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Fertility Management of Cotton

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The proper fertilization of cotton is difficult to determine because many variables can affect development and production. Anything that causes plant stress will affect nutrient uptake. Some factors involved are: soil texture, drainage, field preparation, weather, variety, time of planting, plant populations, emergence and stand, previous crop, and carry-over fertility and/or chemicals. A current soil test is still the best tool for taking the guesswork out of fertilization, and a balanced fertility program is necessary for good yields.

Nutrient needs of a cotton plant

A cotton fiber consists primarily of cellulose, which is comprised of hydrogen, oxygen and carbon. These elements form the backbone for every molecule and plant part. After ginning, the mineral nutrients of nitrogen (N), phosphorous (P), potassium (K) and micronutrients are removed with the seed and trash and make up only 1 percent of a bale's weight.

Table 1 gives the nutrient content of a bale (480 pounds lint) of cotton.

Table 1
Typical nutrient content of cotton (pounds per bale)

	Above ground (leaves, stems, fruit)	Seed cotton	Lint
Oxygen	2,100	700	250
Carbon	1,650	550	190
Hydrogen	360	120	35
Nitrogen	62	35 to 40	1
Potash (K_2O)	61	5	3
Phosphate (P_2O_5)	22	13 to 20	0.3
Calcium	27 to 62	1	0.2
Magnesium	11 to 27	5	0.3

Sulfur	8 to 16	1 to 2	trace

All other nutrients contribute at most 3 pounds of weight to the leaves, stems and bolls

Source
Cotton Physiology Today, volume 2, number 3, National Cotton Council, Memphis, Tennessee.)

Soil nutrients are taken up in direct proportion to growth and temperature. Total nutrient uptake for nitrogen, phosphorus and potassium tracks cumulative heat units precisely. During the spring growing months when heat units are low, cotton grows slowly and takes only limited amounts of nutrients. It is during the peak growing months of June and July when nutrients need to be most readily available.

Cotton absorbs the highly soluble and less soluble nutrients by different methods. The highly soluble nutrients in the oxidized form of nitrate, sulfate and borate are readily available for plant uptake in the solution of water, but can be readily leached from the soil. Mobility in soil solution reduces the value of soil sampling for soluble nutrients (nitrogen, sulfur and boron), but soil sampling is useful at any time of the year for less mobile nutrients (phosphorus, potassium, calcium and magnesium) and soil acidity.

Nitrogen

Plants can use two forms of soil nitrogen: ammonium (NH_4^+) and nitrate (NO_3^-). The NH_4^+ form is held in the soil by negatively charged soil clays or colloids. Because soils have this negative charge, the NO_3^- form (also negatively charged) is repelled by soil particles and is subject to movement with water in the soil profile.

Nitrification is a bacterial process in the soil that involves changing the ammonium form of nitrogen to the nitrate form. Conditions that affect the speed of the reaction are: soil oxygen, pH, temperature and moisture. Denitrification (especially under waterlogged soil conditions) occurs when anaerobic bacteria get their oxygen from chemical forms, such as the nitrate molecule. In the process of breaking down the nitrate molecule to obtain oxygen, nitrogen loss occurs when nitrogen gases are released to the atmosphere.

For economic yields, cotton must have the right amount of nitrogen in all phases of growth and fruit development. Excessive nitrogen delays maturity, causes rank growth, can intensify insect infestations, encourages diseases and increases the risk of boll rot and reduced lint quality. A nitrogen deficiency will cause small stalks, pale green leaves, small bolls, fruit shed and low yields.

Very little nitrogen is used by the cotton plant in the seedling stage. The heaviest demand for nitrogen is during the fruiting stages of squaring and boll formation, but the amount of nitrogen required for optimum yields will vary with the situation. Based on studies at the MU Delta Research Center, a nitrogen application of 80 pounds per acre is recommended for irrigated, continuous cotton on a sandy loam or silt loam soil having a yield potential of two or more bales per acre. It can be split 30-50 as preplant and sidedress at prebloom, or the entire 80 pounds can be sidedressed before bloom. Nonstressed cotton can be sidedressed until about three weeks after first bloom with good results.

In the case of nonirrigated cotton, or where cotton follows soybeans or corn (with a likelihood of residual nitrogen), the nitrogen rate should probably be reduced.

A recommended procedure for nitrogen fertilization is to apply 30 pounds of nitrogen at planting, then after soil temperatures have warmed to 65 degrees Fahrenheit (around the last of May), take 0- to 6-inch and 6- to 18-inch depth soil samples for "available" nitrate nitrogen analyses to determine the **amount** of additional sidedressed nitrogen needed. Do **not** take samples from fertilizer bands.

The amount of nitrate nitrogen at any given time is subject to rapid change with changing climate and growing conditions. It may consist of recently released reserve nitrogen from organic matter, recently applied fertilizer nitrogen and/or residual carry-over fertilizer nitrogen.

Assuming timely sampling, commonly recommended amounts of nitrogen to sidedress (based on a soil nitrate test) are shown in Table 2.

Table 2
Commonly recommended amounts of nitrogen to sidedress (based on a soil nitrate test)

Tested pounds nitrate-nitrogen, 0- to 18-inch depth after June 1	Pounds of nitrogen to sidedress	
	Silt and sandy loam	Clay
0 to 30	50	75
31 to 45	25	50
46 to 60	0 to 15	15 to 25
60+	Very high — apply no nitrogen	

If the sidedress nitrogen is applied prior to early square, the cotton plant may run out of nitrogen too early, which can reduce the top crop. On the other hand, late applications of nitrogen (especially excess nitrogen) can delay maturity.

To summarize, plan a fertility program based on past field production levels and realistic expectations. Only small amounts of nitrogen are needed in the seedling stage, and split applications are recommended. If the season gets off to a bumper start, there is still time to supplement with extra nitrogen, using soil and plant monitoring. The correct amount of nitrogen will result in an abrupt nitrogen deficiency and fruiting cutout around mid to late August, which helps mature the crop for defoliation and harvest.

Phosphorus

Solubility of phosphorus (P) in the soil is the opposite extreme of nitrogen. Phosphorus has low mobility in the soil and leaching is not a problem. Instead, mobility to the roots is the prime limitation to uptake. Because of the low mobility of phosphorus, root interception is the prime method of uptake, regardless of soil pH. Cotton roots are aided in their interception of soil phosphorus by mycorrhizal fungi. These fungi grow in the small feeder roots and surrounding soil. They derive food from the plant and in return increase uptake of immobile nutrients by enhanced interception. Cotton is highly dependent on mycorrhizae for phosphorus uptake.

Phosphate is tightly bound in the soil, especially at either low or high pH, which reduces its solubility. Cold soils further decrease phosphorus uptake due to the slow root growth and reduced solubility of phosphate in cold water. Despite cotton's peak consumption of phosphorus during the summer months, deficiencies often occur in seedling cotton, when the plant outgrows the stored phosphorus in the seed.

Because of the strong influence of soil temperature on phosphorus uptake, winter crops such as small grains generally require a higher level of soil phosphorus than do warm-season crops such as cotton. Phosphorus fertilizer is often applied to these rotation crops, then cotton benefits from residual carry-over. A high level of residual phosphorus is present in much of the alluvial soil in the Missouri Bootheel.

Where carry-over phosphorus is not available, such as with continuous cotton, applications are made to provide phosphorus during the "cold soil" periods, often as a starter fertilizer mixed in the surface soil. Subsoils can become deficient in phosphorus due to its poor mobility, which restricts root growth and water uptake from the subsoil.

The Bray I soil test, or weak Bray test, is used to determine available phosphorus. An available phosphorus level of 45 pounds per acre is recommended.

Potassium

Of all the nutrients, potassium (K) is the only one that comes close to being specific to a plant part. All nutrients (including potassium) are needed during the plants' entire growth cycle, but the need for potassium rises dramatically when bolls are set on the plant. Bolls are major sinks for potassium, and high concentrations of potassium are required to maintain sufficient water pressure for fiber elongation. Potassium is also involved in enzyme activation and pH balance in the cell, which is important for plant health and disease suppression.

Potassium mobility in soils is intermediate between nitrogen and phosphorus, but is not easily leached because it has a positive charge (K^+) which causes it to be attracted to negatively charged soil colloids. Roots have to grow near the source of potassium, but micorrhizae are not required for potassium uptake. Potassium is stored in leaves for reuse later by developing bolls, just like nitrogen. Peak need of potassium is during boll filling, and to be available at this time potassium must be in solution where late-season roots are inactive.

When fruit retention is low, crop demand for potassium is less. Foliar potassium has been successfully used in some areas to partially satisfy potassium demand for high yield conditions, but soil applications should be the best way to supply all fertilizer nutrients, including potassium.

The desired potassium soil test level varies with the yield goal and cation exchange capacity (CEC) of the soil. The desired exchangeable potassium level would be 220 pounds per acre +5 (CEC), so a silt loam soil with a cation exchange capacity of 16 would need a potassium soil test level of 300 pounds per acre to place it in the high range. Additional amounts would serve as a "reserve" supply. Fertilizer potassium often is applied prior to winter tillage to allow mixing and to reduce surface buildup.

Boron

Regular soil tests will provide most of the information that is necessary to build an efficient fertilization program. However, a separate boron analysis is needed for certain suspect fields (low organic matter, excess lime, sandy texture, severe fruit drop and/or delayed maturity).

Although a micronutrient, boron (B) plays an essential role in plant cell formation and in converting nitrogen and carbohydrates into protein. It performs a key function in the growth and fruiting process **and must not be overlooked**. The farther north cotton is produced, the more crucial boron supply becomes. This is due to a shorter season and lower temperatures during the latter part of the fruiting season.

Pre-emergence or sidedressing of 1 pound of actual boron per acre annually is normally recommended for sandy loam and silt loam soils. The first two years after applying lime, 2 pounds per acre of boron may be needed. With heavy rates of nitrogen and potassium fertilization, growers might need to make three to five weekly foliar applications of 0.1 to 0.2 pounds of boron per acre during the crucial fruiting period of mid-bloom to heavy boll stage from mid-July to mid-August. This is the time when lower bolls are developing and the demand for boron is greatest. Also, soil boron is 90 percent unavailable at this time because root growth has all but stopped and foliar applications can make up the difference. Boron is compatible and easily applied with foliar applications of growth regulator and/or insecticides. Another important factor is that soil moisture influences boron availability. Drought conditions limit normal release of soil boron, especially the supply normally made available through organic matter breakdown.

Secondary nutrients

Secondary nutrients would include calcium (Ca), magnesium (Mg) and sulfur (S). This trio of nutrients, which may be identified as "the synthesizers," play key roles that are essential for plant growth and health. Cotton plants take up magnesium and sulfur in about the same quantities as phosphorus, a major nutrient. Calcium is required in even greater amounts.

Calcium functions include strengthening of cell walls to prevent their collapse, enhancing cell division and plant growth, protein synthesis, carbohydrate movement and balancing cell acidity. Increased susceptibility to seedling diseases and poor stalk strength are possible effects of calcium deficiency. All calcium is taken up from the soil.

Magnesium is essential for the production of the green pigment in chlorophyll. Chlorophyll is essential for photosynthesis, the conversion of sunlight into plant food (carbohydrate synthesis). The need for both calcium and magnesium is best determined by taking routine soil tests and applying lime (calcitic or dolomitic) as needed.

Sulfur is essential for the production of three amino acids, which are the building blocks in the synthesis of proteins. Assessing the need for sulfur is difficult. A soil test is of limited value since sulfate sulfur (SO_4), the form used by plants, can be readily moved out of the root zone by percolating water.

Soil organic matter is the primary storehouse of sulfur in the soil. Thus, a low organic matter soil would suggest a possible need for added sulfur. The mobile nature of the sulfate ion indicates that a sandy soil with a low cation exchange capacity (CEC) would also be a prime candidate for sulfur shortage. Common sulfur-bearing fertilizer materials include ammonium sulfate, ammonium thiosulfate (liquid), gypsum, potassium sulfate and sul-po-mag.

Micronutrients

Micro means small. The essential micronutrients are elements that are needed in only small amounts. There are seven of these: Boron (B), Molybdenum (Mo), Zinc (Zn), Iron (Fe), Manganese (Mn), Copper (Cu) and Chlorine (Cl).

Plants can suffer from a deficiency or an excess of any of these nutrients, depending on their soluble concentrations in the root zone. The micronutrient availability is influenced by soil pH. As the pH increases from 4.0 to 7.0, the solubility of boron, zinc, iron, manganese and copper decreases. In contrast, the solubility and availability of molybdenum increases as the pH increases. Liming to a pH of 6.0 to 6.5 usually strikes a favorable medium.

Soils can be tested for micronutrients, but testing is expensive and generally is not needed. Instances where a micronutrient deficiency might exist would be: sandy soils low in organic matter; subsoils exposed due to grading or land leveling; cold and wet weather with slow breakdown of organic matter; alkaline soils; and very high levels of other nutrients (high phosphate levels can induce zinc deficiency).

Soil salt pH

Soils have two types of acidity:

- Active or soil solution acidity
- Reserve or exchangeable acidity.

Active acidity can be measured by a pHs (salt buffered pH) soil test. A salt buffered pH is generally 0.5 pH units less than pH determined with distilled water.

All crops have a most favorable range of soil acidity for growth. For cotton, it is pHs of 6.0 to 6.5, with 6.5 being optimum. Agricultural limestone is used to increase the pHs, or lower the soil acidity. For agricultural purposes the lime may be one of two types: "calcitic," which contains little or no magnesium carbonate, or "dolomitic," which has a magnesium carbonate content greater than about 5 percent. Dolomitic limestone is used primarily in those areas with known soil or crop magnesium deficiencies. Where magnesium deficiency is not a problem, calcitic limestone is normally used. The analysis of the limestone, and the "effective neutralizable material" (ENM) needed by the soil, will dictate the recommended tons of lime to apply per acre.

Some of the benefits derived by liming soils include:

- Improved availability of soil nutrients.
- Increased efficiency of fertilizers.
- Reduced availability and toxicity from aluminum and manganese.
- Favorable microbial activity.
- Better soil structure and tilth.
- Improved activity of certain herbicides.

Summary

An efficient fertilizer program can be developed by keeping in mind the time when different nutrients are needed and the fate of those nutrients when applied to the soil. Cotton needs for nitrogen are greatest during boll filling, but carry-over into harvest is detrimental. Phosphorus is needed all season long, but the ability of roots to extract phosphorus is reduced in cool spring soils, justifying "at planting" fertilizer applications for increased availability. The heaviest demand for potassium and boron occurs during boll filling. Phosphorus, potassium, calcium and magnesium stay where they are placed until that soil zone is disturbed; but nitrogen, boron and sulfur are vulnerable to losses from the root zone prior to plant uptake.

Much of the information in this publication is taken from the National Cotton Council newsletter Cotton Physiology Today, volume 2, number 3, authored by Kater Hake, Ken Cassman and Wayne Ebelhar in January 1991.

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Related MU Extension publications

- G4258, Plant Growth Regulators for Cotton http://extension.missouri.edu/publications/DisplayPub.aspx?P=G4258
- G4268, Cotton Plant Development and Plant Mapping http://extension.missouri.edu/publications/DisplayPub.aspx?P=G4268

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