# FERTILIZER USE IN WESTERN EUROPE: TYPES AND AMOUNTS

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**Keywords:** fertilizer use in Western Europe, types, amounts, consumption, crops, fertilizer industry

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## Summary

The modern mineral fertilizer industry was founded in the nineteenth and early twentieth century. The supply of natural sources of plant nutrients which had been used hitherto was becoming inadequate in the face of a growing world population and industrialization. The production of single superphosphate on an industrial scale began in England in 1843. The first potash mine was opened, in Germany, in 1862. The industrial manufacture of ammonia began, using an electric arc process, in Norway in 1905 but the main innovation was the Haber-Bosch process, the first plant coming into operation in Germany in 1913. The average cereal yields in West Europe increased gradually from 1000 kg $ha^{-1}$ to 1600 kg $ha^{-1}$ in the 100 years prior to the early 1950s.

Then progress in plant breeding permitted a substantial increase in cereal yields from varieties whose expression required increasing quantities of nitrogen, supported by the other plant nutrients. Today the average wheat yield in France, for example, is over 7000 kg $ha^{-1}$. Fertilizer consumption in West Europe increased rapidly until peaks in the mid 1970s in the case of phosphate and potash, nitrogen continuing to increase until the mid 1980s. Subsequently fertilizer consumption has declined steadily, as a result of progress in farming techniques and a more efficient use of organic manures.

In Western Europe, about three quarters of the nitrogen applied is in the form of 'straight' fertilizers i.e. fertilizers containing only one major plant nutrient, whereas at least 70% of the potash and 86% of the phosphate is applied in the from of multi-

nutrient fertilizers. This is explained by the use of nitrogen fertilizers on grassland and as a top-dressing on cereals.

The preferred single nutrient nitrogen fertilizers in Western Europe are ammonium nitrate and calcium ammonium nitrate, together accounting for over 40% of total nitrogen. Solid urea and urea ammonium nitrate solutions account for about a quarter.

The trend towards a gradual decline in fertilizer consumption in Western Europe is expected to continue at least until 2006. By 2010 it is anticipated that nitrogen use will have fallen by 20%, phosphate by 50% and potash by 40% from their peaks between the mid 1970s and mid 1980s.

## 1. Introduction

Until the eighteenth century, a poor harvest in Western Europe was likely to result in famine, particularly for the poor, and in disease due to weakened resistance. It was difficult to feed an increasing population. Plant nutrients were provided largely from animal manure but its supply was limited by the number of livestock. In any case nothing was added if the nutrients were just recycled and the inevitable losses not replaced. Farmers had to leave one third, or, on poor soils, as much as half of the land in fallow each year in order to reconstitute its fertility. Substantial areas of land, often marginal, were brought into cultivation. Forests were felled.

To take France as an example, the last major famine occurred in the early 1700s although "food crises", when cereal prices increased by 50% to 150%, continued to occur from time to time until the mid 1880s. The crises of 1788/1789 and 1846/1847 both preceded popular revolt. The crises then became less frequent due to a slow increase in agricultural productivity, relatively good climatic conditions and improved communications which permitted more efficient internal distribution of food and made grain available from other regions of the world, particularly America.

However, by the end of the nineteenth century scientists were becoming increasingly concerned about the adequacy of food supplies, in particular due to the dependence for nitrogen supplies on increasingly scarce natural sources.

## 2. Crops

| Year | Wheat yield (kg/ha) | Fertilizer consumption (in Mt total nutrients) |
|---|---|---|
| 1850 | 1000 | Negligible |
| 1950 | 1600 | 1.2 |
| 1973 | 3500 | 6.0 |
| 2000 | 7104 | 4.7 |

Table 1. Wheat yields and fertilizer consumption in France

In 1850, the average wheat yield in France was 1000 kg $ha^{-1}$, with virtually no consumption of mineral fertilizers. Between 1850 and 1950, there was continual

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progress in manufacturing techniques. Fraud became a problem and regulations were imposed and methods of fertilizer analysis were standardized. Methods of soil analysis were developed and advisory systems were instituted. By 1950 the average wheat yield was 1600 kg $ha^{-1}$, fertilizer consumption 1.15 million metric tones (Mt). All the major fertilizer producers had research and development services, thus giving a substantial impetus to the development of fertilizer use.

Average wheat yields in France developed as shown in Table 1.

The figures illustrate remarkable improvement in the efficiency of fertilizer use in recent years, with higher yields produced using a smaller quantity of fertilizers. Improved crop varieties and management practices are no doubt important factors.

In the early 1950s, after having risen from 1000 kg $ha^{-1}$ to 1600 kg $ha^{-1}$ in 100 years, cereal yields began to increase sharply. A problem had been that at the optimum rates of N at the time (78 kg nitrogen $ha^{-1}$), the cereal varieties that were available tended to lodge (lay flat). In practice about half the optimum amount of nitrogen was used. However, with the availability of more efficient combine harvesters, grain-drying facilities, new varieties with shorter straw and higher yield potential and the increasing use of fungicides and pesticides, cereals responded to more nitrogen and its use increased appreciably from1950 onwards (See Table 2).

| Country | Kg/ha Arable Land in 1936 | | | Kg/ha Agricultural Land* in 1996 | | |
|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| France | 6 | 19 | 10 | 95 | 40 | 56 |
| Germany | 25 | 32 | 50 | 110 | 26 | 40 |
| Netherlands | 68 | 103 | 100 | 191 | 32 | 37 |
| UK | 10 | 28 | 10 | 125 | 36 | 45 |

* Including fertilized grassland

Table 2. Average rates of fertilizer use

At the turn of the nineteenth century, phosphate was often the most limiting nutrient in Western Europe but an analysis, made in the UK in the 1940s, of the results of field trials since 1900, showed that cereal crops were no longer responding to fresh applications of phosphate and potash. Soils had become progressively enriched with these nutrients.

| Country | Nutrient ratio in 1936 | | | Nutrient ratio in 1998/99 | | |
|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| France | 1 | 1.8 | 1.0 | 1 | 0.41 | 0.53 |
| Germany | 1 | 1.3 | 2.0 | 1 | 0.21 | 0.33 |
| Italy | | | | 1 | 0.57 | 0.48 |
| Netherlands | 1 | 1.5 | 1.5 | 1 | 0.16 | 0.21 |
| UK | 1 | 2.8 | 1.1 | 1 | 0.29 | 0.37 |

Table 3. Nutrient ratios

Today the differences in the ratio of nutrients (N:P or N:K) between countries, are due not only to differences in the crops grown but also to the use of nutrients of animal

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origin, which are amply available in Belgium, the Netherlands and Denmark and certain areas of France and Germany (see Table 3).

There are also large variations between different European countries in the average application rates on individual crops, in view of the diversity of climatic conditions. To take nitrogen as an example, in the case of wheat it varies from 80 to 185 kg N $ha^{-1}$ according to the country, with an overall average of 139 kg $ha^{-1}$. For grain maize, the variation is even greater, with rates going from 45 to 230 kg $ha^{-1}$ depending on whether the crop is irrigated, with a high yield potential, is rain-fed, and whether it sometimes receives livestock effluents. Nitrogen fertilization of grass varies from 15 to 265 kg $ha^{-1}$ depending on the country, being fertilized more heavily in areas where climatic conditions are favorable. The crops with the least variation are those which receive little fertilization, such as sunflower, or perennial crops, including vines.

## 3. Fertilizers and Their Types

### 3.1. Nitrogen

The first nitrogen fertilizer to be commercialized in Europe was sodium nitrate, mined from natural deposits in Chile and imported into Europe and America from about 1830 onwards. Next came ammonium sulfate. This was initially obtained as a by-product of the coke industry, which was developed to provide gas for street lighting and to serve the expanding steel industry in Europe and America in the nineteenth century.

By 1900, it was apparent that, without a technology for fixing nitrogen from the atmosphere, food supplies would be insufficient for the growing populations of the industrialized countries. By 1905, the idea of passing air through an electric arc was successfully developed in Norway to produce nitric acid and calcium nitrate. About the same time, calcium cyanamide was produced by reacting lime and coke in an electric furnace. However, both these processes were soon outdated by the discovery of a technology to synthesize ammonia from atmospheric nitrogen and hydrocarbons. This was to revolutionize the nitrogen fertilizer industry. The first commercial plant using this process began to operate in Germany in 1913.

Initially, fertilizers took only a minor share of this new source of fixed nitrogen, because it was quite costly and there were higher-value industrial uses. But the age-old agricultural dependence on organic manures and the relatively rare sources of mineral nitrogen compounds had been broken.

The early nitrogen fertilizers—mainly ammonium sulfate, calcium cyanamide and calcium nitrate—contained what, by modern standards, were relatively low concentrations of N, in the range of 15 to 21%. The next step was to produce more concentrated products. However, it was not until the 1940s that ammonium nitrate, with about 34% N, and calcium ammonium nitrate, with around 27% N, became important fertilizers. By the 1960s these had become the leading nitrogen fertilizers.

Today, the world's cheapest and most commonly used nitrogen fertilizer is urea. Containing 46% N, it is more economic to transport over large distances than less

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concentrated materials. It is produced by reacting ammonia and carbon dioxide, thus making use of the large amounts of by-product carbon dioxide produced by ammonia plants. Consequently, urea plants are always located together with ammonia plants. However, in Europe ammonium nitrate and calcium ammonium nitrate remain the predominant nitrogen fertilizer for both agronomic and historical reasons.
The main nitrogen fertilizers used in West European agriculture are shown in Table 4.

| | **Mass of N used** (x1000 tonnes) | **% of straights** | **% of total** |
|---|---|---|---|
| **Product** | | | |
| Ammonium sulfate | 228.6 | 3.1 | 2.3 |
| Urea | 1356.2 | 18.5 | 13.5 |
| Ammonium nitrate* | 4292.9 | 58.5 | 42.7 |
| Ammonia, direct application | 53.8 | 0.7 | 0.5 |
| Nitrogen solutions | 1107.8 | 15.1 | 11 |
| Other straight nitrogen | 300.0 | 4.1 | 3 |
| **Total straight nitrogen** | **7339.3** | **100** | **73** |
| **Compounds** | | | |
| Ammonium phosphate | 159.0 | | 1.6 |
| Other NP** | 309.7 | | 3.1 |
| NPK | 2250.6 | | 22.4 |
| **Total compound nitrogen** | **2719.3** | | **27.0** |
| **Total nitrogen** | **10058.6** | | **100** |

* Ammonium nitrate and calcium ammonium nitrate

** In principle nitrophosphates but may include other NP products. Nitrophosphates are produced by reacting phosphate rock with nitric acid, instead of sulfuric acid.

Table 4. Nitrogen fertilizers use in western European agriculture, 1998/99

'Straights' are single nutrient fertilizers containing just one major nutrient. Compounds are multi-nutrient fertilizers containing more than one major nutrient.

Calcium ammonium nitrate (CAN), a mixture of ammonium nitrate and calcium/magnesium carbonate, is the main source of straight N in Western Europe. Its N concentration ranges from 25% to 28% and it contains, in addition, about 10% calcium (Ca). The lime content of CAN helps to neutralize soil acidity. Ammonium nitrate (AN) is more concentrated (33.5% to 34.5% N) and is most commonly used in France, the UK, Spain and Italy. The use of ammonium nitrate is restricted in certain countries.

Urea is the most concentrated solid nitrogen fertilizer available (46% N) but ammonia volatilization from the product is possible following application, unless it is incorporated into the soil after application. Urea ammonium nitrate solutions (UAN), which contain 28% to 32% N, are used where distribution and application techniques suit liquid fertilizer use, for example on large arable farms in France, Germany and the UK, but the use of liquids is much less prevalent than in the USA. Since 1973/1974 there has been a substantial increase in the consumption of urea and UAN (urea ammonium nitrate solutions) in Western Europe, but in 1988/1989 together they still accounted for only a fifth of total nitrogen consumption.

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**Biographical Sketch**

**K.F. Isherwood** was head, now retired, of the information service of the International Fertilizer Industry Association, IFA, located in Paris France. He started his career as an agronomist in Africa, followed by several years in the plant protection industry, joining IFA in 1969. He is the author of numerous papers concerning all aspects of the mineral fertilizer industry. He was instrumental in the preparation of a series of publications on the environmental aspects of fertilizer production, distribution and use, in co-operation with the United Nations Environment Programme, UNEP. He worked on fertilizer questions also in co-operation with the U.N. Food and Agriculture Organization, the FAO. He has a particular interest in fertilizer statistics and their interpretation and was member of the FAO/Fertilizer Industry Working Party on Fertilizer Statistics. He has academic qualifications in temperate and tropical agriculture and agricultural economics.

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