Chapter 6

Soil Fertility in Cotton

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Soil fertility has a dramatic impact on the profit equation because the lack of fertility limits production. Enterprise budgets for cotton reveal that fertilizer inputs are generally less than 10 percent of the variable production costs. Yet, a large number of producers risk $300 to $500 per acre cotton crops each year by not soil testing. To economically produce cotton, soil fertility must be properly managed.

Cotton requires at least 16 nutrients for growth and reproduction. A deficiency in any one of those nutrients will reduce yield. Most of those nutrients are obtained from the soil. For convenience, the nutrients may be grouped as: **organic nutrients**--oxygen, hydrogen, and carbon; **primary nutrients**--nitrogen, phosphorus, and potassium; **secondary nutrients**--calcium, magnesium, and sulfur; and **micronutrients**--boron, manganese, zinc, iron, chlorine, copper, and molybdenum. Fortunately, most cotton-producing soils in Oklahoma have adequate supplies of the secondary and micronutrients.

The first step in a fertilizer program is to estimate the nutrient requirements for production of cotton in a specific environment. Fertilizer amounts can be estimated by soil tests, field trials, nutrient removal, plant analyses, and past experience. Probably, the most reliable estimates are obtained by soil testing regularly (with support from the other methods listed). Soil test interpretations are based on many years of calibration research and field verification. Reliable interpretation leads to sound fertilizer recommendations to obtain the desired response. By examining soil test results over a period of years, a general assessment can be made of the fertilizer program being followed. For example, an increase in the test values for a particular nutrient over time will indicate that applications of that nutrient are not being totally utilized by the crop. Conversely, a decrease in test values over time will indicate that the crop is utilizing more of that nutrient than is being replaced by fertilization. Broadcast applications of **immobile** nutrients, like phosphorus, to a deficient soil will usually cause the soil test to increase slowly over time. This is a desirable result of a good phosphorus fertilization program. Accumulation of **mobile** nutrients, like nitrogen, over time indicates an excess is being applied, and this is not a desirable result.

Periodically, soils should be sampled below the top 6 inches. The majority of cotton roots are in the top 24 to 36 inches of the soil profile. A mobile nutrient may move below the usual 6-inch sampling depth and yet be available to the cotton plant for use during the season. Fertilizer recommendations based on the top 6 inches of soil might indicate a deficiency of such a nutrient when in fact the nutrient was abundantly available somewhat lower in the soil profile.

Fertilizer recommendations for cotton are based on realistic yield goals to be expected under existing soil and climatic conditions. The soil and its ability to produce essential nutrients and a favorable root environment for cotton along with climatic conditions (particularly the amount, distribution, and timing of rainfall) largely determine yield potential. Other factors influencing yield include length of growing season; cotton variety; rotation and cropping system; tillage and management practices; weed, insect, and disease control; and type of fertilization program.

The primary plant nutrients (nitrogen, phosphorus, and potassium) are the most important in cotton production in terms of amounts required and frequency and magnitude of plant response. For that reason, those elements will be discussed first, followed by a brief discussion of secondary and micronutrients. Nitrogen deficiencies can be partially alleviated by sidedressing in the season they occur. Phosphorus deficiencies cannot be, but should be dealt with before the next year?s crop is planted. In Arkansas, some success has been attained with foliar applications of potassium within the season, but soil application before the season begins should be the primary remedy used in potassium-deficient soils.

Nitrogen

Approximately 33,000 tons of nitrogen are in the atmosphere as a gas over every acre, but that nitrogen is unavailable to the cotton plant. Cotton can extract oxygen, hydrogen, and carbon from air, but not nitrogen. Nitrogen for fertilizer comes from many sources, but it is mobile and will not stay in the soil where placed. It may volatilize back into the atmosphere as a gas or leach below the root zone in soil moisture. Nitrogen is usually the first limiting element in cotton production. The producer will normally obtain larger yield responses from nitrogen than from any other fertilizer element.

Cotton extracts nitrogen from the soil throughout the life of the plant. The highest rate of uptake is from flowering until boll maturity. Cotton plants require an adequate level of available nitrogen from the beginning of their growth and an ample supply during the flowering and later stages. Best lint yields and fiber quality are produced if soil nitrogen is depleted during the maturation period. This nitrogen-use pattern creates some difficulty in nitrogen application and management.

Sufficient soil nitrogen must be available early in the season to produce a stalk with ample fruiting sites. Insufficient nitrogen results in stunted and woody plants with few branches. Mature leaves turn a pale yellowish-green, then yellow, and are prematurely shed. New leaves are smaller than normal. Bolls open earlier than usual with resulting losses in lint yield and in fiber length, strength, and micronaire. Mature leaf symptoms can be confused with bacterial blight; therefore, leaves should be examined for blight lesions. On the other hand, excess nitrogen can result in tall plants which are difficult to harvest with strippers. It can also cause the cotton plant to remain in the vegetative stage later in the season, thereby increasing the crop?s vulnerability to late-season insects, verticillium wilt, and an early freeze. Excess nitrogen also affects the fiber by lowering micronaire and reducing strength. Nitrogen in cotton is an example of a production input where if ?X? amount has positive effects, an ?X + Y? amount may not increase those positive effects, but may actually be detrimental.

The amount of available soil nitrogen required for cotton is a function of yield. Yield expectations are greater under irrigation than on dryland; therefore, nitrogen fertilization rates will be higher under irrigation. Nitrogen required to produce a bale of cotton is estimated at 60 pounds. If one bale per acre is the projected yield, then 60 pounds of nitrogen per acre should be available to the crop from all sources. If two bales per acre are the projected yield, then 120 pounds per acre of nitrogen should be available. The soil will furnish some nitrogen from mineralization of soil organic matter, carryover nitrogen from previous fertilization, or as a component of irrigation water.

The soil test for nitrogen is not as reliable as are those for phosphorus and potassium in predicting the amounts available; however, the test does quite well in most soils where cotton is grown in Oklahoma. Available nitrogen (as determined by the soil test) is subtracted from the total requirement to attain the projected yield, thereby determining how much nitrogen to apply. For irrigated cotton or cotton produced on coarse-textured soils, it is especially important to sample both the 0- to 6-inch and 6- to 24-inch depths to determine the total nitrogen available in the root zone. If substantial nitrogen is available in the 6- to 24-inch depth and samples were taken only from the 0- to 6-inch depth, excess fertilization will likely result causing production problems in late season. It?s not unusual for a soil test to reveal 6 to 10 pounds of nitrogen in the upper 6 inches of the soil, but to contain 30 to 40 pounds in the next 18 inches. A long history of nitrogen application may result in significant accumulation of nitrogen in the soil. Reduced rates of nitrogen fertilizer applied over a period of years result in depletion of soil reserves calling for increased rates. It is important that logical and realistic yield goals be set and that expenditures be in relation to those probable yields.

Nitrogen is mobile in the soil. It moves with the soil water. Therefore, placement of nitrogen is not as critical as it is for phosphorus or potassium. If high rates are to be applied (especially on coarse soils), nitrogen should preferably be applied one-half preplant and one-half sidedressed during fruiting of the plant.

Phosphorus

The amount of phosphorus in the cotton plant is low compared to nitrogen and potassium. A cotton crop producing a bale of lint will contain only about 14 pounds of phosphorus compared to 60 pounds of nitrogen and 35 pounds of potassium. Despite this relatively low amount, phosphorus fertilization is important in cotton production because cotton soils tend to be low in available phosphorus. Phosphorus does not leach through the soil; therefore, plant roots must grow into contact with that element for it to be effective. Insufficient phosphorus results in severely stunted plants. Leaves are smaller than normal and a very dark green in color. Fruiting and maturity are delayed increasing the vulnerability of the crop to late-season insects (e.g., the boll weevil) and diseases (e.g., verticillium wilt). Lint yield, fiber strength, and micronaire are reduced.

The amount of phosphorus fertilizer required for cotton production depends on the available phosphorus content of the soil. Unlike nitrogen, phosphorus fertilizer rates are not dependent upon yield goals. The status of available phosphorus in the soil is determined by a calibrated soil test. Once the soil test index for phosphorus has been determined, rates required to obtain the maximum yield under Oklahoma environmental conditions can be estimated from Table 6-1.

Table 6-1. Rate of phosphorus fertilization at various soil test indexes*.

Soil test P index	Percent sufficiency	Phosphorus required (lb./acre)
0	55	75
10	70	60
20	85	45
40	95	30
65+	100	0

* Values are specifically for Oklahoma State University soils laboratory test procedures and calibrations. Example: The rate of phosphorus fertilization required with a soil test index of 20 would be 45 pounds per acre to obtain 100% yield. If no phosphorus is applied, only an 85% yield of that possible will be produced.

The phosphorus rates suggested in Table 6-1 assume the fertilizer is broadcast on the soil surface and incorporated into the plow layer. One-third to one-half that amount will suffice, providing phosphate is banded near the seed at planting time. Band placement should ideally be 2 inches to the side and 2 inches below the level of the seed. Few planters will provide that ideal placement, but any band located at seed level or below is superior to broadcast application on soils testing low on phosphorus especially if low rates are applied. If soils test high in phosphorus and/or high rates of phosphorus are applied, placement becomes less critical. However, phosphorus must be placed where the soil is likely to be moist and where root contact is imminent. For the latter reason, it is crucial that phosphorus never be banded with root-pruning herbicides. Phosphorus cannot be utilized effectively by the plant unless placed below the soil surface planting. High concentrations of fertilizer placed in the seed furrow will retard germination. High concentrations placed immediately below the seed will harm the taproot.

All forms of phosphate fertilizer currently soil in Oklahoma are effective sources. In addition, many mixes are available in both solid and liquid forms. For cotton production, differences in performance of those phosphate materials have been small or undetectable. Price per unit of nutrient, convenience, availability, and ease of handling then become the factors determining the choice of phosphate fertilizer to apply. Liquids lend themselves to greater flexibility and ease of application, but generally cost more per pound of nutrient than do solid forms. Where differences between phosphate sources have been detected, the ammonium phosphates have performed somewhat better than the superphosphates.

Potassium

Most Oklahoma soils have adequate potassium content. Because only about one-fourth of the potassium in the cotton plant is contained in the seed and lint, removal of potassium in the harvested crop is not large. However, the levels in the soil are gradually declining over time. In the future, symptoms of deficient potassium will likely first be encountered on sandy soils. Insufficient potassium causes stunted plants. Leaves fail to develop a normal green color. Mature leaves are mottled after turning light yellowish-green, then reddish-brown between the veins of the leaf and on its margins. Those parts of the leaf appear scorched, then blackened. The tips and edges of the leaves curl downward and shortly thereafter break off. The leaves become reddish-brown, dry, and are scorched and blackened by the time they are prematurely shed. Bolls are small and immature. They may fail to open or only partly open. Yield and all fiber properties are reduced.

Potassium fertilizer requirements are determined in a manner similar to phosphorus. Amounts of potassium recommended at various Oklahoma State University soil test indexes are shown in Table 6-2.

Table 6-2. Rate of potassium fertilization at

various soil test indexes*.

Soil test K index	Percent sufficiency	Potassium required (lb./ acre)
0	40	110
75	60	80
125	75	60
200	90	40
250+	100	0

* Values are specifically for Oklahoma State University soils laboratory test procedures and calibrations. Example: The rate of potassium fertilization required with a soil test index of 125 would be 60 pounds per acre to obtain 100% yield. If no potassium is applied, only a 75% yield of that possible will be produced.

A computer print-out sheet returned with the soil test results shows the potassium deficiency for each soil test value and a fertilizer recommendation is made by local professionals.

All conventional potassium fertilizer sources are water soluble and are simple salts. Their reactions when added to soils are similar; therefore, no major agronomic advantages exist between sources. Because potassium fertilizer is not mobile in the soil, it should be placed in the root zone. When surface applied, the fertilizer should be incorporated into the soil with tillage to achieve maximum effectiveness. Placement of potassium is not as critical as is that of phosphorus because potassium is still available to plants even after reacting with the soil.

Secondary Nutrients

Most of the cotton-producing soils in Oklahoma contain sufficient calcium, magnesium, and sulfur for optimum cotton production. Calcium and magnesium may be added as aglime to correct soil acidity and to provide an additional supply of those nutrients.

The secondary nutrient soil test includes a test for magnesium and sulfur. If magnesium is deficient, it may be added as magnesium sulfate, superphosphate, ammonium phosphate, ammonium sulfate, or gypsum.

No experimental evidence yet indicates a requirement for sulfur on cotton in Oklahoma. Sulfur deficiencies would be expected to occur first on leached, coarse sandy soils low in organic matter. Sulfur is like nitrogen in that the requirements are based upon yield. Therefore, irrigated cotton would require sulfur fertilizer before dryland cotton; however, most water used to irrigate cotton in Oklahoma already contains adequate amounts of sulfur for plant growth. The sulfur requirement is about one-twentieth that of nitrogen. If 60 pounds of nitrogen per acre are needed for cotton, only 3 pounds of sulfur are required. Most soils supply several times that amount.

Deficiency symptoms for calcium in field-grown cotton are not known. In nutrient solution, lack of calcium is indicated by a bending of the leaf petiole about midway between the stem and the leaf blade. The petiole then collapses from that point out to the leaf blade, and the leaf is subsequently shed. An additional requirement for magnesium is indicated by purplish-red leaves with green veins. The lower leaves are affected first. The leaves may die prematurely and be shed from the plant, progressing from the bottom of the plant upwards. Late in the season, this symptom may be difficult to distinguish from normal maturity of leaves. Insufficient sulfur is indicated by stunted plants with slender stems. Older leaves retain their normal green color while new leaves are yellow with dark green veins. (These leaf symptoms are opposite from those indicating a lack of nitrogen.) Bolls are smaller than normal. With all three secondary nutrients, deficiencies reduce boll number (thus yield) and fiber quality.

Micronutrients

Yields of cotton in Oklahoma research trials have not been improved by addition of any micronutrient on a large number of soils. Soil tests are available at Oklahoma State University to determine micronutrient deficiencies.

A deficiency in boron may be suspected if the plant is stunted and has many branches, if the terminal buds die, and if young leaves turn yellowish-green. At very low levels, flower buds become chlorotic, bracts flare open, and buds are shed from the plant. The few bolls that survive are flat-sided, reduced in size, and only partially open. Petioles may be banded, and peduncles may be ruptured. In Arkansas, boron deficiencies in cotton have been reported on fine-textured, weathered soils. Limiting quantities of manganese are indicated if the upper leaves turn a yellowish-gray to reddish-gray between the leaf veins (which retain their green color) and if the plant fails to set fruit. If the soil is too acid and toxic amounts of manganese are present, the leaf will be crinkled. A lack of zinc is suggested by a general bronzing of the first true leaves with a pronounced chlorosis between the veins. The leaves will be thick and brittle with upturned margins. Plants will be small and bushy with slow growth and delayed fruiting. In Texas, zinc deficiencies in cotton have been associated with excessively high applications of phosphorus. Iron, chlorine, copper, and molybdenum have been shown by research to be essential for plant growth, but their deficiency symptoms have not yet been clearly differentiated and described.

Secondary and micronutrient deficiencies can be partially corrected in the season they occur by using foliar sprays. However, caution should be exercised in that these elements are required in only very small amounts. If overapplications are made, toxic symptoms may be expressed.

Soil pH

Cotton tolerates a soil pH in the range from 4.5 to 8.5, but it grows better from pH 5.7 to 7.0. Below pH 5.7, an aglime application can correct the acidity, increase the availability of plant nutrients, add calcium and magnesium to the soil, and improve soil physical conditions. Above pH 7.0, application of anhydrous ammonia and continued cropping will tend to reduce soil pH over time.

When the soil pH falls below 6.0, nutrients with **reduced** availability include nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Nutrients with **increased** availability include boron, manganese, zinc, iron, and copper. In acid soils (i.e., soils with a low pH) manganese and aluminum may increase in availability to the point that they become toxic to cotton.

Considerations in Making Decisions on Fertilization

In financially stressful times, it becomes even more important that the producer ?fertilize the crop, not the soil.? A soil test for nitrogen should be made every year. A soil test for phosphorus and potassium can be conducted on alternate years without too much change being expected. Any reduction of greater than 20 percent in normal nitrogen usage will likely adversely affect yield. The producer will lose less by reducing phosphorus and potassium applications than he will by doing so on nitrogen. If the budget is greatly limited, buy only nitrogen. If the producer has a history of phosphorus application on his farm, he can probably skip application for up to 2 years (maybe more) without detrimental effects on yield. Banding phosphorus properly at planting time can reduce the cost of that element by one-third to one-half, compared to broadcast application.

Other considerations in fertilizer management may be applicable from time to time. For example, well water used for irrigation in some parts of Oklahoma is naturally high in nitrates. If not taken into consideration, overapplications of nitrogen may result because extra nitrogen is being applied with each irrigation. An analysis of the water used will allow reasonable estimates to be made. If the producer plants in a skip-row pattern, less nitrogen will be required because the rows bordering the skips are able to utilize the moisture and nutrients in the soil beneath the skips. If cotton is planted following sorghum, more nitrogen is required than if cotton were continuously planted. Cotton following alfalfa requires no nitrogen the first year and a reduced amount the second year, but phosphorus and potassium requirements may be critical. Annual legumes add about 40 pounds of nitrogen per acre each year to the soil. Nitrogen should be reduced on late planted cotton because its yield potential is less than on a normally planted crop. If land is leveled for irrigation, cut areas are often deficient in phosphorus.

Summary

Fertilizer requirements for cotton production in Oklahoma re primarily limited to the annual use of nitrogen, frequent use of phosphorus, and occasional use of potassium. Although cotton production can be reduced if any of the essential elements are deficient, most Oklahoma soils are relatively fertile.

Nitrogen fertilizer requirements can be easily determined from consideration of the yield potential and the available nitrogen reported by a recent soil test. Soil test information is the most reliable way of determining phosphorus, potassium, secondary nutrient and/or micronutrient fertilizer needs. Because adequate, but not excessive, nitrogen is important to the development of high fiber yield, nitrogen management is especially critical to irrigation cotton production. Regular, annual soil testing is an inexpensive approach to good nitrogen management.

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