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NITROGEN, PHOSPHORUS, AND POTASSIUM USE TRENDS BY COTTON IN THE PAST 40 YEARS

Clifford Snyder
Potash & Phosphate Institute
Conway, AR
Mike Stewart
Potash & Phosphate Institute
San Antonio, TX
Rob Mikkelsen
Potash & Phosphate Institute
Davis, CA

Abstract

Trends in the U.S. cotton acreage and the use of nitrogen (N), phosphorus (P) and potassium (K) fertilizer since 1964 were reviewed using USDA National Agricultural Statistics Service and Economic Research Service data. Total cotton acreage has varied over the years and is below the 1964 acreage. The average rate of N applied to cotton has increased gradually since the late 1970s and is currently near 90 lb/A. The average rates of applied P and K to cotton (expressed as P_2O_5 and K_2O, respectively) declined until the early 1990s and increased slightly since then to about 30 lb P_2O_5 /A, 40 lb K_2O /A, respectively. Trends in the pounds of lint cotton produced per pound of fertilizer N, P_2O_5 and K_2O applied to cotton showed striking differences since 1964. Cotton produced per pound of N applied has remained virtually unchanged since 1964. Trends in cotton lint production per pound of K_2O applied were especially dynamic. The K_2O data reflect a general neglect of appropriate K use on cotton in the early 1980s, followed by increased use afterward, especially since about 1995. The percentage of the cotton acreage fertilized with K_2O in the Misdoubt and western states has increased since 1964, while it has remained high in the southeastern states. Increased K_2O use since about 1995 may be related to greater farmer recognition of the importance of K in achieving high yields and lint quality. The increase in total K_2O applied to cotton in the U.S. may also be related to the increased cotton acreage in the southeastern states since the early 1990s, where the majority of the cotton is planted on sandy, Coastal Plain soils with relatively low K fertility. Striking differences among states were observed in the estimates of the ratio of cotton harvest K removal (expressed as K_2O) to fertilizer K_2O applied. Continued high yields and the associated harvest removal of K and other nutrients will require close attention to fertilizer and plant nutrition management to sustain yields and quality.

Introduction

The role of the United States (U.S.) in meeting the world demand for fiber and food is critical and is increasingly being scrutinized by the public. In addition to public misperceptions about nutrient use in cotton production, many within the agricultural community are often confused about the importance of plant nutrients in meeting current demands and the challenges of tomorrow. To address some of these concerns and misperceptions, the Potash & Phosphate Institute (PPI) reviewed nutrient use in North American agriculture and published a report (Potash & Phosphate Institute, 2002). In the chapter on inorganic nutrient use in the PPI report (Stewart and Roberts, 2002) some striking information was revealed regarding nutrient use in U.S. cotton production.

Recent concerns about lint quality issues have been raised within the cotton industry, especially since more of the U.S production is being marketed and milled overseas. Farmer and industry concerns about length and micronaire discounts have been exposed in popular media articles in the southeast U.S. Potassium is known to play a critical role in both yield and quality attainment (Pettigrew, 1997; Pettigrew and Meredith, 1997). Mullins and Burmester (1997) reported that newer cotton varieties accumulate K more rapidly during the growth cycle than older varieties, with K accumulation exceeding 3 lb/A/day during peak uptake after flowering.

Since the early 1980s, there has been considerable research to investigate cotton response to soil-applied K management: in the West (Cassman, 1986; Miller et al., 1997), the Midsouth (Adeli and Varco, 2002; Howard et al., 2001; Maples et al., 1988; Pettigrew et al., 1996; Varco, 2000) and the Southeast (Mullins et al., 1999), for example. Many scientists have also studied foliar response to K by cotton (Howard et al., 2000; Oosterhuis et al., 1994; Snyder et al., 1995; Weir, 1999) and the preliminary results of some of that work were the subject of a special program sponsored by the Soil Science Society of America and the proceedings were published by the Potash &

Phosphate Institute and the Foundation for Agronomic Research (FAR) (PPI/FAR, 1993) . Much of this work began after widespread recognition of K deficiency across the U.S. cottonbelt in the early 1980s (Maples et al., 1988).

The objectives of this paper are to review information on the U.S. N, P_2O_5 (phosphate), and K_2O (potash) use on cotton since 1964 in consideration of cotton acreage, yields, and production in selected states across the U.S. cottonbelt. The trends in K_2O use, consumption, and balance are of special interest in this report because of its importance to cotton yield and lint quality (Pettigrew, 1997; Pettigrew and Meredith, 1997).

Methods and Materials

Cotton acreage, yield, and production data were obtained from the USDA National Agricultural Statistics Service (USDA NASS, 2005a, 2005b). Data on fertilizer applied to cotton were obtained form the USDA Economic Research Service (USDA ERS, 2003) and personal communication with Dr. Wen Huang (December 2004) with the USDA ERS, and from information published by the Potash and Phosphate Institute. The collected data were used to determine trends in the use of N, P_2O_5 , and K_2O on cotton, cotton yields, and apparent nutrient use efficiency (expressed as pounds of lint cotton per pound of applied fertilizer nutrient). An estimate of apparent nutrient balance was also made by comparing the seed plus lint cotton harvest removal of N, P (expressed as P_2O_5), and K (expressed as K_2O) versus the fertilizer nutrient input. Data were not available from the USDA NASS or ERS for some years for some states which now produce cotton, because of past USDA survey objectives and limitations. Data from the following 12 states, which represent 94 to 97 percent of the U.S. cotton production were used in this paper: Alabama, Arizona, Arkansas, California, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, and Texas.

Results and Discussion

Fertilizer use

Data collected by the American Plant Food Control Officials and The Fertilizer Institute on the national consumption (sales) of N, P_2O_5 , and K_2O (across all crops) in the U.S. indicate that N consumption has increased slightly since 1980, while consumption of P_2O_5 and K_2O has declined 19 to 20 percent (Figure 1).

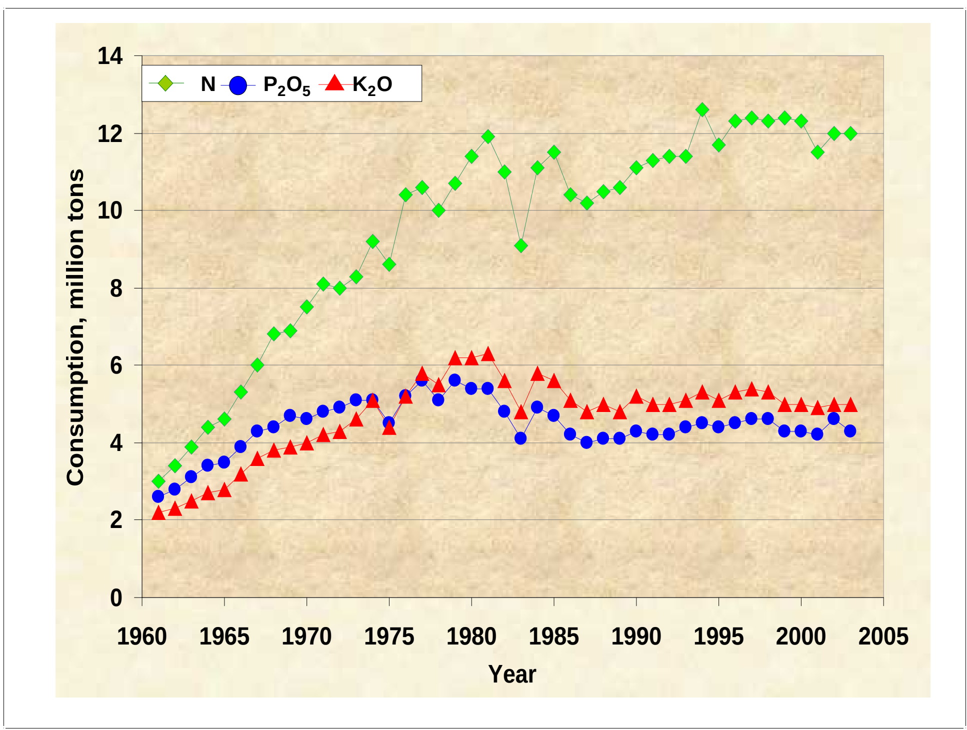

Figure 1 – Consumption of fertilizer N, P_2O_5, and K_2O by all crops in the United States

from 1961 through 2003 (fiscal years ending June 30).

The Potash & Phosphate Institute (2002) reported that total K_2O harvest removal by all crops continues to outstrip K_2O application. The P_2O_5 crop harvest removal has exceeded fertilizer P_2O_5 inputs since about 1984, contrary to public perception. The ratio between harvest removal of P_2O_5 and K_2O, and fertilizer P_2O_5 and K_2O use, is increasing, which indicates that P and K deficits are developing or are getting worse in parts of the U.S.

Based on USDA survey data, the average rates of N, P_2O_5, and K_2O applied to cotton in the U.S. from 1964 through 2000 are shown in Figure 2, and are contrasted with rates applied to corn, wheat and soybean for comparison.

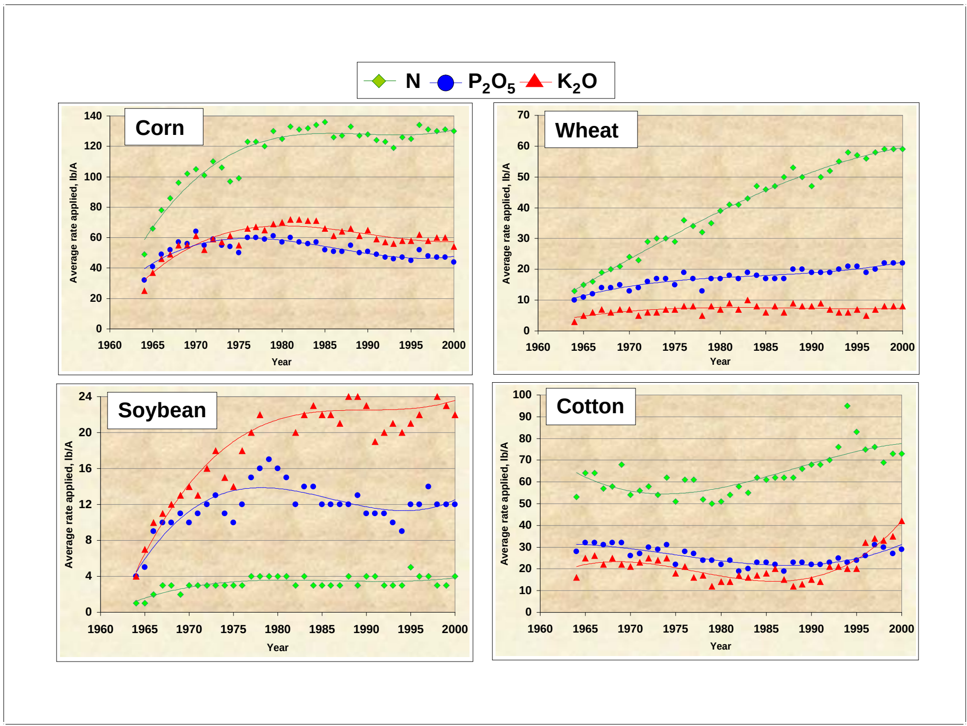

Figure 2 - Average rates of fertilizer N, P_2O_5, and K_2O applied to corn, wheat, soybean and cotton from 1964 through 2000.

The average rates of fertilizer N applied to cotton have increased since the 1960s, but not as rapidly as with the other major crops shown. The rates of P_2O_5 applied to cotton declined from the 1960s through the 1990s, but may be increasing. The average P_2O_5 rates applied to cotton are greater than those applied for soybean and wheat, but lower than for corn.

The average rates of fertilizer K_2O applied to cotton declined from the 1960s through about 1992, but an increase was observed, especially since about 1995. A closer look since 2000, with additional data through 2003, showed that the increasing trend in the average K_2O rate applied to cotton land in the U.S. is continuing (Figure 3).

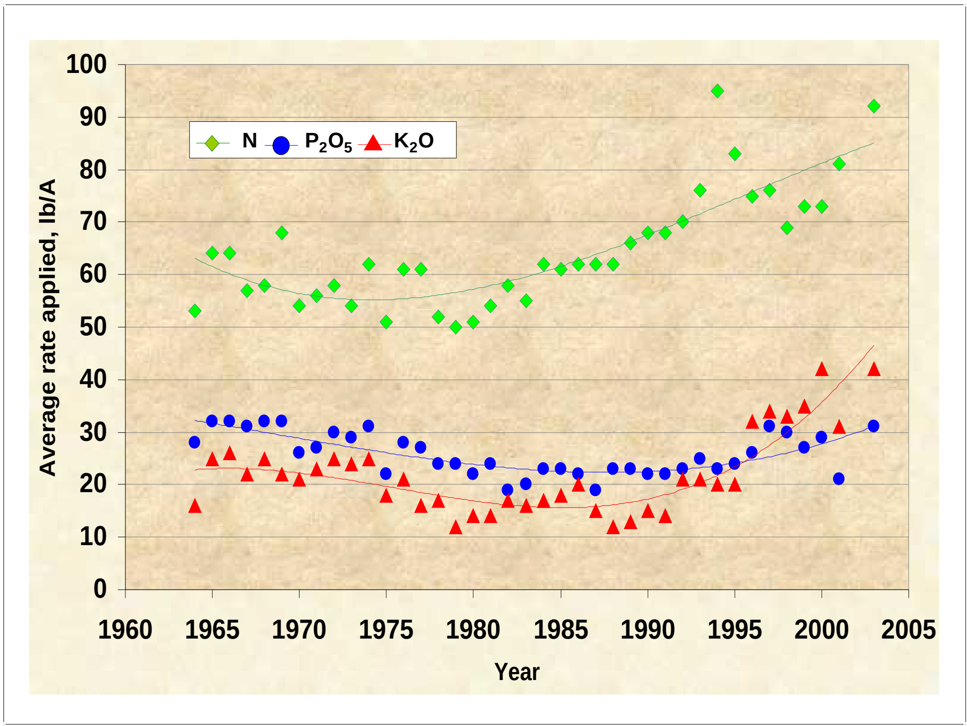

Figure 3 - Average rates of fertilizer N, P_2O_5 , and K_2O applied to cotton land in the U.S. from 1964 to 2003.

The average rates of potash (K_2O) applied to the fertilized cotton acreage varies among states, and has varied over time. Figure 4 shows the striking differences among states, and also helps to illustrate the impact that some states have on the calculation of the national average rate of K_2O applied to planted cotton acreage.

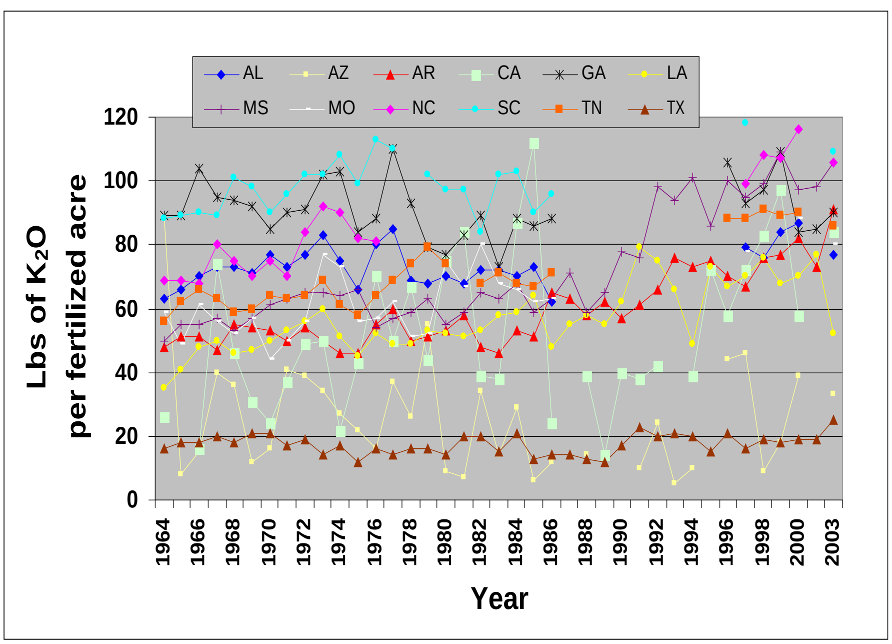

Figure 4 – Rate of potash (K_2O) applied to fertilized cotton acreage for different states from 1964 through 2003.

Cotton Acreage, Total Potash Applied, Cotton Yields and Production

Since the 1960s, there has been considerable fluctuation in the planted cotton acreage among states. The total cotton acreage in 2004 is slightly lower than the planted acreage in 1964 (Figure 5). Texas acreage remains the largest. Sizeable increases in planted cotton acreage have occurred in Georgia, North Carolina, and South Carolina since the early 1990s. The acreage expansion in the southeast during the 1990s is noteworthy and probably a result of boll weevil eradication success and many other factors, including the availability of adapted cultivars with improved genetic traits after 1995 (e.g. glyphosate tolerance, insect resistance), more reduced tillage and other beneficial cultural practices.

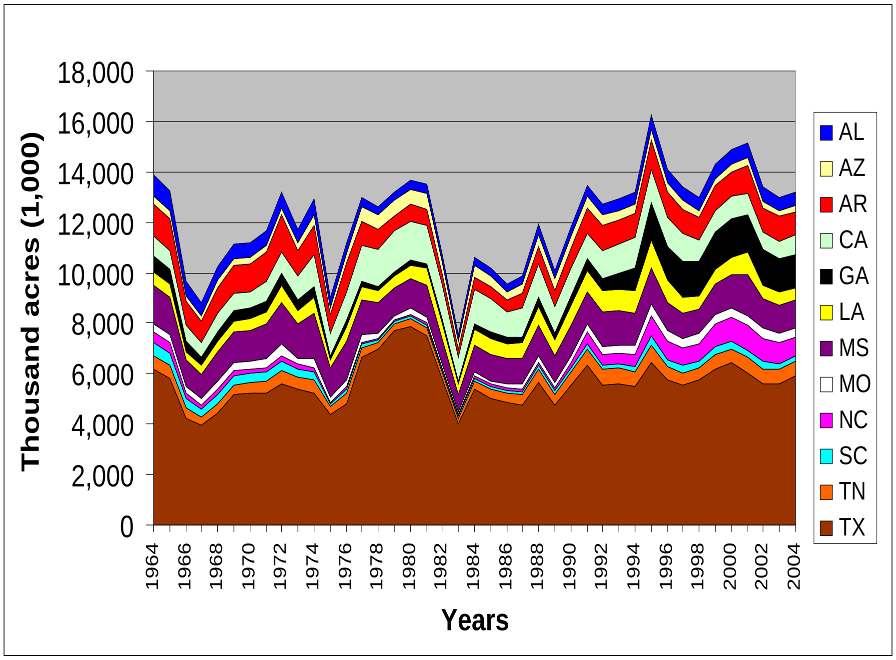

Figure 5 - Cotton acreage among states from 1964 through 2004.

The impact of the increased K_2O rates and the percentage of planted acres receiving K_2O was a net increase in total K_2O applied to cotton (Figure 6). The graph shows the decline in total K_2O application form the 1970s to the 1980s, and the increase after the mid-1990s. The required data were not available from the USDA for some states in several years, especially 2002, which prevented comprehensive calculation of K_2O tonnage, which helps explain the dips observed in the trends in some years. However, in 1975 data were available for each state shown, and only data for North Carolina were unavailable in 1983; years when striking declines were observed.

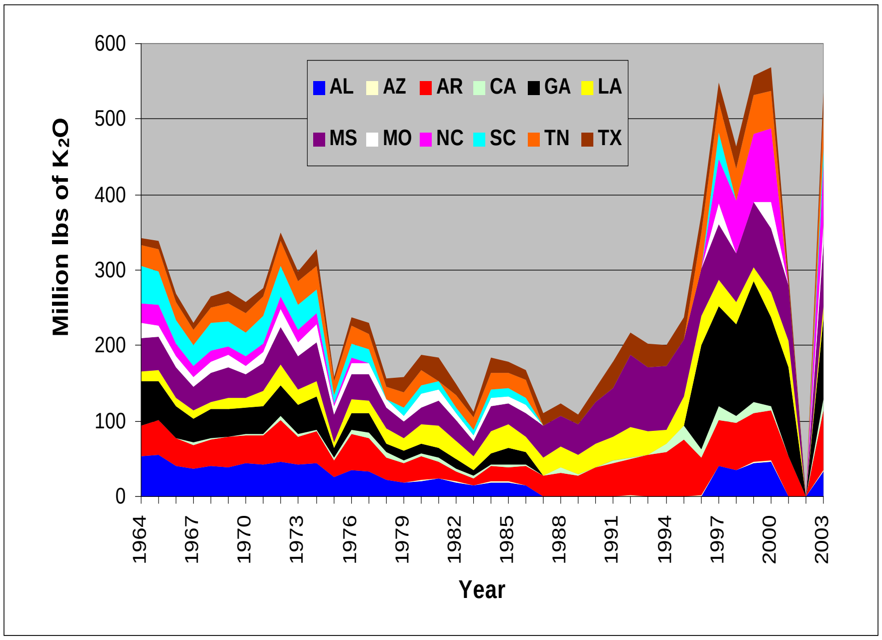

Figure 6 – Estimate of total K_2O applied to cotton in different states from 1964 through 2003.

Cotton yields have increased since the 1960s, but a concern about possible yield stagnation during the 1990s was registered by many farmers and was reported by Dr. Bill Meredith with the USDA Agricultural Research Service (Meredith, 2000). However, cotton yields may be increasing again in the U.S. There has been an upward trend in yields since about 1999 (Figure 7).

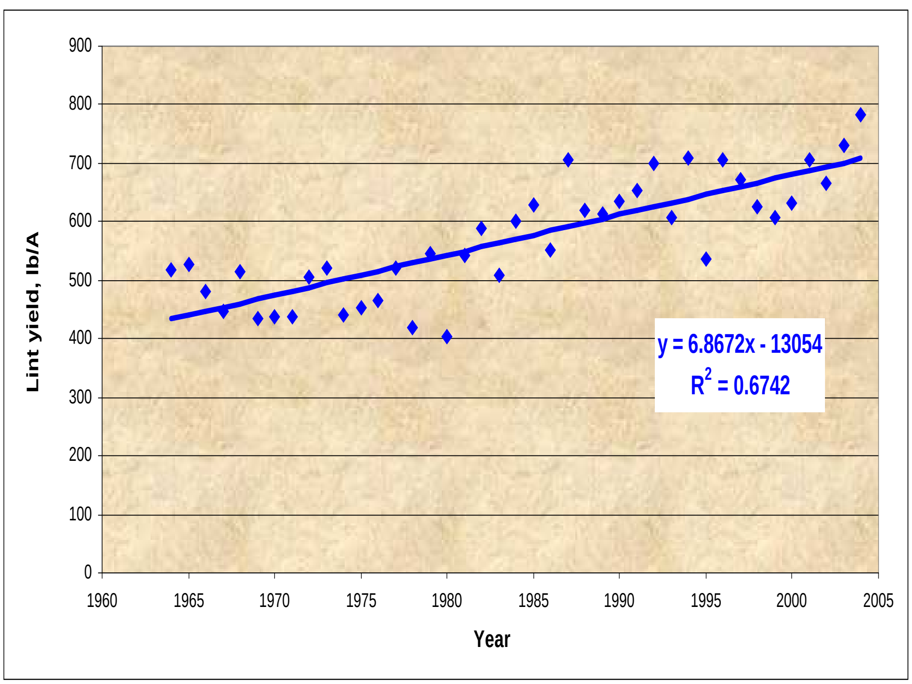

Figure 7 – National average cotton lint yield in the U.S. from 1964 through 2004.

As a result of the increased lint yield and increased cotton acreage, the total cotton production in the U.S. has increased, especially since about 1990 (Figure 8). The increased yield since 1990 may be somewhat related to the increased use of K_2O on cotton across the U.S.

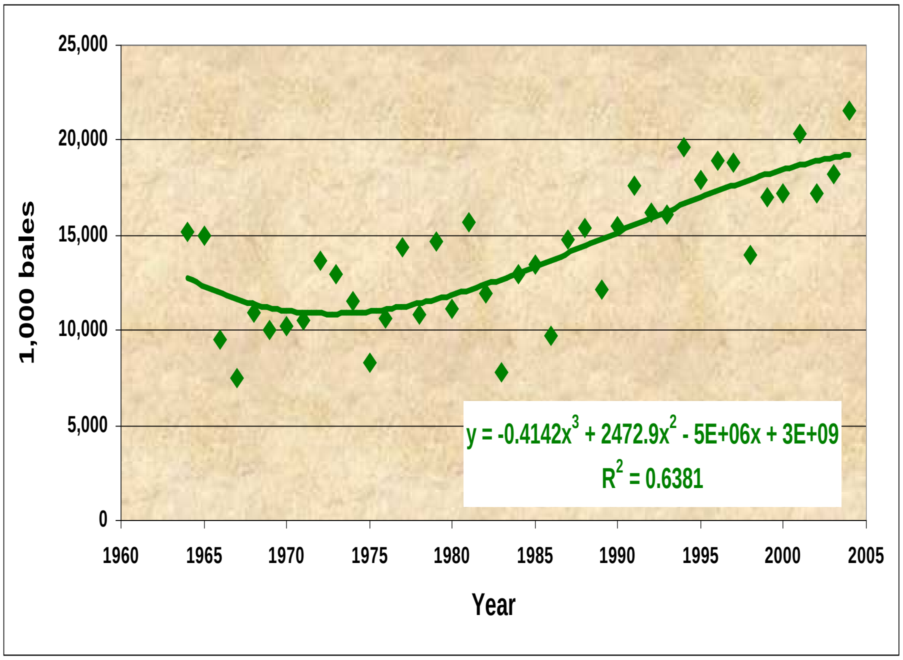

Figure 8 – Total cotton production in the U.S., presented as number of 480-pound bales from 1964 through 2004.

Lint yield versus fertilizer nutrient input

Crop production to fertilizer use ratios are sometimes considered indicators of apparent fertilizer use efficiency (Stewart and Roberts, 2002). However, there are many other factors such as native or residual soil fertility, changes in crop genetics, and other factors that influence the production per unit input of fertilizer. Figure 9 illustrates the trends in the ratios of lint cotton production versus the fertilizer applied to cotton.

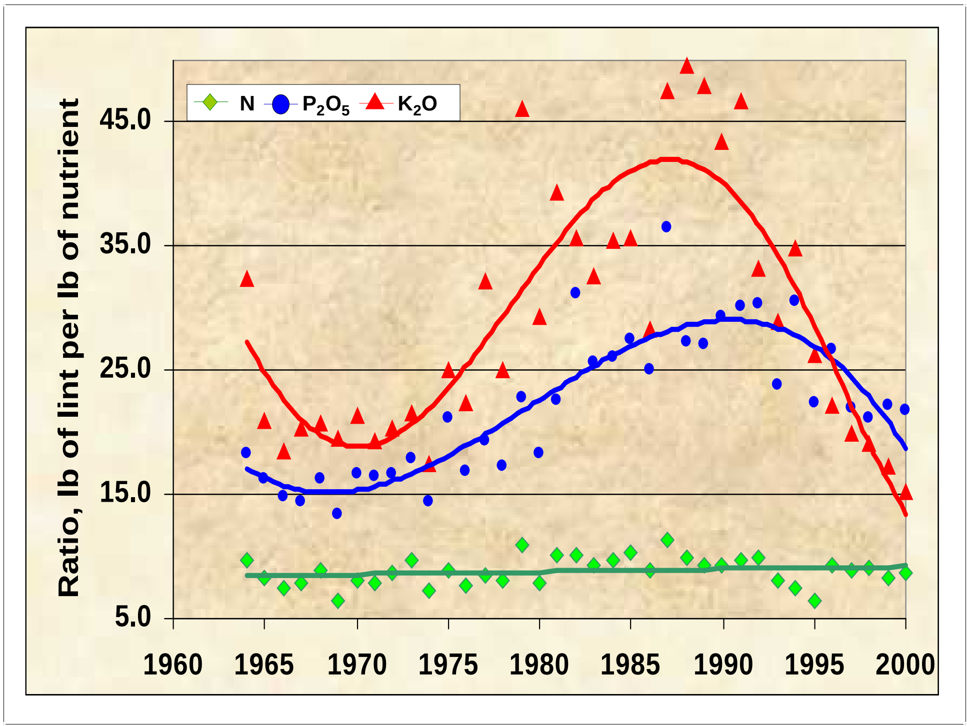

Figure 9 – Ratio of the cotton lint production versus the fertilizer N, P_2O_5 and K_2O applied to cotton from 1964 through 2000.

The lint production per pound of fertilizer N applied to cotton has remained virtually the same since 1964. In contrast, lint production per pound of fertilizer P_2O_5 and K_2O increased and then decreased. Increased lint production per pound of applied P_2O_5 and K_2O may have resulted from improved crop yields and somewhat limited or reduced application of P_2O_5 and K_2O rates on cotton, and might give the false impression of efficiency. In fact, rates of these two nutrients applied to cotton did decline from the 1960s into the 1990s (Figures 2 and 3). When widespread K deficiency began to be recognized across the cottonbelt (Maples et al., 1988) because of inattention to appropriate soil K fertility, research efforts increased and educational programs were developed to stimulate increased K_2O fertilization of cotton to improve cotton yields and farmer profits. These research and educational programs contributed to an increase in the average rate of K_2O applied to the fertilized cotton acreage (Figure 4), and total potash (K_2O) applied to cotton (Figure 6) beginning in the early 1990s, which caused a decline in the ratio of cotton produced per pound of K_2O applied. This declining trend in the ratio is not necessarily undesirable because there is a significant percentage of the sampled farm acreage in need of fertilizer K_2O, especially in the midsouth and southeast U.S., based on a recent summary of soil test data from public and private labs in the U.S. (Figure 10) (Potash & Phosphate Institute, 2001).

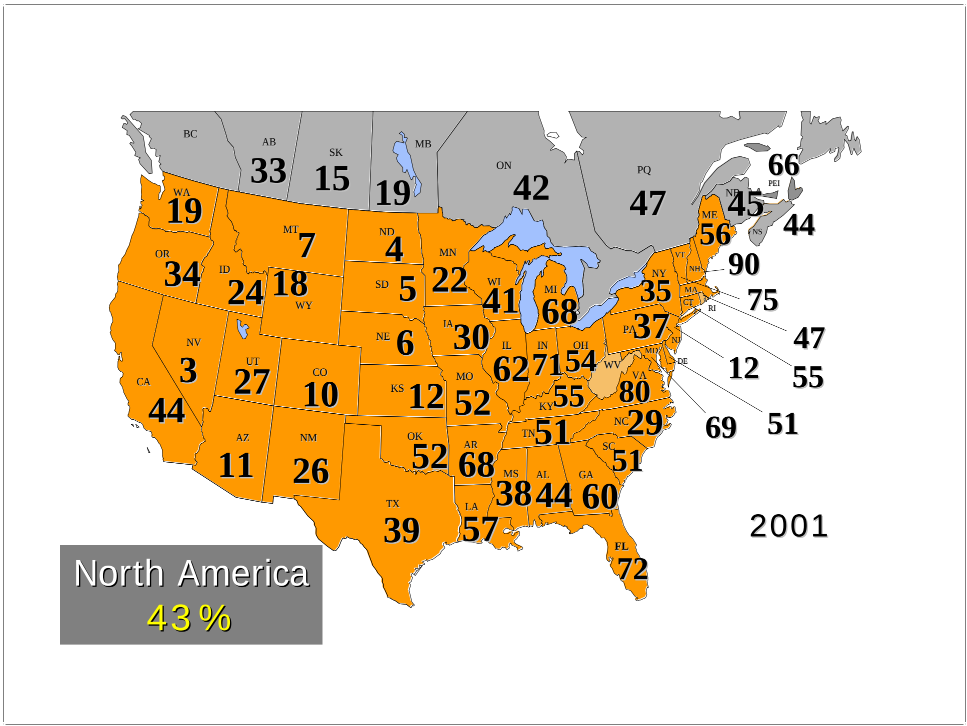

Figure 10 – Percentage of all sampled soils (>2.5 million samples) with extractable soil test K rating medium or below in 2001.

The soil test demand for K shown in Figure 10 is somewhat reflected in the percentage of each state's cotton acreage which received fertilizer K_2O (Figure 11). States with a higher percentage of soil samples testing medium or lower tended to have a higher percentage of the planted cotton acreage receiving K_2O.

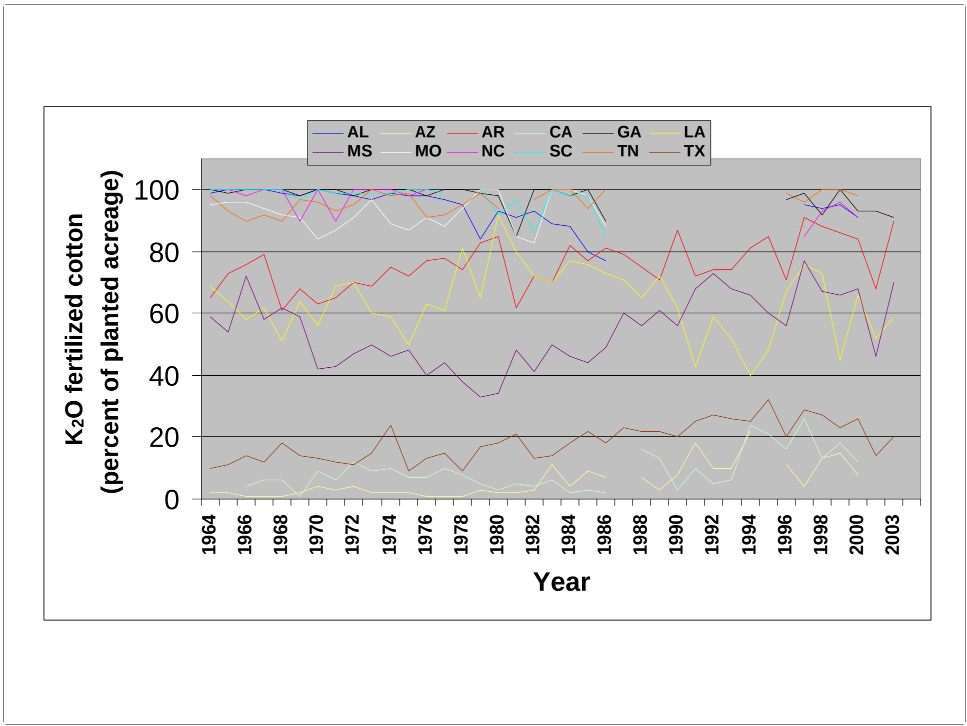

Figure 11 – Percentage of the cotton acreage in different states which received fertilizer K_2O from 1964 through 2003.

In a slightly different way of evaluating the cotton output per input of fertilizer, we calculated the ratios of the national average lint yield versus the national average rate of N, P_2O_5, and K_2O applied to planted cotton acres (Figure 12). This slightly different approach (does not involve an estimate of the percentage of the cotton acreage that was fertilized) to calculating the ratios enabled inclusion of data through 2003, and the trends in the ratios were similar to those shown in Figure 9. An upturn in the trend for lint yield versus average rate of K_2O applied to planted cotton acreage may be occurring (Figure 12). This upturn, coupled with the trend for increasing K_2O rates applied to cotton (Figure 3) and the percentage of cotton acreage receiving fertilizer K_2O (Figure 11) may indicate a trend for improved cotton soil K fertility, which may result in increased cotton productivity.

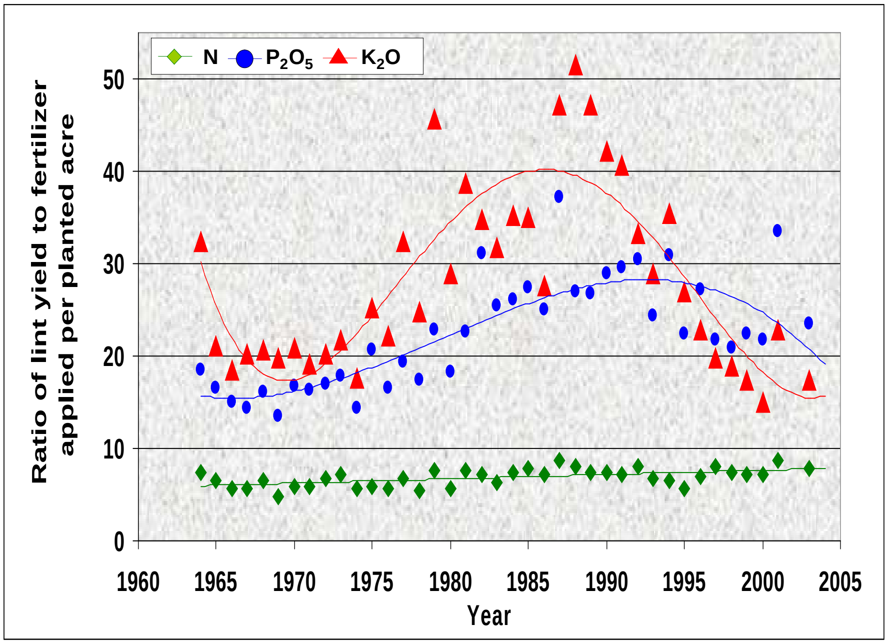

Figure 12 – Ratios of the national average lint yield versus the national average rate of fertilizer N, P_2O_5 and K_2O applied to cotton from 1964 through 2003.

Nutrient harvest removal versus fertilizer input

The ratio of the harvest removal (seed plus lint) of N, P and K (P and K expressed on the oxide basis for simplicity in comparison) to the fertilizer application of these nutrients was determined, based on the national cotton lint production versus the total fertilizer N, P_2O_5 , and K_2O. These values were calculated where USDA NASS and ERS data were available. There are striking differences in the ratios from the west and Central Great Plains (Figure 13) to the midsouth (Figure 14) and the southeast (Figure 15), which is largely a reflection of the different soil textures, mineralogy, and native soil K fertility among the regions.

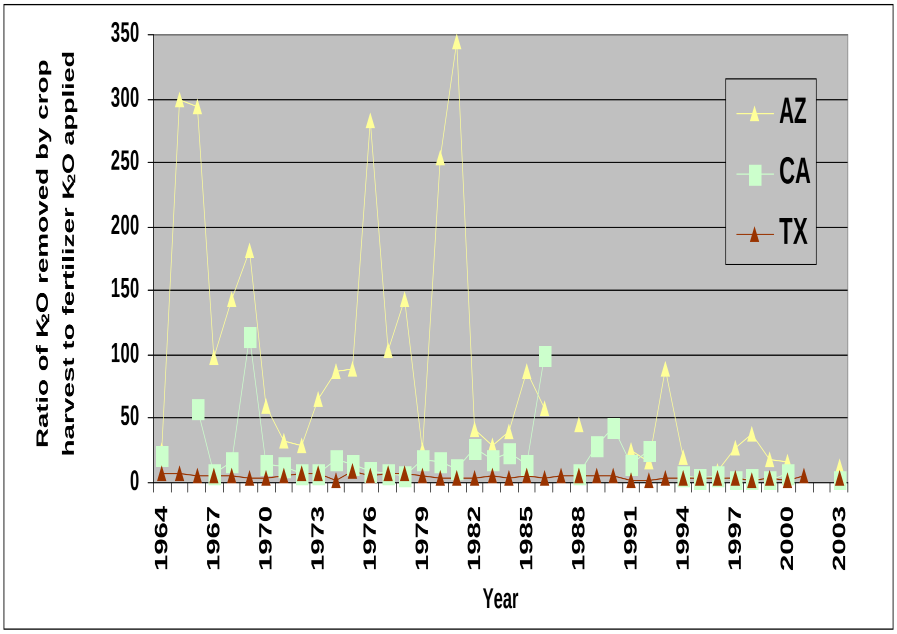

Figure 13 – Ratio of cotton harvest removal of K_2O to the rate of fertilizer K_2O applied in the West (and Central Great Plains) from 1964 through 2003.

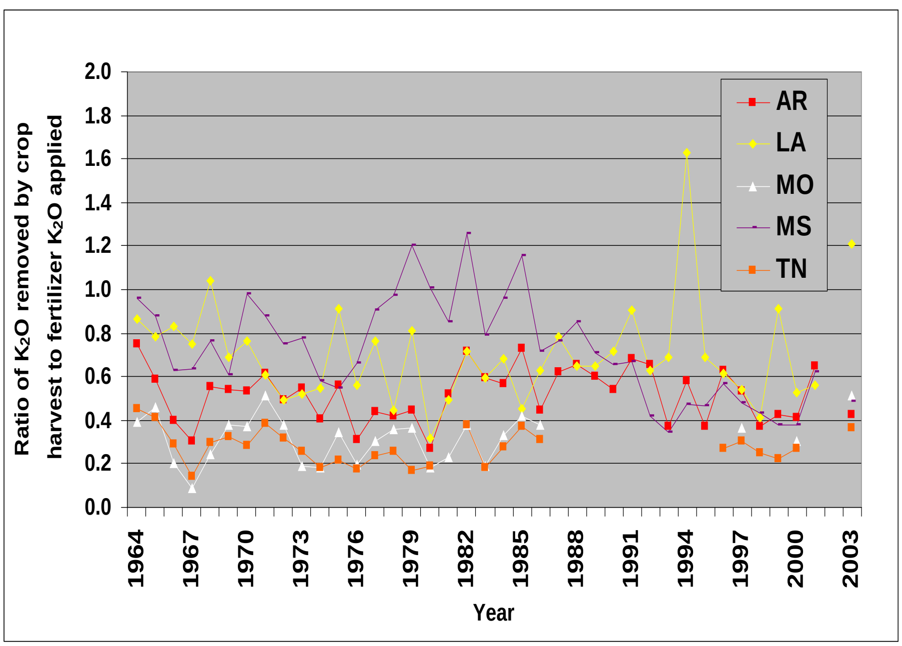

Figure 14 – Ratio of cotton harvest removal of K_2O to the rate of fertilizer K_2O applied in the Midsouth from 1964 through 2003.

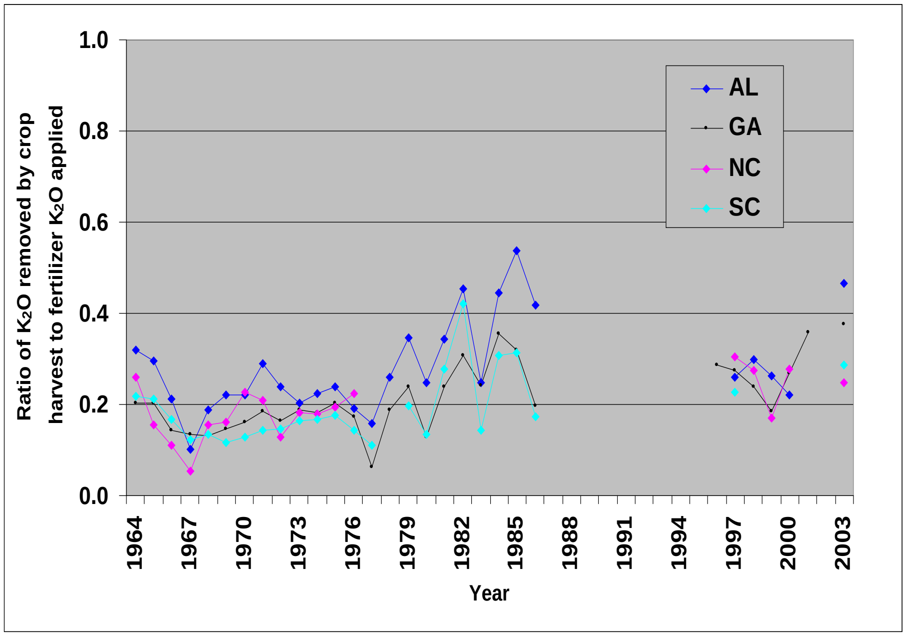

Figure 15 – Ratio of cotton harvest removal of K_2O to the rate of fertilizer K_2O applied in the Southeast from 1964 through 2003.

Conclusions

Cotton produced per pound of N applied has remained virtually unchanged since 1964. The K_2O data reflect a general neglect of appropriate K use on cotton in the early 1980s, followed by increased use afterward, especially since about 1995. The percentage of the cotton acreage fertilized with K_2O in the midsouth and western states has increased since 1964, while it has remained high in the southeastern states. Increased K_2O use since about 1995 may be related to greater farmer recognition of the importance of K in achieving high yields and lint quality, and the impact of intensive research and educational programs by university and industry agronomists. An upward trend in national cotton yields was experienced after the initiation of increased K_2O use on cotton. The increase in total K_2O applied to cotton in the U.S. may also be related to the increased cotton acreage in the southeastern states since the early 1990s, where the majority of the cotton is planted on sandy, Coastal Plain soils with relatively low K fertility. Striking differences among states were observed in the estimates of the ratio of cotton harvest K removal (expressed as K_2O) to fertilizer K_2O applied.

Continued high yields and the associated harvest removal of K and other nutrients will require close attention to fertilizer and plant nutrition management to sustain yields and quality.

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