formation, chlorophyll formation and nitrogen me-

tabolism. 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 (Zn) 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 (Mn) 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 (B) 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, but practicality and leaching dictate using several times this much. Boron fertilizer is required for cotton, peanuts, reseeding clovers, and alfalfa, and vegetable crops often require boron fertilization on sandy soils.

Molybdenum. Molybdenum (Mo) is involved in protein synthesis, leg-

ume 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 (Fe) is important in chlorophyll and protein formation, enzyme systems, respiration, photosynthesis, 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 (Cl) 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 the depletion of nutrient reserves.

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