Chapter II

Soil Nutrient Management Practices

This chapter presents information about fertilizer and nutrient management practices used in the production of major field crops, fruits, and vegetables. The estimates are developed from producer surveys in the major production States for the selected crops and from other information sources. See appendix A for a description of the surveys.

Managing soil fertility is essential for obtaining and sustaining high yields and making crop production profitable. While fertilizer expenditures account for a relatively small share of the total production cost for crops, commercial fertilizer is the largest cash expenditure in corn production as well as a significant share of the cash expenditures for other commodities [USDA, ERS, 1999]. Determining soil nutrient needs, selecting the right fertilizer material, and deciding when and how to apply commercial fertilizer are important decisions for profitable crop production. Yield expectations, soil characteristics, previous crops, the use of livestock manure or other waste materials, or other cultural practices are other factors that can affect the quantity of commercial fertilizer applied. Timely applications that make nutrients available at the time needed by the plants are important not only for high yields, but also to prevent nutrient losses from leaching, volatilization, runoff, and soil erosion. Excessive rainfall, drought, and other weather conditions also affect soil nutrient levels, nutrient use by crops, and losses to the environment.

Marginal productivity estimates of fertilizer inputs have been estimated both from field trials using incremental changes in application rates and at aggregate levels using econometric models. Early econometric studies [Griliches, 1963; Padgitt, 1969; and Headley, 1972] show a marginal value return of $3 to $5 for each additional dollar of fertilizer expenditure. In 1975, Miranowski reported lower returns for cotton and provided some empirical evidence that there may be some overuse of nitrogen by corn producers in some areas [Miranowski, 1975]. Field-level experiments for corn on highly productive, irrigated, silt loam soils in Kansas in 1991 estimated a maximum profit nitrogen application at about 160-170 pounds per acre [Schlegel and Havlin, 1995]. Maximum profit fertilization levels, however, can vary widely from this estimate depending on other inputs, production practices, and climatic conditions.

Fertilizer use and nutrient management practices potentially can harm the environment [Mueller and Helsel, 1996]. Concentration of nitrogen and phosphate in surface water stimulates the growth of plants in lakes, streams, and estuaries and reduces their potential for recreational or other economic uses. High concentrations of nitrates in drinking water can also be a human health concern. Materials containing nitrogen or phosphate are the most widely used fertilizers and may contribute to these water quality problems. The U.S. Environmental Protection Agency reported that nutrient loadings were the leading cause of water quality impairment in both lakes and estuaries, and the third and sixth leading causes of impairment in rivers and wetland systems [EPA, 1995].

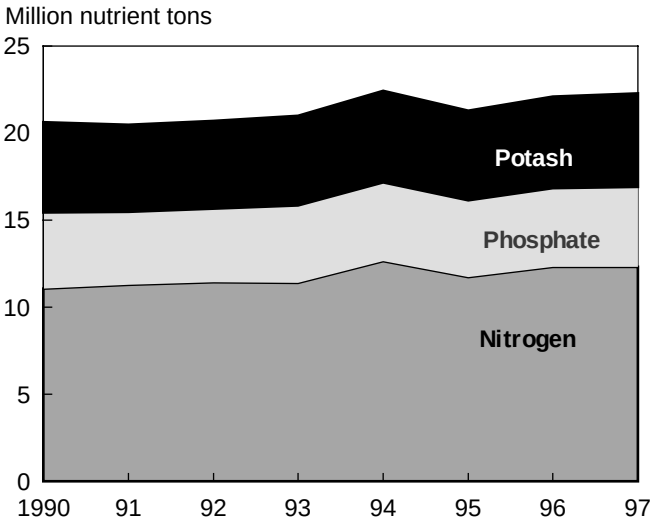
Primary Nutrient Consumption

Nitrogen and phosphate fertilizers are the nutrients applied to the largest share of acreage, according to USDA surveys. Nitrogen accounted for over half of fertilizer consumption, with some nitrogen fertilizer being applied to more than 70 percent of the cropland in the surveys. Nearly 60 percent of the cropland in the surveys received phosphate fertilizer and about 44 percent received potash (fig. 2A1). The total tonnage of potash, however, exceeded phosphate because of its higher application rates. Potash is a primary nutrient needed for plant growth, but it is less mobile and does not present the environmental concerns of nitrogen or phosphate. Many soils also contain sufficient levels of potash and require little or no supplemental application, at least on an annual basis.

Nitrogen and phosphate application intensities varied widely among crop production regions. High nitrogen and phosphate application rates corresponded closely to regions where there was a large acreage of corn or specialty crops. The highest application rates were in production regions where a high proportion of the cropland was used to grow potatoes, vegetables, or citrus fruit. However, some corn production areas in Illinois, Iowa, and Nebraska also received high application rates.

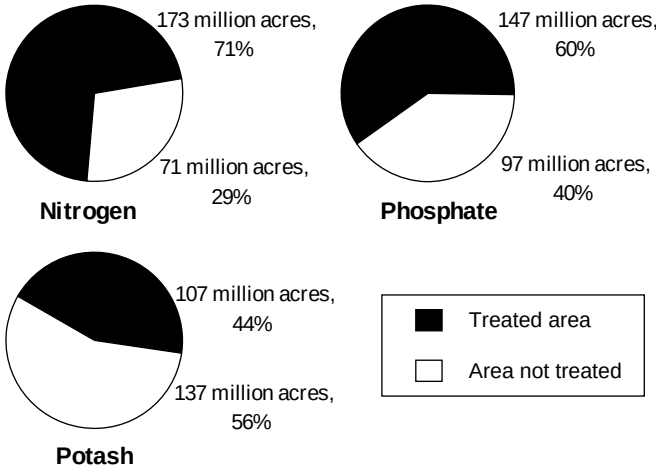
Figure 2A1

Primary nutrients applied remains stable



Source: Association of American Plant Food Control Officials, 1998.

Area treated with primary nutrients 1/



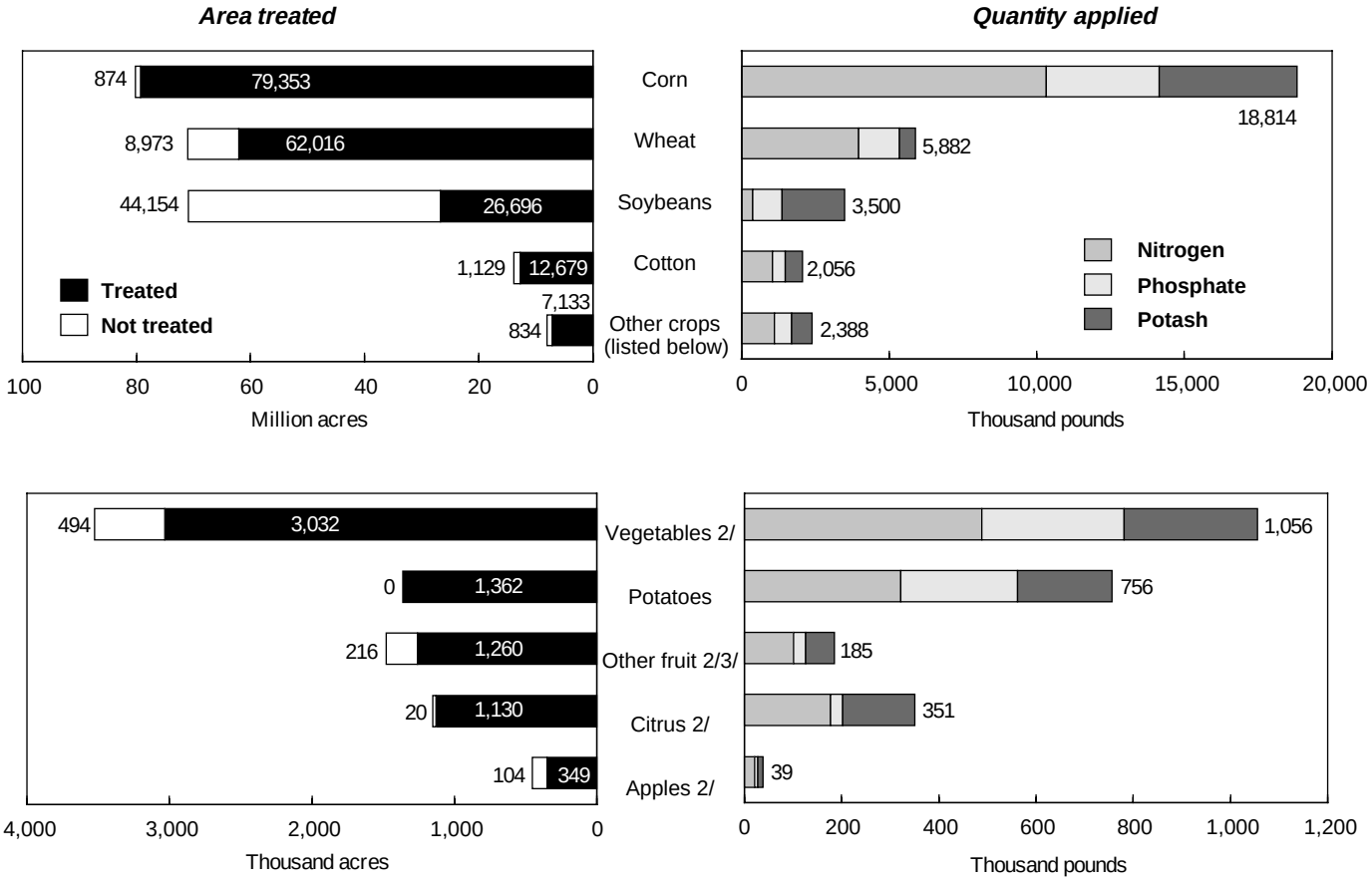
1/ Constructed to represent 244 million acres of 1997 U.S. cropland planted to corn, soybeans, wheat, cotton, potatoes, vegetables, and fruit. See appendix table B1.

Fertilizer Use Greatest for Corn

Corn, which accounted for one-third of all acres surveyed, was the leading crop in plant nutrient use (fig. 2A2). Almost all corn acres were treated. Fertilizer applied to corn accounted for 61 percent of all nitrogen, 53 percent of all phosphate, and 54 percent of all potash applied to the surveyed crops. Like corn, most of the acreage planted to wheat, cotton, potatoes, fruits, and vegetables was also treated with fertilizer, but due to their smaller acreage, fertilizer consumption by these other crops was less. Wheat, cotton, potatoes, and other crops are often grown in rotation with corn and can benefit from the residual fertilizer nutrients from corn. [See the Crop Rotation section, Chapter IV, for information about the difference in fertilizer use from crop rotations.] Less than 40 percent of the soybean acreage received any commercial fertilizer. Soybeans, like other legumes, process atmospheric nitrogen to meet most nitrogen needs. Most specialty crops (potatoes, vegetables, and fruits) received fertilizer at relatively high rates, but accounted for less than 10 percent of the total commercial fertilizer tonnage, due to the small acreage.

Figure 2A2

Fertilizer use greatest for corn 1/



1/ Constructed to represent 244 million acres of 1997 U.S. cropland planted to corn, soybeans, wheat, cotton, potatoes, vegetables, and fruit. See appendix table B1.

2/ Treated area includes only the area treated with nitrogen.

3/ Includes most other deciduous fruits and berries (except apples and citrus).

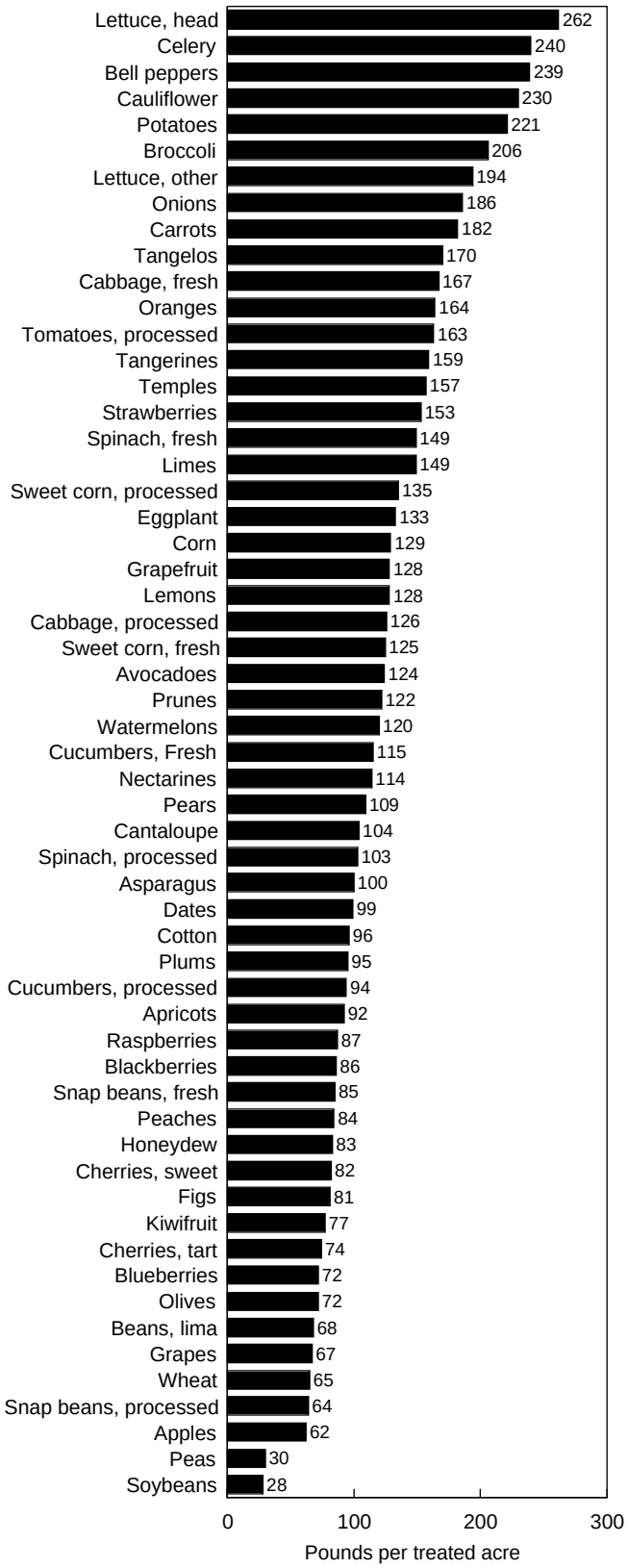
Source: USDA, ERS and NASS, 1996c.

Nutrient Application Rates Highest on Vegetables

Fertilizer needs of crops vary widely (figs. 2A3, 2A4, and 2A5). Average nitrogen and phosphate application rates were generally highest for nonlegume vegetable crops and potatoes and lowest for noncitrus fruit and legume crops. For the field crops, nitrogen and phosphate application rates were highest for corn and lowest for soybeans. Although commercial fertilizer was not applied to most soybeans, when it was applied, potash was the ingredient applied most often and generally at rates higher than for other field crops.

Figure 2A3

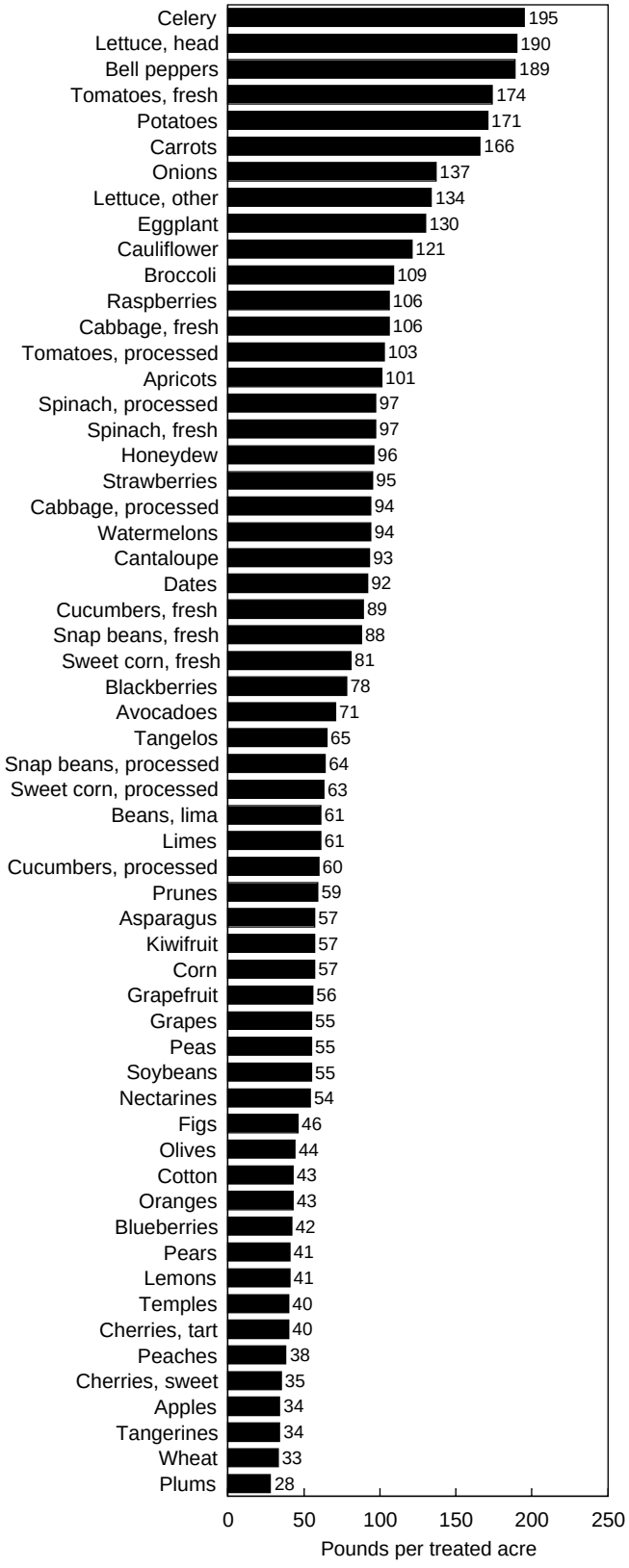
Nitrogen application rates for selected crops



Sources: USDA, NASS and ERS, 1996b, 1996a, and 1995a.

Figure 2A4

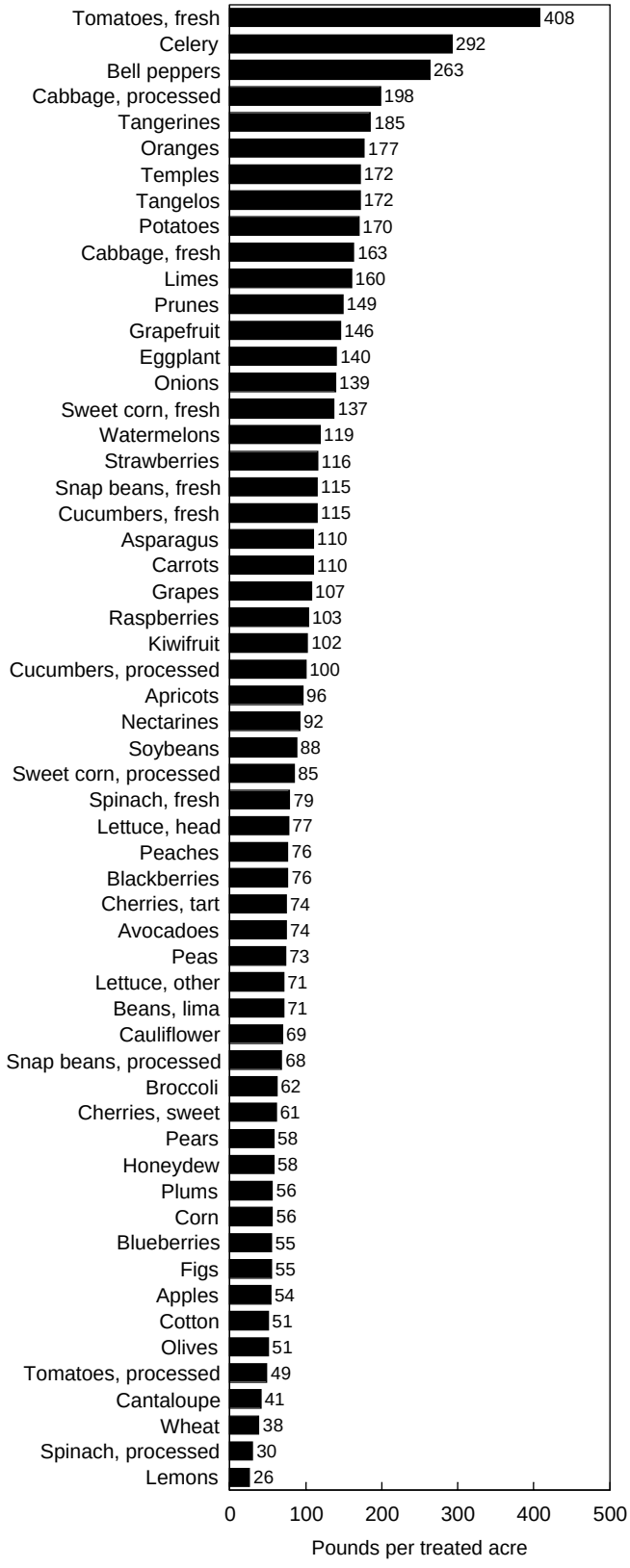
Phosphate application rates for selected crops



Sources: USDA, NASS and ERS, 1996a, 1996b, and 1995a.

Figure 2A5

Potash application rates for selected crops



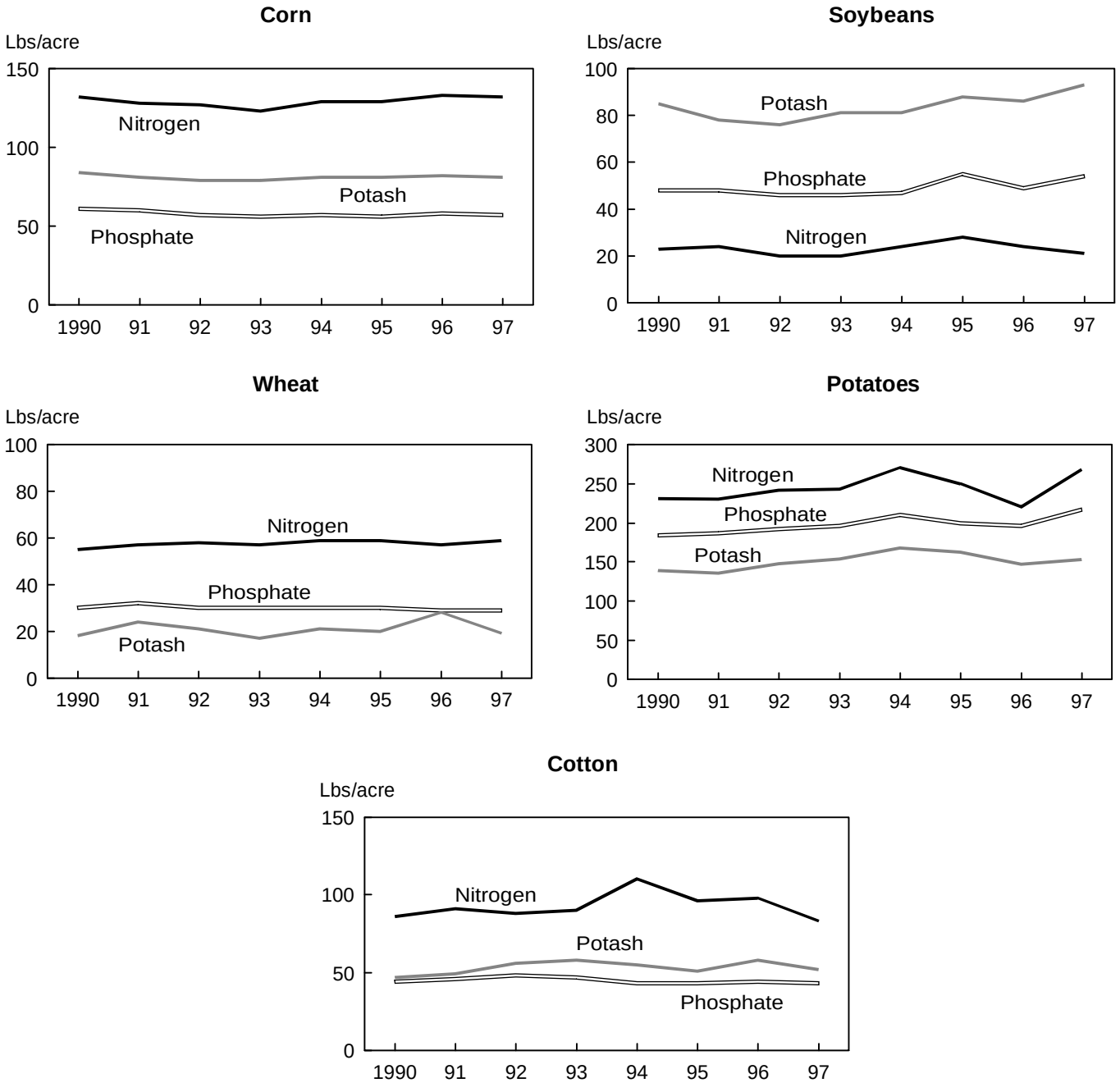
Sources: USDA, NASS and ERS, 1996a, 1996b, and 1995a.

Crop Nutrient Application Rates Remain Stable, 1990-97

Between 1990 and 1997, nutrient application rates remained relatively stable for field crops (fig. 2A6). Annual changes in fertilizer prices, commodity prices, expected yields, weather, and participation in Federal farm programs are factors that can affect fertilizer use decisions. Nitrogen application rates on corn dropped slightly between 1990 and 1993, but were up in the following years. For cotton, nitrogen rates were up between 1990 and 1994, but decreased in 1994-97. For soybeans, wheat, and potatoes, the trend was generally up between 1990 and 1997.

Figure 2A6

Crop nutrient application rates remain stable during 1990-97



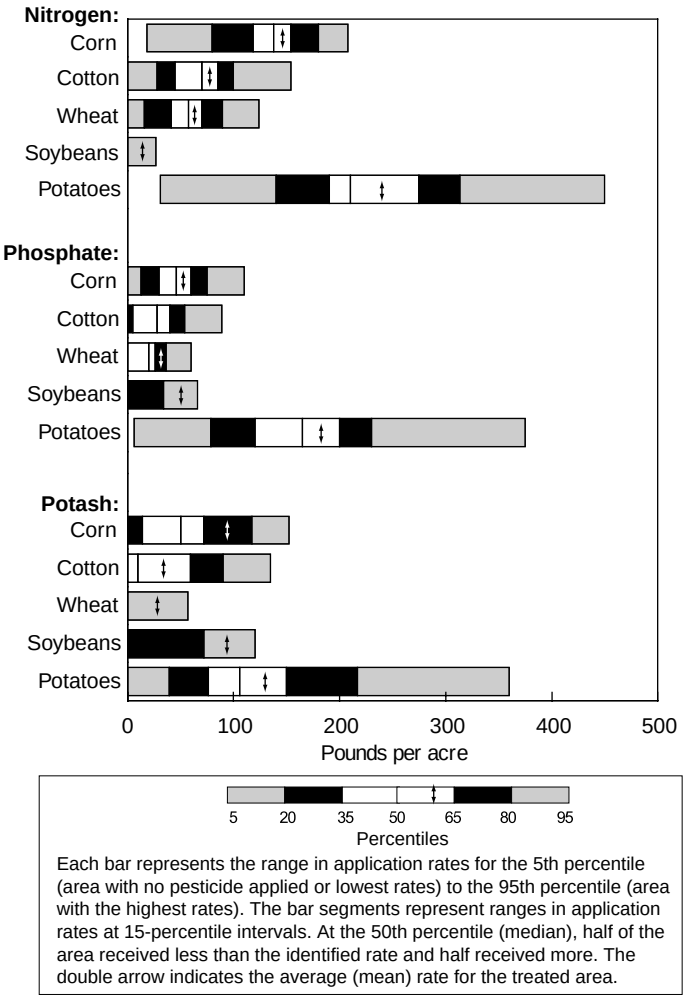
Sources: USDA, NASS and ERS, 1998b.
See appendix table B2 for States represented.

Variation in Nutrient Application Rates Highest Across Potato Fields

Besides the variation in application rates between crops, there was also wide variation in the application rates between fields of the same crop (fig. 2A7). Soil characteristics, yield expectations, previous crops, cultural practices such as irrigation, weather, and other factors can cause fertilizer rates to vary among fields. While some fields received no fertilizer, other fields were intensively treated. For example, the 5 percent of the potato area having the lowest application rates (5th percentile) received 31 pounds or less of nitrogen per acre, while the 5 percent of the area having the highest application rates (95th percentile) received 450 pounds or more of nitrogen per acre. For corn, the highest 5 percent received 208 pounds or more per acre of nitrogen and 110 pounds or more of phosphate. At the median (50th percentile), half of the acres receive more than that rate and half receive less. The mean is the average rate for all acres treated, but excludes untreated acres. Because some acres are not treated and because the rate on the the treated acres does not necessarily follow a normal statistical distribution, the mean rate is often higher than the median rate.

Figure 2A7

Nutrient application rates vary between fields



Each bar represents the range in application rates for the 5th percentile (area with no pesticide applied or lowest rates) to the 95th percentile (area with the highest rates). The bar segments represent ranges in application rates at 15-percentile intervals. At the 50th percentile (median), half of the area received less than the identified rate and half received more. The double arrow indicates the average (mean) rate for the treated area.

Source: USDA, NASS and ERS, 1996b

Nutrient Management Practices

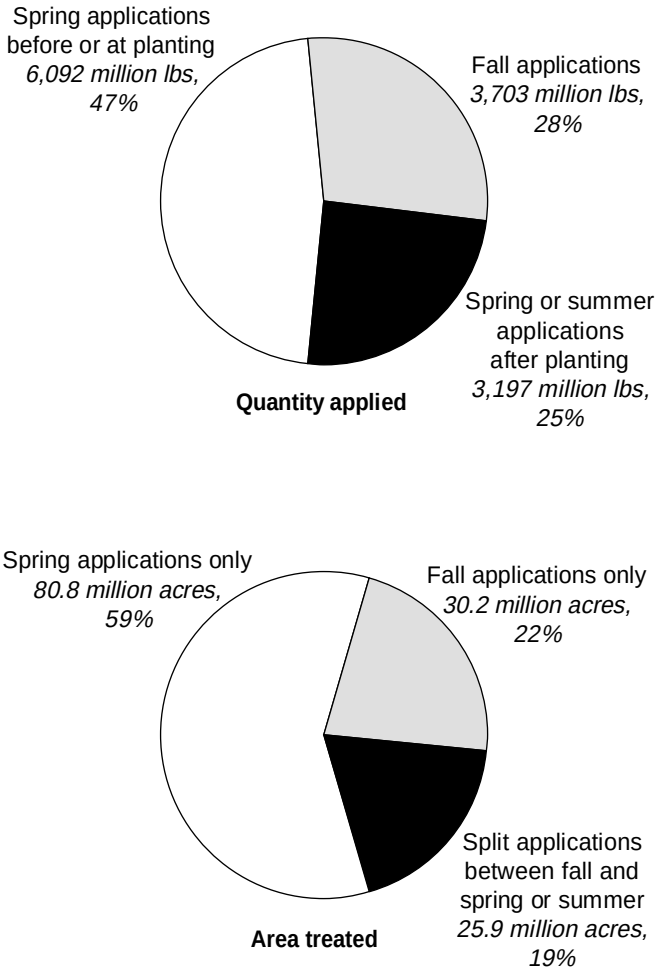
Most Nitrogen Fertilizer Applied Before or At Planting

Timing fertilizer applications to the plant's biological needs helps to reduce nutrient losses from leaching, runoff, or volatilization [Aldrich, 1984] (fig. 2B1). Nitrogen, in a form that can be used by plants, is mobile and can quickly be lost through leaching and runoff. The longer the nutrients are in the soil before they can be used by the crop, the more likely that they may be lost. Applications made during the growing season when the nutrient is most needed by the plant can reduce some of these losses. However, because of the cost of additional treatments and other factors, many farmers chose to apply their nutrients before or at planting time. Delaying fertilizer application until later in the growing season poses an additional risk that wet fields or other conditions may prevent timely treatment and result in yield losses. To free labor for the peak spring planting periods, some farmers apply their nutrients in the fall or at other off-peak times.

About three-fourths of all nitrogen used on the surveyed field crops (corn, soybeans, wheat, cotton, and potatoes) was applied before or at the time the crop was planted. An estimated 28 percent of the total nitrogen was applied in the fall, including that applied to winter wheat at or before planting. Winter wheat accounts for about one-third of the fall applications while the remainder was applied to crops planted the following spring. Nitrogen applications made after planting, which better coincides with plant needs, accounted for about one-fourth of the total quantity. About 22 percent of the area treated with nitrogen was treated with only fall applications. Fifty-nine percent of the area received all of the nitrogen treatments in the spring or later in the growing season. Split treatments, with part of the nitrogen applied in the fall and part the following spring or summer, occurred on about 19 percent of the area.

Figure 2B1

Most nitrogen fertilizer applied before or at planting



Represents fertilizer applied to 194 million acres of corn, soybeans, wheat, cotton, and potatoes.

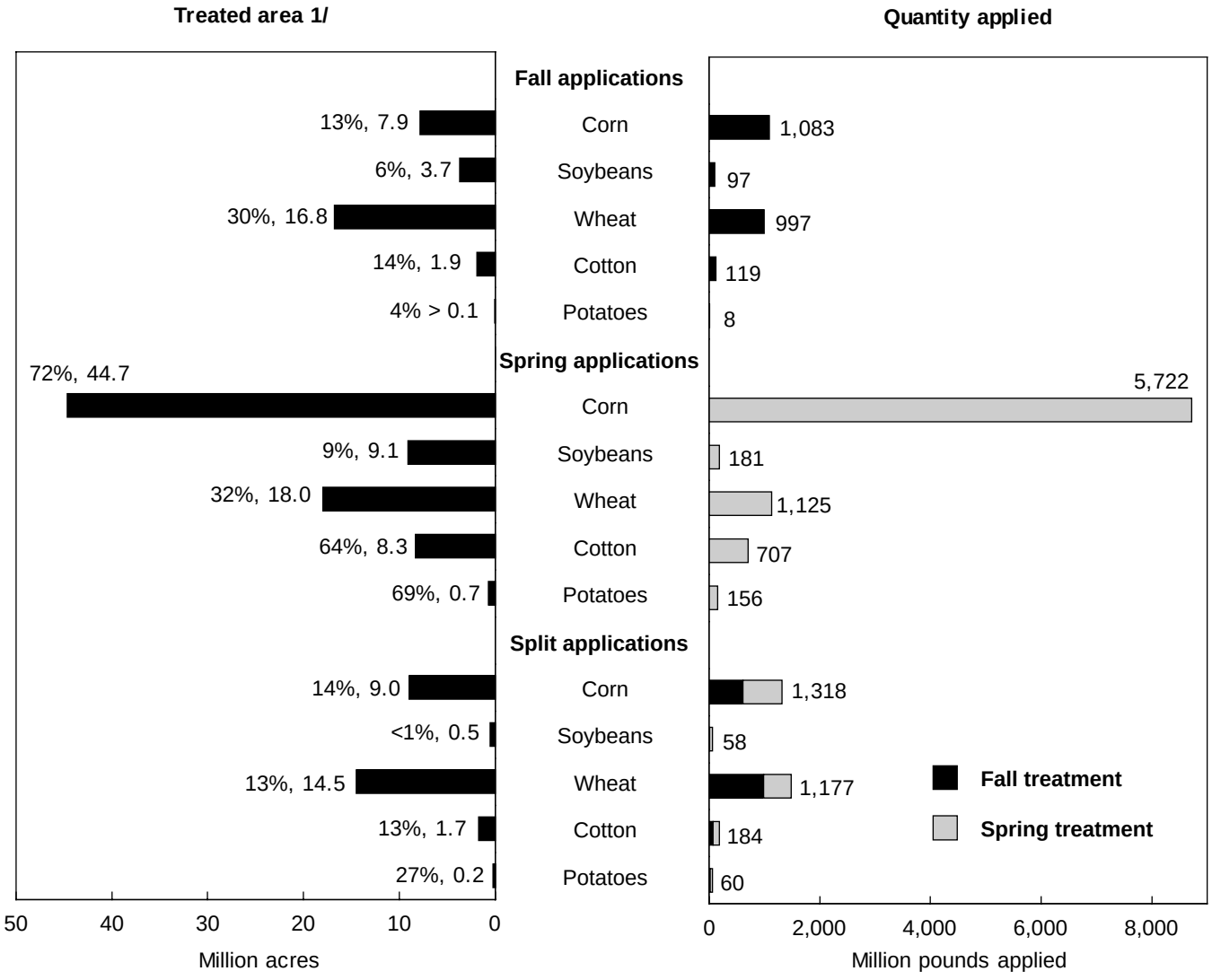
Source: USDA, NASS and ERS, 1996c.

Fall Nitrogen Applications Common for Corn and Wheat

Except for winter wheat, other crops received most of their nitrogen applications in the spring (fig. 2B2). For winter wheat or other fall-planted crops, split applications between fall and spring can better time the treatment with plant needs. For corn and other spring-planted crops in northern regions, nitrogen can normally be applied late in the fall without loss of nitrogen so long as the soil remains cold. About 27 percent of the corn area received fall nitrogen fertilizer applications and for about 13 percent of the area no other nitrogen was applied. Nitrogen applications were split between the fall and following spring or summer on 14 percent of the corn area.

Figure 2B2

Fall nitrogen applications used mostly for corn and wheat, 1997



1/ The first value at the end of each bar is the percentage of area treated, and the second value is million acres treated.

Source: USDA, ERS and NASS, 1996c.

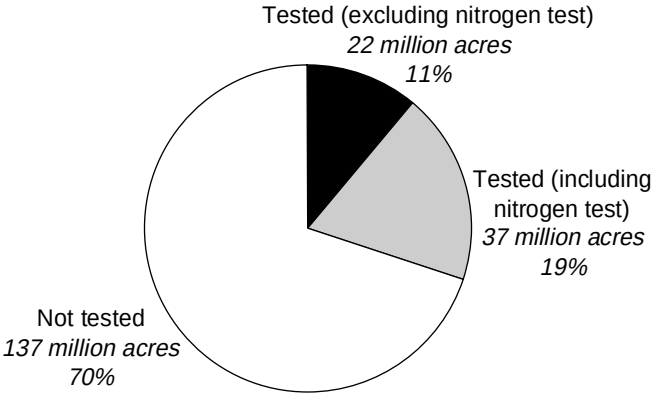
Annual Soil Nutrient Test Not Widely Used

Soil tests help farmers monitor soil nutrient levels in their fields to make more informed fertilizer application decisions (fig. 2C1). Analysis of soil samples in laboratories can help scientists and farmers more precisely develop fertilizer treatment plans that are cost effective and that do not result in excess nutrient levels. Laboratory tests of soil samples often include analysis of soil pH, organic matter content, amount of phosphate, potash, nitrate, and micronutrients along with recommendations for fertilizer treatments. The amount of nutrient actually available to plants depends on many factors and changes over time as some nutrients are lost or temporarily tied up in the soil.

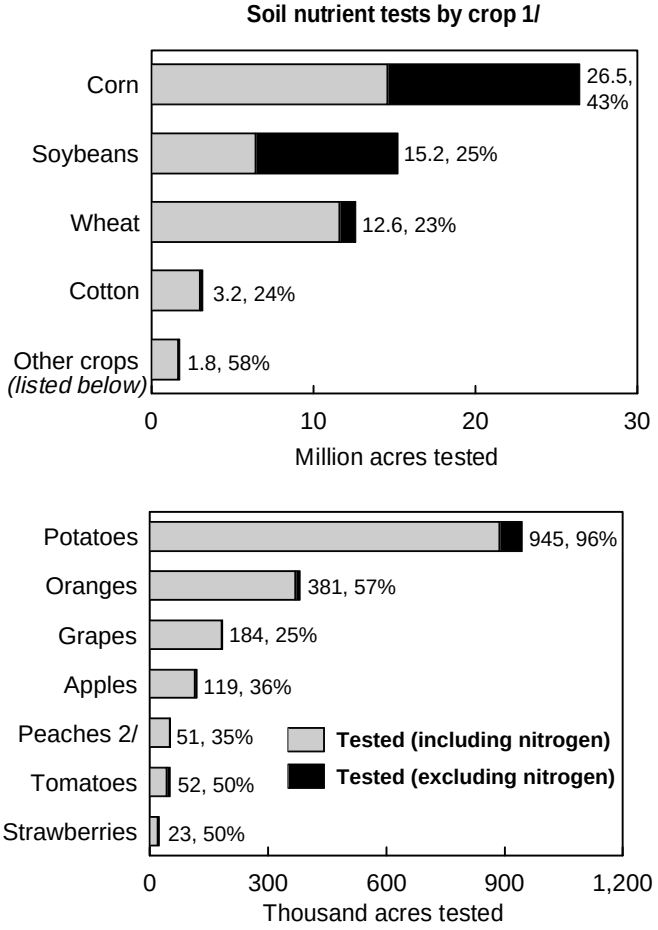
Less than a third of the represented crop acreage in the surveys had soil nutrient testing, at least on an annual basis. Soil nutrient testing was more often reported on crops that require large quantities of commercial fertilizer, such as potatoes and vegetables, than for crops that require less fertilizer, such as soybeans. About two-thirds of the area reporting soil tests also reported that the tests included one for nitrogen.

Figure 2C 1

Annual soil nutrient tests used on 30 percent of surveyed acres, 1994-95



Represents 196 million acres of corn, wheat, cotton, soybeans, potatoes, oranges, grapes, peaches, fresh market tomatoes, and strawberries.



1/ The first value at the end of each bar is total area tested, and the second value is the percent of the planted area tested.
2/ Information regarding nitrogen tests was unavailable.

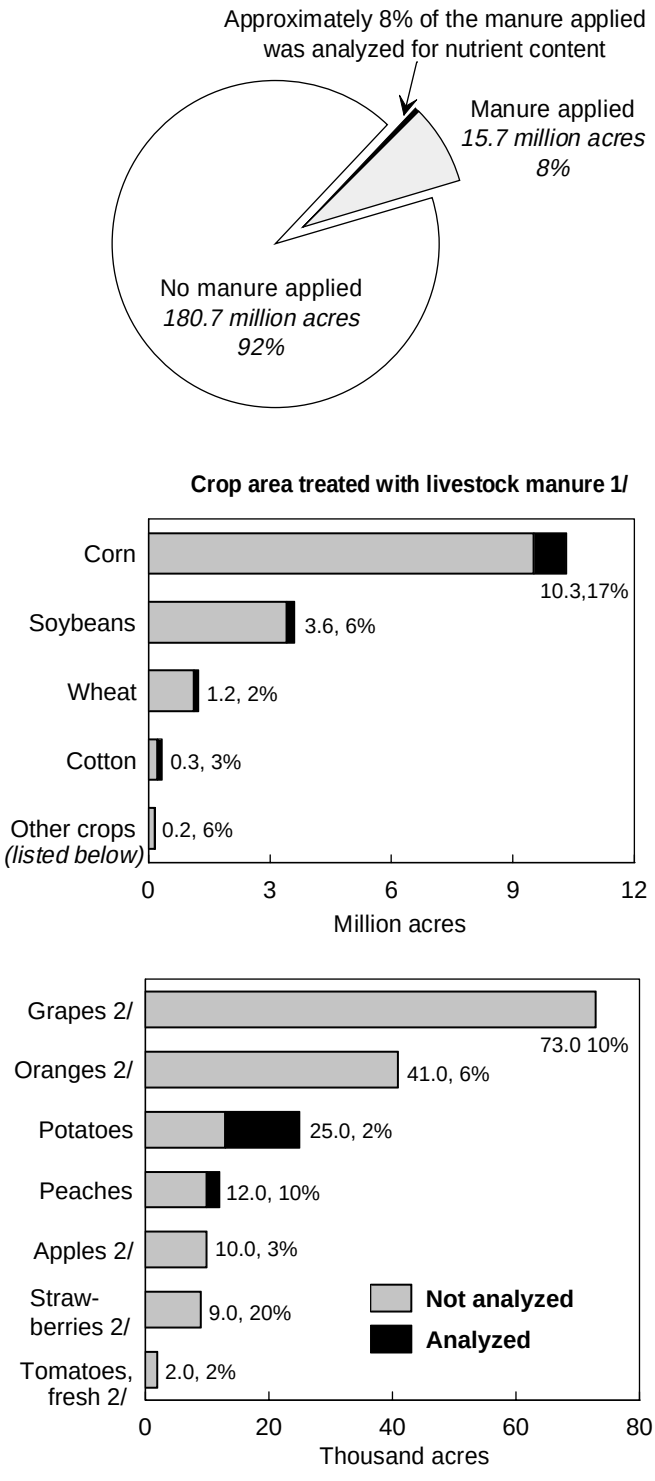
Source: USDA, NASS and ERS, 1994, 1995c, 1995d.

Acres Treated with Livestock Manure

Livestock manure is a source of plant nutrients, but it can also contribute to water quality problems (fig. 2C2). The nutrient content of manure can differ significantly depending on the livestock species and the storage and application methods. For more accurate crediting of nutrient content, farmers can pay for a laboratory analysis of the manure's nutrient content. Only about 8 percent of the area surveyed had any manure applied and very little of the manure was analyzed for its nutrient content. Most of the area treated with manure was planted to corn. The manure discussed here excludes any prepared and sold as a commercial fertilizer.

Figure 2C2

Few acres treated with livestock manure and analyzed for nutrient content



1/ The first value at the end of each bar is total area tested and the second value is the percent of crop area treated.
2/ Information was not available on manure analysis for nutrient content.

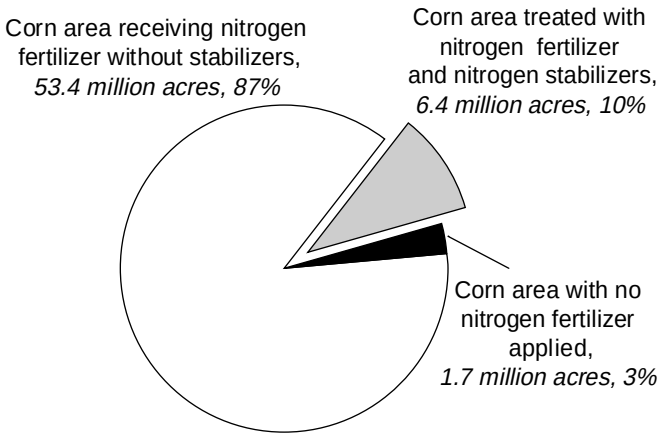
Source: USDA, NASS and ERS, 1994, 1995d, 1996d.

Use of Nitrogen Stabilizers for Corn

Without a stabilizing material, many nitrogen fertilizers quickly dissolve in water and move easily through the soil (fig. 2D1). Stabilizing materials have been developed that temporarily immobilize the fertilizer material and help prevent it from leaching below the crop root zone or being lost in runoff. The nutrient is then more slowly released during the growing season as the plant develops and requires the nitrogen. The use of nitrogen stabilizers allows earlier application of nitrogen and reduces potential losses. The stabilizers were most commonly used on corn and in areas subject to potential losses from high precipitation or irrigation. About 6 million acres (10 percent) of the surveyed corn area in 1997 used a nitrogen stabilizer. Extremely wet soils in 1993 delayed normal fertilizer applications, and use of nitrogen stabilizers was much lower that year.

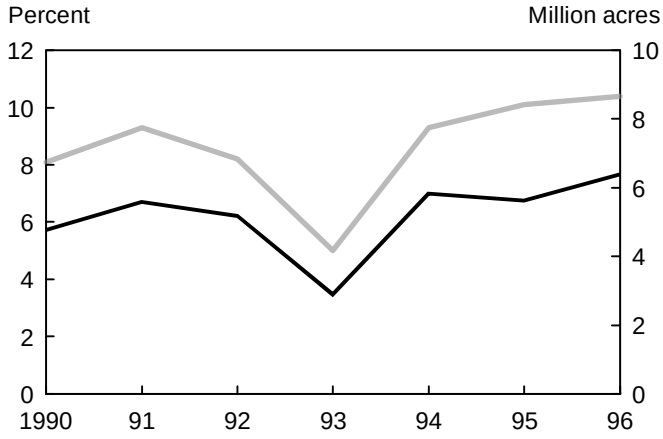
Figure 2D1

Limited use of nitrogen stabilizers for corn in 1996



Represents 61.5 million acres of corn in IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI in 1996.

Corn area receiving nitrogen stabilizers, 1990-96



Source: USDA, NASS and ERS, 1995c, 1996c.