The history of fertilizers: Part 1

The emergence of mineral fertilizers

In the first of a six part series Michael Freeman offers an in-depth account of the origins of mineral fertilizer supply.

In the introduction to his 1757 book on The Principles of Agriculture and Vegetation, which had been commissioned by the Edinburgh Society for the Improvement of Arts and Manufactures, Dr Francis Home observed that agriculture in Europe was little better understood in his day than it had been in the time of Virgil and Columella.

A generation before Dr Home's work, the Berkshire landowner Jethro Tull published his book on Horse Hoeing Husbandry in which he grappled with the following question: "The chief art of the husbandman is to feed plants to their best advantage; but how shall he do that unless he knows what is their food?" Tull considered the possible contributions of nitre and of the four classical elements - water, air, fire and earth. He rejected nitre (sodium nitrate) because in his view it had a toxic effect when applied to the roots of plants, commenting that "nitre is as much the food of plants as white arsenic is the food of rats." He concluded that earth is "surely the food of all plants". In his view the only value of dung, or of compost, was that after application it fermented in the earth, breaking it up so that it became easier for plant to assimilate the soil. This could be achieved more efficiently by tillage, i.e. hoeing with horses, making the use of manure unnecessary.

Dr Home attempted to carry out a more scientific investigation of soil samples, but was hindered by the limitations of analytical chemistry in the middle of the 18th century. He also carried out primitive pot trials on barley using different additives that might be expected to influence plant growth, while noting that there is always a danger of some mistake in reasoning based on single experiments. Despite his efforts to harness contemporary science for this research, he remained attached to the idea that the four classical elements plus oil and salt were responsible for crop nourishment.

Crop rotation

Dr Home's sweeping statement, from his standpoint in the mid-18th century, about the absence of progress in agriculture over the centuries did not take account of the changes in crop rotation that had taken place. Two-course rotation had been replaced in the early Middle Ages by the three-course rotation system with two cultivated fields and one fallow field. Farmers in the Low Countries, who needed to improve harvests obtained from their poor quality sandy soils, extended the rotation cycle to four or more, and incorporated roots crops, such as turnips, and legumes into the planting programme, while paying greater attention to manuring. The good results obtained from extended rotation caught the attention of foreign observers, among whom was Sir Richard Weston, who travelled to Flanders in 1644 to study new farming methods, which he described in his "Discourse on the Husbandry of Brabant and Flanders". It is not known whether Sir Richard introduced the new system on his Surrey estate before he died in 1652, but in any case four-course rotation with turnips was better suited to the light soils of Norfolk. It was here that the 2nd Viscount Townsend farmed his Raynham estate where, in the 1730s, he introduced four-course rotation on newly-enclosed farmland where sheep were kept. His enthusiasm for turnips as feed for the sheep earned him the lasting soubriquet of "Turnip Townsend". Other landowners followed his example, including Thomas Coke, Earl of Leicester, who had inherited a big Norfolk farming estate in 1776 at Holkham. Arthur Young, another landowner in eastern England around this time, was less successful in the introduction of improvements at his properties, but he was a diligent and perceptive writer on the state of agriculture in Britain and, notably, in France, where he travelled extensively in the years before the Revolution. These men were examples of the custom among the larger English landowners to live on their estates and to study agricultural improvements that they could implement, which included the controversial practice of land enclosure.

In his book "Horse Hoeing Husbandry" Jethro Tull looked at how to feed plants to their best advantage'

The second half of the 19th century saw a marked improvement in yields

This was also happening in other northwest European countries although, as Arthur Young noted, France lagged considerably behind its neighbours. The output of cereals and other arable crops certainly increased in Europe during the period 1700-1850, but it is not possible to find reliable statistics to illustrate this trend.

However, in most places the growth was the result of expansion of the area being farmed due to the consolidation of land ownership and the elimination of unproductive fallow land, the latter also resulting in the introduction of a broader range of crops for cultivation. In this period, average wheat yields were around 1t/ha in NW Europe but only around two-thirds of this level in France, Spain and Italy. By the second half of the 19th century there was a marked improvement in yields across Europe and in North America, as farmers began to acquire the knowledge to satisfy the nutrient needs of the crops they were growing.

Population growth

The need to produce more food crops was driven by the change in the rate of growth of the world's population. During the last millennium (1000-

The biggest component of population growth total was, and still is, in Asia

1999), the trend of population plotted with UN estimated data takes the form of a familiar J-curve, in which there is straight-line growth of roughly 50 mn per century in each of the first seven centuries, as the Four Horsemen of the Apocalypse did their effective job of preventing the exponential growth that would normally take place in population without constraints. The change started to become evident in the 18th century when the world total grew by 400 mn, reaching 1 bn in 1804. The corresponding increase in the 19th century was 670 mn, according to the UN's estimates, and of course the world population increase in the 20th century was several times greater than this. The biggest component of the total, then as now, was the population of Asia, which was followed by that of Europe which represented 20% of it.

The implications of a surge in population numbers were discussed by the Reverend Thomas Malthus in his first Essay on the Principle of Population, that was published in 1798, and re-issued with revision four times over the next three decades. The basic proposition put forward by Malthus was that population grows exponentially, whereas food production can only grow arithmetically, at best, which implies a rising deficit in the supply of food. His proposed solution to this dilemma was the spread of "moral restraint", noting that "in all the more improved countries of modern Europe, the principal check which at present keeps the population to the level of the actual means of subsistence is the prudential restraint on marriage". Malthus does not seem to have been interested in agriculture and so was unable to anticipate the potential for increased productivity which, it must be admitted, had not been evident in the period during which he was writing, as any growth in output in Europe and North America at that time was the result of bringing more land into cultivation, and Malthus forecast that this resource would soon run out.

The ideas of Malthus, as laid out in the Essay, are unlikely to have had a direct impact on farmers and farming methods. A more relevant factor would have been the change in the distribution of population as country dwellers, many of whom must have been subsistence farmers, moved into towns and cities where the new industries were in need of more workers. Farms therefore found themselves having to meet the increasing food requirements of these expanding centres of population, with the result that areas of intensive food cultivation grew up around them, at least until the emergence of the railways in the middle of the 19th century made it possible for food to be delivered over longer distances.

At the end of the 18th century, the idea of agricultural improvement had become established as an important concept, particularly among the larger landowners in northwest Europe, who were eager for information and advice. In Britain, the Board of Agriculture was established, with Arthur Young as its first secretary, to collect information and to provide advice. It commissioned the young chemist Humphrey Davy to present a series of lectures at the Royal Institution in London on The Elements of Agricultural Chemistry. Davy delivered these lectures annually between 1802 and 1812, then putting them together for publication in 1814. The eight lectures represented a summary of contemporary scientific knowledge, and included developments that had taken place during the decade, such as Humboldt's discovery of guano and Saussure's analytical work on the chemical composition of crops.

In his sixth and seventh lectures, Davy presented lists of materials that could be used as manures (see table 1).

Davy, Sir Humphrey, Bt (1778-1829)

One of the best known of a group of scientists that advanced the knowledge on chemistry in the early years of the 19th century,

He was born in Penzance in 1778 where, after leaving school, he was apprenticed to an apothecary. He showed a strong interest in experimental chemistry and it was not long before he was offered a junior position at the Royal Institution, in London. This allowed him to pursue his research into electrochemistry that resulted in the isolation of potassium and sodium in 1807 and of several other elements in the following year.

He was also interested in the chemistry of agriculture and gave a series of annual lectures on the topic to the British Board of Agriculture between 1802 and 1812, published in 1813 as "Elements of Agricultural Chemistry". They did not break new ground, but provided a reasonably clear summary of current scientific knowledge in a form that could be circulated in the farming community.

Davy was knighted in 1812, made a baronet in 1819 and received many other honours during the rest of his life. He died in 1829.

By the end of the 18th century, the idea of agricultural improvement was established

Manures of animal and vegetable origin

At the time when Davy was writing, almost all farmers used manure of natural origin, i.e. animal dung and urine, as well as other wastes from their activities, often supplemented with by-products from industries that processed animal and vegetable materials. Farmyard manure (FYM) was certainly the most important product in use at this time on European farms. Examples of manuring programmes based on FYM for two farms in northwest Europe are quoted in Slicker von Bath's book on the agrarian history of Western Europe: a 21 ha farm near Lille, which consumed 260t of solid and liquid manure over a ten-year period, and another probably bigger farm located near Antwerp that used nearly 400t over five years. To deliver these amounts the former required 319 cart journeys and the latter 492 cart journeys, showing how labour-intensive was the use of such low grade fertilizer materials.

Table 1. Manure products available in the early 18th Century

Manures of animal and vegetable origin	Manures of mineral origin
Green crops	Common salt
Rape cake	Gypsum
Malt dust	Phosphate of lime (Powdered bone)
Linseed cake	Saline compounds of magnesia
Seaweed	Wood ashes (*potash?*)
Dry straw	Mineral alkali, or Soda
Wood ashes	Nitre (Nitrous acid + Potasa) (*saltpetre?*)
Animal manures	Sulphate of potasa
Fish	Ammonium salts
Blubber	
Bones	
Horn	
Hair, Woollen rags & Feathers	
Urine	
Skin and Leather	
Bird dung, including Guano	
Night soil	
Animal dung	
Soot	

Source: H.Davy, The Elements of Agricultural Chemistry- Lectures VI & VII (1814)

Table 2. Fertilization plan for a 21ha farm near Lille

Year	Solid Manure (t)	Liquid Manure (t)	Ash ('000 litres)	Oil Cakes (tonnes)	Crops
1	76.8	14.25	-	-	Rapeseed, Turnips, Brassica
2	-	-	-	-	Oats
3	19.2	-	2.176	1.0	Clover, Flax
4	-	-	-	-	Wheat
5	-	-	-	-	Vetches, Rye
6	57.0	-	-	1.5	Rapeseed
7	-	-	-	-	Wheat
8	25.6	30.4	1.088	-	Barley, Clover, Potatoes, Beets
9	38.4	-	-	1.0	Rapeseed, Beans
10	-	-	-	-	Wheat
TOTAL	**217.7**	**44.65**	**3.264**	**3.5**	

A lack of understanding is evident in some of the materials used as manure

Two-course crop rotation had been replaced in the early Middle Ages by the three-course rotation system with two cultivated fields and one fallow field

In the early 1800s there was limited understanding of the nutrient content of manures, but this changed in the following decades as techniques of chemical analysis improved and with them the understanding of the composition of the materials being used to feed the soil. In a paper published in 1862, Lawes calculated the theoretical nutrient of fresh undecomposed manure (0.64% N, 0.23% P_2O_5, 0.53% K_2O) and with it presented analytical results for various farming products and waste materials, all of which are characterised by a low content of the three primary nutrients. It is therefore no surprise to find that in the Rothamsted trials conducted by Lawes & Gilbert, FYM is applied at the rate of 14t per acre (35t per ha), while less than one tonne per acre of mineral fertilizers was needed to supply similar nutrients on the same scale.

Lawes was well aware that the knowledge being developed by agricultural scientists did not spread across the wider farming community. In an 1847 issue of the Journal of the Royal Agricultural Society of England he wrote "ask the most experienced farmer to explain the principles which govern the routines he is daily in the habit of practising. Ask him to determine the value of any rotation of crops or their comparative exhaustive powers. Ask him what ingredients must be restored to the soil to keep its fertility unimpaired. Or the exact manner in which climate influences his produce. His answers will be vague and unsatisfactory. But these and a thousand other questions of a similar nature are capable of solution by science and they must be answered before agriculture can be said to rest on a satisfactory foundation."

Utilising waste

This lack of understanding is evident in some of the materials used as manure that, by modern standards, appear to have little or no fertilizing value. As some farms began to specialise in arable or market garden crops, thus having no access to FYM from livestock, they sought alternative supplies of manure. One option was to load the empty carts that had taken their crops to market with 'town muck' obtained from the dust contractors who handled the collection and disposal of rubbish from streets and homes - readers of Charles Dickens' novel Our Mutual Friend (1865) will be familiar with London's dust heaps, that he treated in a satirical way. A more scientific approach was adopted by Henry Mayhew, author of "London Labour and the London Poor", who made a detailed estimate of the value of the rubbish collected in London during the course of one year. He assessed the value of some 78 types of refuse that were bought, collected or found in the streets of London, worth a total of GBP1.4 mn, of which

Table 3. Fertilizer deliveries to Erdegem farm, near Antwerp

Year		
1	60 loads solid manure	48t
2	160 loads solid manure	128t
3	30 loads liquid manure	30t
4	80 loads solid manure	64t
5	160 loads solid manure	128t
	TOTAL	**398t**

Source: BH Slicker von Bath, The Agrarian History of Western Europe (1964)

Table 4. Annual summary of London refuse products sold for use in agriculture

Cesspool soil	700,000 loads @ 10s	GBP375,000
House dust (also sold for bricks)	900,000 loads @ 2s 6d	GBP112,500
Bones (also sold for knife handles)	3,494,400 lb @ 3d	GBP105,625
Street sweepings	142,800 loads @ 2s 6d & 3s	GBP23,479
Soot	800,000 bu @ 5d	GBP16,667
Rags	4,659,200 lb @ ½d	GBP9,707
	TOTAL	**GBP542,978**

Source: H Mayhew, London Labour and the London Poor (1851)

39% were materials that could be sold for use in agriculture.

Table 4 does not include horse manure, a potential source of nutrient, presumably because of the difficulty of separating it from the street sweepings, although it is likely that the owners of stables would have collected and sold their manure.

Mayhew's survey was carried out around 1850, some years before Joseph Bazalgette built London's underground system for handling the city's sewage. Some night soil was collected prior to this and transformed into 'poudrette' - a dry product that could be shipped overseas, for example to the sugar plantations in the West Indies. This was a much bigger business in Paris where the huge Montfaucon facility made poudrette for the local market,

Modern sewage systems generated a huge amount of waste for disposal

as well as for overseas territories. However, the use of night soil in Europe was negligible compared with the practice in the Far East of Asia, which greatly impressed European observers. Davy commented that "the Chinese have more practical knowledge of the use and application of manures than any other people living", and Liebig in his 1859 volume of Letters on Modern Agriculture stated that "it is quite impossible for us in Europe to form an adequate conception of the great care which in bestowed in China in the collection of human excrements". In his 1862 book on The Natural Laws of Husbandry, he included an appendix on Japanese farming methods, describing the collection and processing of human waste for use as fertilizer, based on the observations of a Prussian bureaucrat who had visited the country.

The introduction of modern sewage systems in London and elsewhere in Europe in the 1860s generated a huge amount of waste for disposal. Various schemes were formulated to pump this material onto farmland, and Liebig was brought in to provide advice, but nothing permanent materialised from these projects. ■

Michael Freeman writes:
For some 45 years until I retired in 2010, I was an economic analyst specialising in the study of the mining and chemical sectors, in particular the mineral fertilizer industry. When I started out, many of the active companies had names that related to their origins in the 19th Century as producers of superphosphate and potash, traders in guano, or as suppliers of meat processing by-products. Consolidations and closures caused most of these old names to disappear, and with them the links to the industry's origins.

Retirement gave me an opportunity to explore the early years of the modern mineral fertilizer industry and to write about it. I chose to terminate my coverage at the end of the 19th Century, by which time the production of phosphate and potash fertilizers had become well established, at least in Europe and North America, but the creation of a nitrogen fertilizer industry was still waiting for the invention of the Haber-Bosch process for synthesis ammonia early in the 20th Century.

Being based in London, I have been able to use the resources of the British Library and the London Library to supplement the material that is available on line. I have tried to prevent my account from being too Anglo-centric, although there is no doubt that the UK's highly-developed farming and finance sectors did allow it to be the industry leader for a brief time in the middle of the 19th Century.

I would welcome any comments, amplifications or corrections to the text, and can be reached via Fertilizer Focus.