Chapter 1

History, Growth, and Status

By Ronald D. Young and Norman L. Hargett

Liquid (fluid) fertilizer production and use is generally regarded as a relatively new (mid-20th century) practice, which is true if we are thinking of commercial significance. But like many other developments popularly regarded as new departures, the beginnings of liquid fertilizer go far back in history.

Early History

Possibly the earliest recorded use of a fertilizer material in liquid form, if we broaden the definition of fertilizer to include the manures, was the practice in ancient Athens of fertilizing truck gardens and orange groves by city sewage carried in canals. Various other mentions of liquid manure, and of other liquids used to promote plant growth, are found in ancient histories.

Much later, but still quite early in the history of fertilizer technology, Sir James Murray in 1843 referred to the “new” practice in England of supplying fertilizers in solid form. The new type, he said, was “exempt from loss by leakage, more safe, portable, etc.,” as compared with the previous liquid products, normally sold in 30-gallon casks. In the same year, Bishop in Scotland reported that aqua ammonia gave improved yields of grass. Subsequently, gas house liquors and other wastes were sold in liquid form.

One of the first references to use of a fertilizer in liquid form in the United States was by Joseph H. Webster, a “resident of Cumberland, in the County of Webster and State of Mississippi,” who in 1899 patented a solution “consisting of water, saltpeter, sal-soda, blue-stone, nitrate ammonia, and potash.” He did not use this solution directly as a fertilizer but sprinkled it over a mass of manure, “ashes, salt, lime, phosphate, kainit, and cotton-seed meats.” However, his proposal deserves some note because the solution specified bears some resemblance to the liquid mixes made today (1).

Early Commercial Production

Possibly the first U.S. plant for producing a liquid fertilizer was the G&M Liquid Fertilizer Company, built in Oakland, California, in 1923. This was followed by the work of the Prizer Brothers who in 1928-30 developed the “Prizer Applicator,” a machine for dissolving a solid fertilizer and metering the resulting solution into irrigation water through either a gravity-flow or pressure system (2).

Ammonia production began in this period in the United States. Plants were built in Syracuse, New York, in 1921 by a subsidiary of Allied Chemical Corporation; at Belle, West Virginia, in 1926 by E. I. du Pont de Nemours and Company; and at Hopewell, Virginia, in 1928 by Allied. With a domestic supply of ammonia available, the liquid fertilizer industry was in position to move forward at a faster rate. In 1932, Shell Chemical Company began research on introduction of ammonia into irrigation water and followed this by injection into the soil in 1942 (2). In about the same period, ammoniating solutions were developed for use in making solid fertilizers. For example, in 1932 du Pont first introduced urea-ammonia-water solution, composed of urea, ammonia, ammonium carbamate, and water. Such solutions, containing ammonia with urea or ammonium nitrate, were likely candidates for direct application, and the first application of a nitrogen solution took place on a cane field in Louisiana in 1942.

There were problems in handling and application of solutions that were under pressure and subject to emission of ammonia fumes. This led to research aimed at the development of nitrogen solutions without any vapor pressure of ammonia. In 1942, Allied Chemical Corporation
began testing a solution of urea and ammonium nitrate, materials that have such a mutual solubility effect as to allow nitrogen concentrations as high as 32%. This work was interrupted by the war and was resumed in 1950, when the first farm application took place. Prior to this, ammonium nitrate solutions were used in California as early as 1944.

Liquid mixed fertilizers, after the start in 1923, grew very slowly. The practice was of necessity based on dissolution of solid materials because little or no phosphoric acid was available. As late as 1943 less than 1,000 short tons of liquid mixed fertilizer was reported sold in California. The high cost of the raw materials restricted liquids mainly to special uses, such as foliar spraying, flower and garden fertilization, and correction of unusual soil deficiencies.

In 1937, Shell Chemical Company demonstrated the feasibility of adding phosphoric acid directly to irrigation water, and in 1940 the first commercial use of the method took place. Other pioneers in use of phosphoric acid were the John Pryor Company (Salinas, California) and the Hayward and Wood Company (Oxnard, California) (1).

In the 1940s, phosphoric acid—mainly the furnace type—became more available in California and production of liquid mixed fertilizers began to increase. The Leslie-Agriform Company, later to become a major producer of liquid mixes, started operation about 1946 in Newark, California. This company originally handled all its product in 15- and 30-gallon wooden barrels, and distributed solution as far as Phoenix, Arizona. The barrels were replaced a few years later with tanks of 1,000- to 2,000-gallon capacity. Corrosion was a severe problem and raw material costs were high. However, production by Agriform and others increased, to the point that by 1953 more than 22,000 tons of liquid mix was produced in California; this represented about 9% of all mixed fertilizer made in California.

In other areas of the country, Cominco Products, Inc., began making an 8-24-0 solution at Trail, B.C., in 1955. This was a new departure, because Cominco made the 8-24-0 from lower cost wet-process phosphoric acid (in conjunction with ammonium phosphate production), whereas the production in California was based on furnace-type acid. Much of the Cominco product was sold in Washington and Oregon.

In the middle and eastern parts of the United States, the only known production of liquid mixes prior to 1953 was in the form of specialty liquids made from soluble salts and usually packaged rather than sold in bulk. Startup of the Liquilizer Corporation plant at Vincennes, Indiana, in 1953 marked the beginning of the new practice—neutralization of phosphoric acid with ammonia and dissolution of potash in the resulting hot solution. The first grade made was a 4-10-10 but the next year ammoniating solution and solid urea were used to give such products as 9-9-9, 12-6-6, and 12-8-4 (1).

Two Dramatic Decades

The preceding discussion brings us to 1955, at which time both nitrogen liquids and liquid mixed (NPK) fertilizers were struggling industries. They were striving to break into an established, conservative industry with a drastically different product form. The need for a different marketing system and for providing additional services, including custom application, were already apparent. The early pioneers had both technical and economic problems, and some of the companies did not survive. In a few years, however, the liquid products began to gain acceptance and use increased rapidly. The rate of growth from 1955 to about 1975 was greater than for any fertilizer in any similar period in fertilizer history.

Probably because of the first publication on liquid mixed fertilizer production and use was published in 1955 (4). About 100 companies reportedly were operating in the field, but only 72 appeared to be making bulk fertilizer for farm use. Only 25 were reported east of the Rockies and most of these had gone into production in 1954-55, U.S. production in the year ended June 30, 1954, was only 27,500 tons. The dramatic growth in fluid mixed fertilizers during the period of 1954-75, both in number of producing units and in production of material, is shown in figure 1.

The approximately 1 million tons of liquid mixed fertilizers consumed in 1965 represented about 7% of the total mixed fertilizers consumed in the United States. Production for the approximately 1,200 fluid plants averaged less than

![Figure 1. Growth in production of fluid mixed fertilizers, U.S.](image)
1,000 tons per year. The next decade (1965-75) saw even more rapid growth in production and use of fluid mixed fertilizers. Suspension fertilizers, fluids in which some particles are suspended rather than dissolved, came into the picture after 1963 when TVA shipped the first tank car of 12-40-0 base suspension, offering considerably higher analysis than liquid (solution) fertilizers. Production of suspensions became substantial by the late 1960s and their production and use have grown steadily since. Suspensions contributed substantially to fluid production by 1970.

The number of mixed fluid plants in the United States grew from 1,200 in 1965 to about 2,800 in 1974. Total nutrient consumption as mixed fluids was only 143,000 tons (N + P₂O₅ + K₂O) in 1960. This increased sharply to 823,000 tons in 1970 and to about 1.3 million tons in 1975. Total nutrient content of mixed fluids (N + P₂O₅ + K₂O) was estimated to be about 28% in 1960. Growth of the higher analysis suspensions resulted in an increase to about 34% in 1974, and to about 35.2% total plant food content in 1981 (5).

Growth in number of plants slowed, but the total reached about 3,000 in 1976 and 3,200 in 1980. The total tonnage of mixed (NPK) fluids increased to about 1.8 million tons of nutrients (N + P₂O₅ + K₂O) in 1981. This represented about 5 million tons of fluid fertilizer materials. The 1.8 million tons of nutrients as mixed fluid fertilizers in 1981 accounted for about 7.5% of total nutrients applied in the United States, or 17% of total nutrients in mixed fertilizers.

T. P. Hignett in his Sixth Francis New Memorial Lecture in 1969 (6) gave a good assessment of the advantages for liquids.

Liquid fertilizers are dependably free-flowing. They are well adapted to handling and application by mechanized, labor-saving methods. Precise metering and placement and uniform distribution are easier with liquids than with solids. Liquids are homogeneous, free from dustiness or caking, and unaffected by hygroscopicity. They are fully water soluble. With liquids, there are no sacks to lift, open, and dispose of; there is little delay in refilling applicators. Liquid fertilization may be combined with irrigation or with application of herbicides or pesticides.

These advantages and others, coupled with the high analysis and lower cost of suspensions, have led to the development of a dynamic and progressive segment of the fertilizer industry (7).

History of Suspensions

The highlight of the decade of the 1970s for fluid fertilizers was the continuing vigorous growth in production and use of suspensions. Growth was continuing in 1982, but in fact, suspensions were the only type of fertilizer showing real growth into the 1980s. By 1981 almost half of the 3,200 fluid fertilizer plants in the United States produced suspensions that accounted for more than 40% of the fluid mixed fertilizer market.

In the late 1950s and early 1960s, there were substantial efforts to break through the grade (solubility) ceiling imposed by liquid (solution) fertilizers of good quality. A main effort was through fluids that contained a large part of their nutrient content as finely divided solids. In the early years such fertilizers were commonly referred to as slurries. Later the term suspension came into use for higher analysis fluids that were much more dependable in storage, handling, and application. It may be well here to differentiate the terms suspension and slurry.

Suspension fertilizers are fluid mixtures of solid and liquid materials in which the solids do not settle rapidly and can be redispersed readily with agitation to give a uniform mixture. Certain types of clay are added as suspending agents. The suspension is fluid enough to be pumped and applied to the soil in application equipment commonly available for liquid fertilizers with little alteration of the equipment.

Slurry fertilizers are fluid mixtures of solid and liquid materials in which the solids settle rapidly in the absence of agitation to form a firm layer which is difficult to resuspend. Continuous agitation is required to ensure a uniform mixture that can be pumped and applied to the soil. Commonly available application equipment usually needs some modification to handle this type of product successfully (1).

Beginning dates for suspension fertilizers are difficult to identify, for various innovators have experimented with suspensions from time to time and produced material for distribution. The use of base suspensions presumably began when TVA shipped the first car of 12-40-0 in January 1963. This pioneering work by TVA, and continuing research, development, and demonstration work with industry during the next two decades, led to suspensions reaching a status in the United States approaching that of clear liquids (solutions) by 1980.

There were many problems and false steps along the way, and some people became discouraged. But the clear-cut advantages of suspensions spurred researchers, technologists, and industry innovators to find ways to deal with the problems. Here are some important main advantages for suspensions.

- The practical limit in concentration is much higher than for clear liquids (solutions), particularly when potash is a component. Solubility is not a limiting factor. When the N:P₂O₅ :K₂O ratio is 1:1:1, the suspension grade (14-14-14) is twice that of clear liquids.
- Adequate proportions of secondary and micronutrients can be readily incorporated, as can pesticides, herbicides, etc.
Materials commonly used in formulating suspensions generally cost less and are more widely available than those required for clear liquids (8).

The growth of suspensions was spurred in the mid-1970s by the development of equipment and technique for readily incorporating solid intermediates such as mono-ammonium phosphate (MAP), diammonium phosphate (DAP), and nitrogen materials as major components in formulations (9). These solid intermediates were available in unlimited quantities and were substantially lower in cost than high-grade wet-process acid and polyphosphates required for high-analysis liquids (solutions) (10).

Suspensions are likely to continue to grow, and because of important advantages, may ultimately dominate the fluid segment of the U.S. industry. Slurries, on the other hand, have essentially disappeared from the market.

Highlights of Fluid History

Table 1 lists a chronology of the history, development, and growth of the fluid fertilizer industry. This listing is primarily for the United States, but developments of lesser scope occurred in France, Belgium, the United Kingdom, and a few other countries.

Role of Polyphosphates

Polyphosphates are the "backbone" of clear liquid (solution) fertilizers. Polyphosphates are formed by removing (or eliminating during production) chemically combined water from orthophosphate molecules (figure 2).

The building block for phosphates, based on modern theories of electronic structure, is the PO₄ tetrahedron—a phosphorus atom surrounded by four oxygen atoms at the four corners of a tetrahedron. Multiple units (polymers) of PO₄ tetrahedra joined by shared oxygen atoms between the tetrahedra are called condensed phosphates. The simplest condensed phosphate is the pyrophosphate formed by the sharing of oxygens between two PO₄ groups. Polyphosphates are linear chain polymers that may contain from two to hundreds of PO₄ groups. Branching probably occurs in chains of more than about 500 PO₄ groups.

Polyphosphates were reported in the literature as early as 1816 when Berzelius heated ordinary phosphoric acid and showed that the products were different from orthophosphoric acid. They were considered to be mixtures of pyro- and metaphosphates and the idea of triphosphate as a crystalline entity was not accepted until 1940. Proof of the existence of a homologous series of

![Figure 2. Diagram showing structural formation of polyphosphates](image)

Table 1. Chronology of fluid fertilizers

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 B.C.</td>
<td>Fertilization of truck gardens and orange groves in Athens by city sewage in canals.</td>
</tr>
<tr>
<td>1843</td>
<td>Sir James Murray referred to &quot;New&quot; practice of using solid fertilizers.</td>
</tr>
<tr>
<td>1899</td>
<td>First liquid fertilizer patent obtained in U.S.</td>
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<tr>
<td>1923</td>
<td>First liquid mixed fertilizer plant in California.</td>
</tr>
<tr>
<td>1942</td>
<td>Injection of anhydrous ammonia into soil introduced (now a major fertilization practice of lowest cost).</td>
</tr>
<tr>
<td>1953</td>
<td>First liquid fertilizer production by neutralizing phosphoric acid with ammonia and dissolving potash.</td>
</tr>
<tr>
<td>1955</td>
<td>147 liquid fertilizer plants in the U.S.</td>
</tr>
<tr>
<td>1956</td>
<td>Superphosphoric acid introduced by TVA (now the &quot;backbone&quot; of liquid fertilizer production).</td>
</tr>
<tr>
<td>1963</td>
<td>Suspension fertilizers emerge in higher analysis (grades such as 15-15-15 and 7-21-21 practical).</td>
</tr>
<tr>
<td>1966</td>
<td>TVA develops wet-process superphosphoric acid.</td>
</tr>
<tr>
<td>1967</td>
<td>About 1,500 liquid and suspension fertilizer plants in U.S.</td>
</tr>
<tr>
<td>1968-70</td>
<td>Fluids developing slowly in France, Belgium, and United Kingdom.</td>
</tr>
<tr>
<td>1972</td>
<td>TVA pipe reactor process for high-polyphosphate liquids introduced (also a boon to wet-process superphosphoric acid production and use).</td>
</tr>
<tr>
<td>1974</td>
<td>2,800 fluid fertilizer plants in U.S.</td>
</tr>
<tr>
<td>1975-76</td>
<td>Use of solid MAP, DAP, etc., spurs growth of suspensions.</td>
</tr>
<tr>
<td>1976</td>
<td>3,000 fluid plants in U.S.</td>
</tr>
<tr>
<td>1980</td>
<td>3,200 fluid plants in U.S.</td>
</tr>
<tr>
<td>1980</td>
<td>Fluids (including NH₃ and N solutions) = 32% of U.S. fertilizers.</td>
</tr>
<tr>
<td>1981</td>
<td>More than 2 million tons of UAN solution used in U.S.</td>
</tr>
<tr>
<td>1981</td>
<td>Suspensions reach 40% of total fluid mixed fertilizers.</td>
</tr>
</tbody>
</table>
chain phosphates (polyphosphates) came only after the
development of paper chromatography in the early 1950s.
The progressive removal of water from orthophosphoric
acid as shown in the diagram produces a series of poly-
phosphoric acids. The polyacids are obtained also when
P₂O₅ from burning of phosphorus is hydrated with water
short of the requirement for formation of orthophosphoric
acid.

Mixtures of orthophosphoric and polyphosphoric acids
are called superphosphoric acids (11).

Sequestration of Impurities

Sequestration of impurities in ammoniated wet-process
phosphoric acid is an important phenomenon in the tech-
nology of preparation of clear liquid (solution) fertilizers of
high quality. This is the process whereby polyphosphate
ions form stable, soluble complexes with metal ions and
hold them in solution. Ammonium polyphosphates are good
sequestering agents and are added to wet-process phosphoric
acid to hold in solution the iron and aluminum which
otherwise would precipitate as orthophosphates when the
wet-process acid is ammoniated. Ammonium pyrophos-
phates are more effective than the higher polyphosphates
in sequestering iron and aluminum in fertilizer solutions,
but the polyphosphates of longer chain length are better
sequestrants for calcium and magnesium.

The sequestering power of ammonium polyphosphates
also aids greatly in production of liquid fertilizers containing
significant amounts of copper, iron, manganese, and zinc.
These important micronutrient elements are almost
insoluble in liquid fertilizers made from ammonium ortho-
phosphates.

TVA has acquired most of its knowledge of ammonium
polyphosphates since the introduction of electric furnace
superphosphoric acid by TVA in 1955 (12).

TVA's pioneering research and development work on
ammonium polyphosphates soon led to 11-37-0 ammonium
polyphosphate solution (made by ammoniation of super-
phosphoric acid) that was provided to the industry for
use in formulating high-quality liquids and for sequestra-
tion of impurities in ammoniated products of wet-process
orthophosphoric acid.

TVA followed with the development of much more
economical wet-process superphosphoric acid in pilot-
plant work in 1961 (13). The industry followed in the
mid-1960s with preparation of this acid by concentrating
wet-process acid to 68% to 72% P₂O₅ content (14).

The real boost for wet-process acid-based polyphosphates
came about 10 years later in 1974 with development by
TVA of the simple pipe reactor and process for preparation of
10-34-0 ammonium polyphosphate solution (15).
Ammoniation of wet-process superphosphoric acid of only
68% to 70% P₂O₅ content (20% to 30% of P₂O₅ as poly-
phosphate) in the pipe produces a melt of high polyphos-
phate content that is dissolved in water and ammoniated
further to produce 10-34-0 with 60% to 75% of the P₂O₅
as polyphosphate.

The simple energy-conserving TVA pipe-reactor process
caught on like wildfire in the industry. By 1980 at least
130 commercial plants were using this "revolutionizing"
process (16). The pipe-reactor process also revolutionized
the production of wet-process superphosphoric acid by
industry, since acid of only 68% to 69% P₂O₅ content is
needed. This acid can be readily produced in a single-stage
stainless steel evaporator that requires only steam for
heating. The much lower viscosity of this "low-conversion"
superphosphoric acid also greatly simplifies its shipment
and handling. It became a commodity in world trade by
1979 (17).

Higher Solubility With Polyphosphates

The polyphosphate system provides greater
solubility, and higher grades can be produced as liquid
(solution) fertilizers. In the orthophosphate system,
maximum solubility at 32°F is 39% total nutrient content
(N + P₂O₅). With about half of the P₂O₅ in polyphosphate
form, the maximum solubility increases substantially to
46% total nutrients (N + P₂O₅). Wet-process superphos-
phoric acid is widely used to produce 10-34-0 ammonium
polyphosphate solution (60% polyphosphate) that is a
major commercial intermediate in production of finished
liquid (solution) fertilizers. Two-component fertilizers with
grades such as 18-18-0, 24-8-0, and 22-11-0 can be produced
using 10-34-0. Lower solubility in the orthophosphate
system limits N:P₂O₅ grades to 14-14-0, 18-6-0, and
18-9-0. When NPK grades are produced the polyphosphate
system offers no grade advantage because solubility of KCl
is limiting; the grade for a 1:1:1 ratio is 8-8-8 in either
system.

Role of National Fertilizer
Solutions Association

The National Fertilizer Solutions Association (NFSA) is
the main trade association for the fluid fertilizer industry,
with member companies in the United States and 14 other
countries. It is dedicated to advancement of all aspects of
fluid fertilizers. This very active organization was established
in 1954—early in the history of the fluid industry, when
there were less than 100 plants that produced mixed fluid
fertilizers. Membership grew to about 1,700 companies in
1983, but NFSA remains fully as dynamic as during its
formative years.

With headquarters in Peoria, Illinois, NFSA provides a
range of services to members. These include assisting with
the transfer of technology and information concerning the
production, marketing, application, economics, and agronomic aspects of fluid fertilizers. They also coordinate with other organizations, including governmental regulatory agencies and universities.

A general meeting each year is attended by more than 3,000, and the annual fluid fertilizer “Round-Up” draws large attendance and is a forum for timely technical presentations. NFSA publishes a bimonthly technical journal, Solutions, the leading journal of the fluid fertilizer industry. They also publish and update handbooks from time to time. The NFSA Foundation was established in 1982 to promote and assist in funding research vital to the industry. The Tennessee Valley Authority (TVA) and NFSA have worked actively together for more than 25 years in promoting the fluid fertilizer industry through technology transfer and other cooperative efforts.

Fluid Fertilizers in Other Countries

Fluid fertilizers also have found substantial use in France, Belgium, England, Mexico, Colombia, the U.S.S.R., and to a lesser extent in other countries.

In the United Kingdom, clear liquid mixtures have been used for several years with excellent results; commercial production of suspensions started in England in 1978. Since about 1970 liquids have been used extensively in France. Ammonium polyphosphate solution of grade 10-34-0 is produced from wet-process superphosphoric acid using TVA pipe-reactor technology. Test marketing of suspensions was underway in Belgium and the Netherlands in 1978. Fluids are expected to become popular in those countries. Other reports show that small amounts of fluids have been used in Spain, Sweden, China, India, and Japan (18).

The Soviet Union has conducted research on polyphosphates and liquid fertilizers since the late 1960s, and there is some production and use of NPK grades. There is substantial use of anhydrous ammonia and urea-ammonium nitrate (UAN) solution. There also is some activity with fluids in Czechoslovakia and Hungary. The Soviet Union started massive imports of wet-process superphosphoric acid from Florida in 1970 for general use in fertilizer production. The more concentrated superphosphoric acid (70% vs 54% P₂O₅) is imported mainly to save on shipping costs; substantial amounts are used in production of fluid fertilizers.

Solutions, in a 1980 account of the export of fluid fertilizer manufacturing and application equipment, shows U.S. firms marketing to a surprisingly large number of countries. Deliveries to the United Kingdom, Mexico, Netherlands, France, Belgium, Australia, South Africa, Spain, Malaysia, Colombia, Jamaica, Nicaragua, Venezuela, and the U.S.S.R. were reported. One manufacturer reported dealings with 23 countries.

Pulgrave (20) has published an interesting account of the history of fluid fertilizer production and use in the United Kingdom.

Fluid fertilizers are not expected to reach the status in other countries that they have in the United States. The primary driving forces—convenience in handling and application and savings in farm labor—are not as important in other countries. Farms are smaller and dispersed, thus not very adaptable to high rates of custom application. In many countries there still is incentive for increased use of low-cost farm labor.

Development of Application Equipment

Fluid fertilizers were not only new from the standpoint of chemistry, physical form, and production equipment, but also required new types of application equipment. This was a major problem to early producers, along with their many other problems. Weed sprayers were adapted in some instances, but they were not entirely suitable. It was necessary to develop new types of equipment, first by the producers themselves to use in custom application (since the farmers usually had no suitable equipment) and later by farm machinery companies.

Early equipment was homemade or adapted. In one of the early types, a slit cut by hacksaw in a pipe provided a nozzle that effectively broadcast the solution, in about the same manner as the flooding nozzles used today (1).

With these makeshift but effective beginnings, design of application equipment has progressed until today there is a wide range of types available. There are gravity-flow types for use in planting, hose pumps, many varieties of nozzle types, special types for suspension application, and several others. Many farmers now have their own equipment, although custom application is still the major practice of the industry (21).

The modern “high-flotation” applicator vehicles, with huge rubber tires, can operate early on frozen or wet fields. When equipped with an 85-foot boom they apply fluid fertilizers at rates as high as 2.5 acres per minute (22, 23). (The development of application equipment and techniques is covered in depth in chapter 9.)

STATUS OF FLUID FERTILIZERS (EARLY 1980s)

Fluids—A Growth Market

Use of fertilizer in the United States has increased spectacularly in the past 20 years. In 1981 plant nutrient use (N + P₂O₅ + K₂O) totaled 23.5 million short tons—compared with only 7.5 million tons in 1960 (table 2). Nutrient use doubled from 1960 to 1970 and tripled from
Table 2. Selected data on U. S. fertilizer use

<table>
<thead>
<tr>
<th>Year</th>
<th>Total nutrients</th>
<th>Fluid nutrients</th>
<th>Fluid mixtures</th>
<th>Total fertilizers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% total</td>
<td>Mixtures</td>
<td>Materials (mainly N solutions)</td>
<td>Total</td>
</tr>
<tr>
<td>1960</td>
<td>7,464</td>
<td>143</td>
<td>327</td>
<td>470</td>
</tr>
<tr>
<td>1970</td>
<td>16,068</td>
<td>823</td>
<td>1,150</td>
<td>1,973</td>
</tr>
<tr>
<td>1980</td>
<td>23,083</td>
<td>1,613</td>
<td>2,188</td>
<td>3,801</td>
</tr>
<tr>
<td>1981</td>
<td>23,451</td>
<td>1,767</td>
<td>2,329</td>
<td>4,096</td>
</tr>
</tbody>
</table>

Average annual growth rates for fertilizer nutrients (23)

<table>
<thead>
<tr>
<th>Year</th>
<th>% total nutrients</th>
<th>% fluid Mixtures</th>
<th>Materials</th>
<th>Total</th>
<th>% anhydrous ammonia Mixtures</th>
<th>Materials</th>
</tr>
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<tbody>
<tr>
<td>1960-70</td>
<td>8.0</td>
<td>19.1</td>
<td>13.4</td>
<td>15.4</td>
<td>17.2</td>
<td>4.6</td>
</tr>
<tr>
<td>1960-80</td>
<td>5.8</td>
<td>12.9</td>
<td>10.0</td>
<td>11.0</td>
<td>10.8</td>
<td>2.9</td>
</tr>
<tr>
<td>1970-80</td>
<td>3.7</td>
<td>7.0</td>
<td>6.6</td>
<td>6.8</td>
<td>4.7</td>
<td>1.3</td>
</tr>
<tr>
<td>1980-81</td>
<td>1.6</td>
<td>8.8</td>
<td>6.9</td>
<td>7.7</td>
<td>2.4</td>
<td>-0.1</td>
</tr>
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Number and average production of fluid mix plants

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated number of plants</th>
<th>Average throughput</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Liquids</td>
<td>Suspensions</td>
</tr>
<tr>
<td>1960</td>
<td>390</td>
<td>-</td>
</tr>
<tr>
<td>1970</td>
<td>2,751</td>
<td>-</td>
</tr>
<tr>
<td>1974</td>
<td>2,800</td>
<td>3,433</td>
</tr>
<tr>
<td>1976</td>
<td>3,000</td>
<td>2,606</td>
</tr>
<tr>
<td>1980</td>
<td>3,200</td>
<td>3,840</td>
</tr>
</tbody>
</table>

1960 to 1981. In 1981 fluid nutrient use (mixtures plus nitrogen solutions) totaled 4.1 million tons, more than doubling since 1970 and increasing from 6.3% to 17.5% of the total nutrient use since 1960. Fluid mixtures (NPK) use in 1981 totaled 1.8 million tons of nutrients—about 17% of total mixed fertilizers or 7.5% of total nutrients used.

The proportion of total fertilizer nutrients applied in fluid form increases greatly if anhydrous ammonia is included. The 4.6 million tons of nitrogen applied as anhydrous ammonia in 1981 increases total fluid nutrients to 8.1 million tons—34.5% of the total nutrients applied in the United States. Fluid fertilizer use has grown nearly twice as fast as total fertilizer use, averaging more than 15% per year increase between 1960 and 1970, and an 11% increase between 1960 and 1980. A large part of this increase occurred during the introductory stages of the new product form and was aided by rapid advances in technology. Although the growth rate has slowed—6.8% per year during 1970-80 and 7.7% from 1980-81—fluid fertilizer use is still increasing faster than total fertilizer use (table 2). In this table, fluid fertilizers include liquids and suspensions as either NPK mixtures or materials (28-0-0, 32-0-0, 10-34-0, etc.). Anhydrous ammonia is not included as a fluid material and is reported separately.

Nutrient use as mixed fluid fertilizers grew almost 13% per year from 1960 to 1980. The average nutrient content of mixed fluids also increased substantially. In 1981 fluid mixtures averaged 9.0-16.0-10.2, a total nutrient content of 35.2% compared with the estimated average of 28% for fluids in 1960. The increased use of suspension fertilizers has been responsible for the rapid rise in the analysis of fluid mixtures in the past few years. The average nutrient content for all U.S. mixed fertilizers in 1981 was 43.8%. Since their introduction in the late 1960s, suspensions have gained rapidly in market share. They moved from 25% of the mixed fluids market in 1974, to 33% in 1976, and to more than 40% in 1981.

Ten States—Iowa, Illinois, Nebraska, California, Texas, Indiana, Kansas, Ohio, Minnesota, and Georgia—account for 65% of the U.S. fluid fertilizer market. In these States, about 21% of the fluids used is applied as mixtures. Anhydrous ammonia consumed in these 10 States amounted to 75% of the total consumed in the United States (25).
Fluid Dealer Characteristics

Statistics compiled by TVA’s National Fertilizer Development Center (NFDC) and the Association of American Plant Food Control Officials (AAPFCO) show the dramatic growth in the number of fluid mixed fertilizer plants from 1960 to 1980. Results (table 2) indicate that those plants having only liquid mix facilities have an average annual throughput of 3,840 tons, Comparable average throughput for suspension plants is 3,604 tons (5).

A typical fluid mix plant is difficult to characterize. It may distribute liquid and/or suspension mixtures, anhydrous ammonia, nitrogen solutions, liquid, and dry direct application materials. A frequency distribution of all fluid plants indicates the greatest number of plants in the 1,000- to 3,000-ton-per-year range. The mode—1,245 tons—is the value occurring with greatest frequency, and the median—2,067—represents the middle value for all fluid mix plants.

Ownership data relating to all fluid fertilizer plants show that 13% of these plants are sole proprietorships, 7% partnerships, 64% corporations, and 16% cooperatives (24).

Prospects for Future Growth

As the fertilizer market becomes more mature, consumption growth rates will tend to be lower than in the past. Total plant nutrient consumption in the United States is expected to grow at just over 3% per year through 1985, with total use reaching 26.5 to 27.0 million tons. Fluid fertilizers have been projected to increase by 4.5% per year reaching a total of 4.7 million tons—18% of total plant nutrient consumption in the United States. These projected growth rates are less than those of the 1970s. However, they represent a significant gain in the total amount of fluid fertilizers used.

Development of the suspension segment of the fluid fertilizer industry, which can use lower cost materials such as solid MAP or DAP and TVA base suspensions 13-38-0 and 9-32-0, has helped make fluids cost competitive with dry mixtures. This, plus the demonstrated advantages for fluids, gave rise to a sharp increase in use of suspensions in the late 1970s. There will be an increased use of lower cost solids to produce suspensions along with further improvements in suspension application equipment for row or starter fertilizer application. The narrowing of the retail price gap between fluids and dry fertilizers coupled with advantages to the farmer, such as overall convenience, relieving critical labor constraints, and better uses of limited investment capital, suggest that use of fluids will continue to grow more rapidly than the total market.

Growth of suspensions will continue higher than for clear liquid (solutions) mixtures because of their lower cost, and the increasing impurities content of wet-process acid that will make production of high-grade clear liquids more difficult and expensive.

Advantages of fluid fertilizers, including the lower investment for production facilities, ease of preparation and incorporation of additives, convenience of handling, and high reliability of fluid application systems will contribute to the continued strong growth of fluid fertilizers in the U.S. market. Growth will continue in several other countries, but fluids will not approach the status of practice by this dynamic segment of the industry in the United States.

References

24. Consumption of Commercial Fertilizers in the United States, Annual Reports; and Consumption of Fertilizers by Class, Annual Reports; Economics, Statistics, and Cooperative Service; Crop Reporting Board, USDA, Washington, D.C.