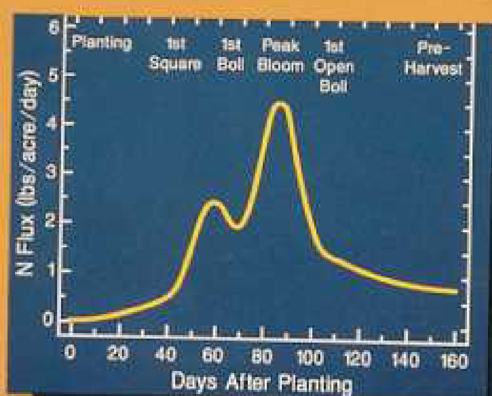
Nitrogen Fertilizer Management in Arizona



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The Role of Nitrogen Fertilizer Use in Arizona Agriculture

Introduction

Nitrogen is the essential nutrient element which is required in the greatest quantities by most commercial crops. Most of the nitrogen utilized by crop plants is derived from synthetic nitrogen fertilizers, from soil organic matter derived from plant and animal residues or byproducts, or from the symbiotic association of certain soil microorganisms with various legume plants. From such symbiotic associations, otherwise unavailable nitrogen gas from the atmosphere can be converted into forms which are useable to the host legume plants.

Alfalfa is the only major crop grown in Arizona which depends primarily on symbiotically fixed nitrogen. The remaining cotton, grain, vegetable, fruit and specialty crops, representing 80 to 85% of total crop acreage are dependent on additions of synthetic and naturally produced nitrogen fertilizers to achieve optimum productivity. Crop production in Arizona is particularly dependent on the use of off farm nitrogen sources for two reasons. The first is the limited availability of animal manures. All of the manure produced in Arizona is sufficient to supply nitrogen for only about 10% of the cultivated crop acreage at typical application rates. The second reason is related to the naturally low levels of organic matter in desert soils. The low levels of nitrogen mineralized from soil organic matter each year are not sufficient to fully support the highly productive irrigated cropping systems found in Arizona. Consequently, the increasing availability of inexpensive synthetic nitrogen fertilizers following World War II has made them the source preferred by most Arizona growers to supply nitrogen for their crops. In short, there is no practical substitute for nitrogen fertilizers in commercial agriculture as it is currently practiced in Arizona.

Figure 1 depicts the sharp rise in synthetic nitrogen fertilizer use occurring in Arizona during the past 50 years. This increasing use has been

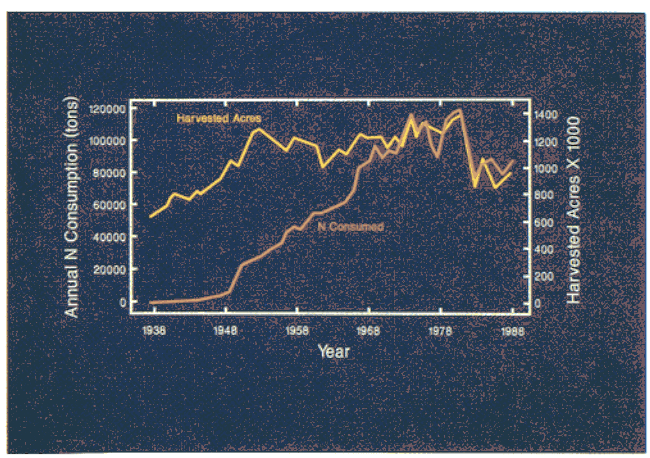

Figure 1.
Annual consumption of nitrogen from commercial fertilizers and number of harvested acres of cropland in Arizona between 1938 and 1988.

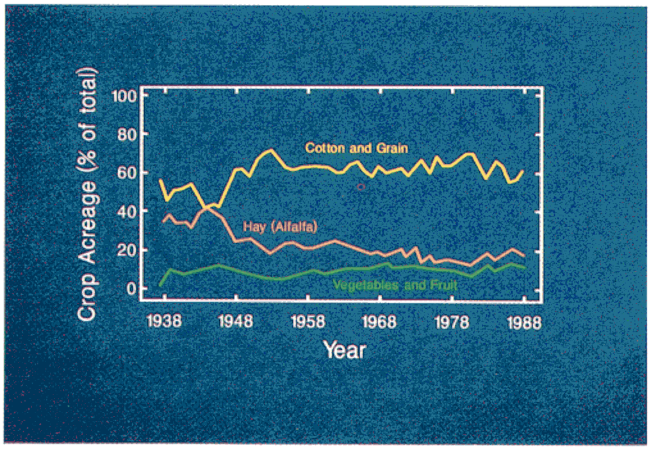

Figure 2.
Annual acreage distribution of major crop types grown in Arizona between 1938 and 1988.

fueled in part by expansion in the harvested acreage during the 1940's and early 1950's (Figure 1) and to some extent by a shift in cropping patterns away from low nitrogen use crops such as alfalfa in favor of cotton, grain and vegetable crops which require much higher nitrogen inputs (Figure 2). In addition, new crop varieties introduced over this period have been bred to produce higher yields which require more nutrients, including nitrogen. This trend of increasing crop yields with time is illustrated in Figure 3 for upland and Pima cotton. The influence of the release of new higher yielding varieties on average crop yields in Arizona is especially evident for Pima cotton where most production is obtained from a very small number of cultivars. Substantial yield increases were observed shortly after the introduction of varieties S-1, S-5 and S-6 in 1951, 1975 and 1983 respectively.

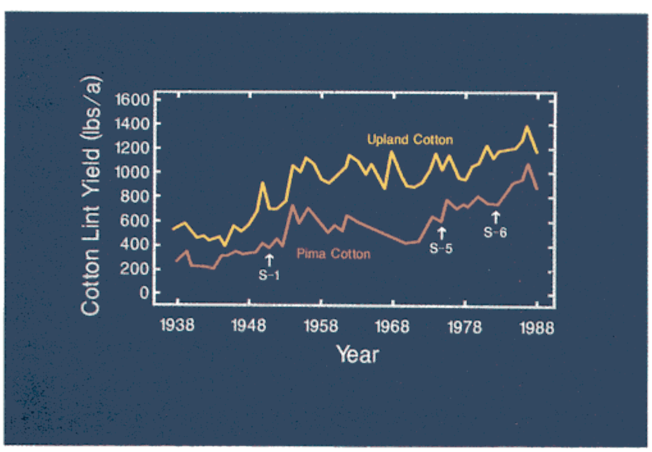

Figure 3.
State-wide average cotton lint yields for Upland and Pima cultivars in Arizona between 1938 and 1988. Arrows indicate the release of new Pima cotton varieties.

An increasing preference for fluid versus dry nitrogen fertilizers is shown in Figure 4. This reflects the greater convenience, flexibility and labor savings of fluid fertilizers over dry materials and in some cases, the lower unit cost of some fluid nitrogen sources. Prior to 1950, sodium + calcium nitrates and ammonium sulfate were preferred while today, urea is the dry nitrogen material most widely used in Arizona (Figure 5). Anhydrous ammonia (NH_3) has long been the most popular fluid

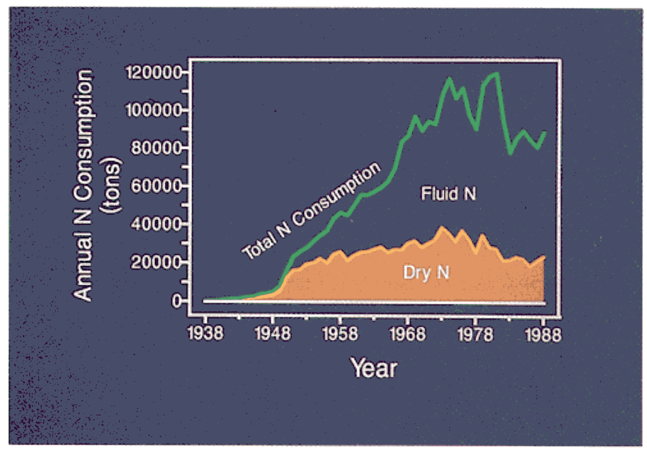

Figure 4.
Average annual consumption of dry and fluid nitrogen from commercial fertilizers in Arizona between 1983 and 1988.

nitrogen source primarily because of its low relative cost. However, anhydrous ammonia requires pressurized storage, transport and handling equipment. In addition, anhydrous ammonia is highly caustic and potentially hazardous and in some cases can lead to deterioration of soil and water quality with prolonged use. These factors have greatly curtailed the consumption of anhydrous ammonia since 1980. In its place, nonpressurized urea-ammonium nitrate solution (32% nitrogen) is now the most widely used fluid N material (Figure 6).

The rise in *total* annual nitrogen fertilizer use in Arizona since 1938 has been accompanied by a similar increase in the *average* amount of nitrogen applied per acre of harvested cropland (Figure 7). This increase may in part reflect subtle changes in cropping patterns and the need for more nitrogen to satisfy the greater nutrient requirements of newer,

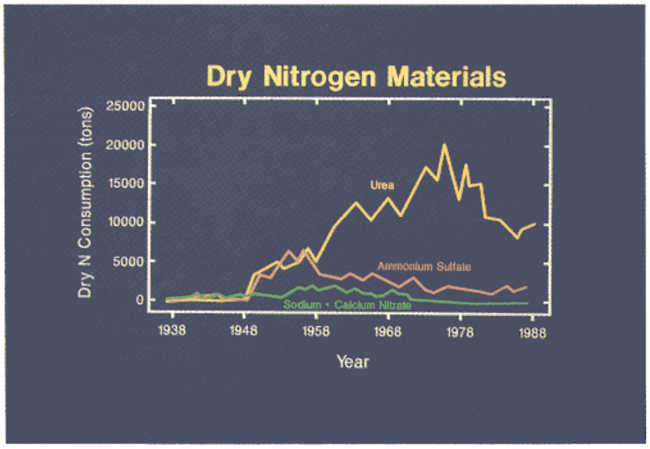

Figure 5.
Average annual consumption of nitrogen from selected dry fertilizer materials in Arizona between 1938 and 1988.

high yielding crop varieties. Arizona leads the nation in the productivity per acre for Upland cotton, spring wheat, barley and alfalfa. Nonetheless, the average nitrogen application rate in Arizona is also one of the highest in the nation, averaging 187 lbs./harvested acre during 1985-1988. Only Florida and California surpass this figure with average nitrogen rates of 418 and 227 lbs./acre respectively (Berry and Hargett, 1988 Fertilizer Summary Data. Tennessee Valley Authority). These two figures may be somewhat inflated due to multiple cropping which occurs each year in fields within these two states.

Nitrogen Fertilizer Use and Environmental Concerns

An approximation of overall nitrogen use efficiency in Arizona can be obtained by dividing the total annual production of harvested materials of the state by the total weight of nitrogen fertilizer applied during that year. This yields a Nitrogen Productivity Index which estimates the amount of harvested agricultural product resulting from each unit of nitrogen applied.

Since 1950 the Nitrogen Productivity Index has not changed dramatically but shows a slight shift downward (Figure 7). This trend plus the perception that much higher nitrogen rates are used in Arizona than in much of the country have fueled speculation that excessive amounts of nitrogen are sometimes being applied. This has caused concern about migration of unutilized nitrogen (usually in the nitrate, or NO_3 form) below the crop root zone and eventually into groundwater supplies. However, little is known about the extent of migration of nitrates into groundwater. Other nonpolluting losses for nitrates in soil also may occur and are discussed in Section II.

Monitoring of groundwater quality by several government agencies has found increasing problems with high nitrate levels in Arizona (personal communication, Carol Russell, Arizona Department of Environmental Quality). A recent compilation of water quality data revealed that 10.2% of the 6864 wells tested in Arizona exceeded

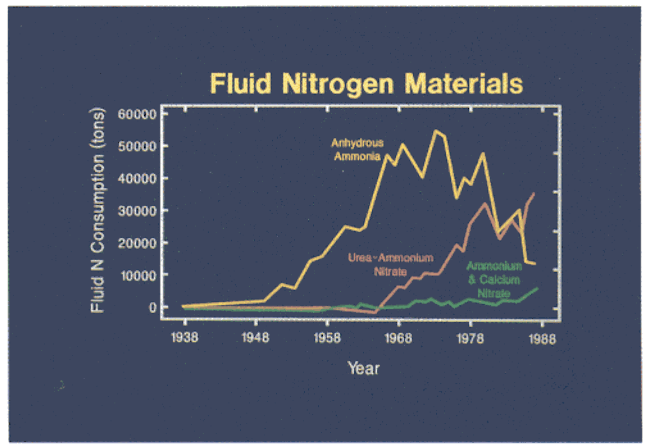

Figure 6.
Average annual consumption of nitrogen from selected fluid fertilizer materials in Arizona between 1938 and 1988.

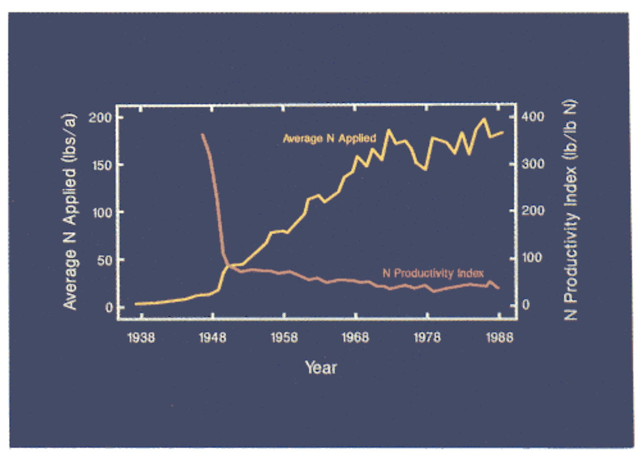

Figure 7.
Average annual application of nitrogen per harvested acre and an estimated Nitrogen Productivity Index in Arizona between 1938 and 1988.

the maximum recommended concentration of 10 milligrams per liter (mg/l) of nitrate-nitrogen (NO_3-N) in drinking water as set by the Environmental Protection Agency. This is equivalent to 45 mg/l of nitrate (NO_3).

The spatial distribution of the wells testing above the 10 mg/l standard does not present any clear association with human activities which may be responsible for these elevated nitrate levels. Intensive agricultural areas as well as locations with no agriculture at all have shown elevated nitrate concentrations in well water. Contributions of nitrates can come from multiple sources, including mineralized soil organic matter, geologic deposits, septic tanks, sewage treatment plants, concentrated animal operations and agricultural applications of nitrogen fertilizer. Elevated levels of nitrate in some Arizona wells prior to 1960 in predominately non-urban areas suggest that geological sources of nitrate can be locally important. It is likely that any nitrate contamination of groundwater that currently exists is related to several sources. The identification of specific contributions from individual sources is presently not possible.

The presence of excessive nitrate in drinking water is most serious for bottle fed infants less than six months old. Their immature digestive systems are not able to properly metabolize nitrate. Bacteria in their stomachs convert nitrate to nitrite which then reacts with hemoglobin to form methemoglobin. This condition is referred to as methemoglobinemia. This methemoglobin molecule, unlike hemoglobin, is unable to carry oxygen. As methemoglobin levels in the blood increase, symptoms of oxygen starvation begin to occur. Because oxygen starvation causes a bluish discoloration of the body, methemoglobinemia is commonly referred to as "blue baby" disease. This condition is potentially fatal but is also very easily treated if diagnosed.

The incidence of methemoglobinemia in Arizona is very difficult to determine. It is not one of the diseases which are routinely reported to public health agencies. To date, no confirmed cases of methemoglobinemia resulting from agricultural contamination have been reported in Arizona (personal communication, Norm Peterson, Epidemiologist, Arizona State Department of Health and Dr. Lynn Tausig, Department of Pediatrics, University Medical Center).

There is additional concern that elevated concentrations of nitrates in drinking water may increase the incidence of stomach cancer in adults. Nitrate can be converted to N-nitrosamines in the digestive system and these compounds have been identified as carcinogens.