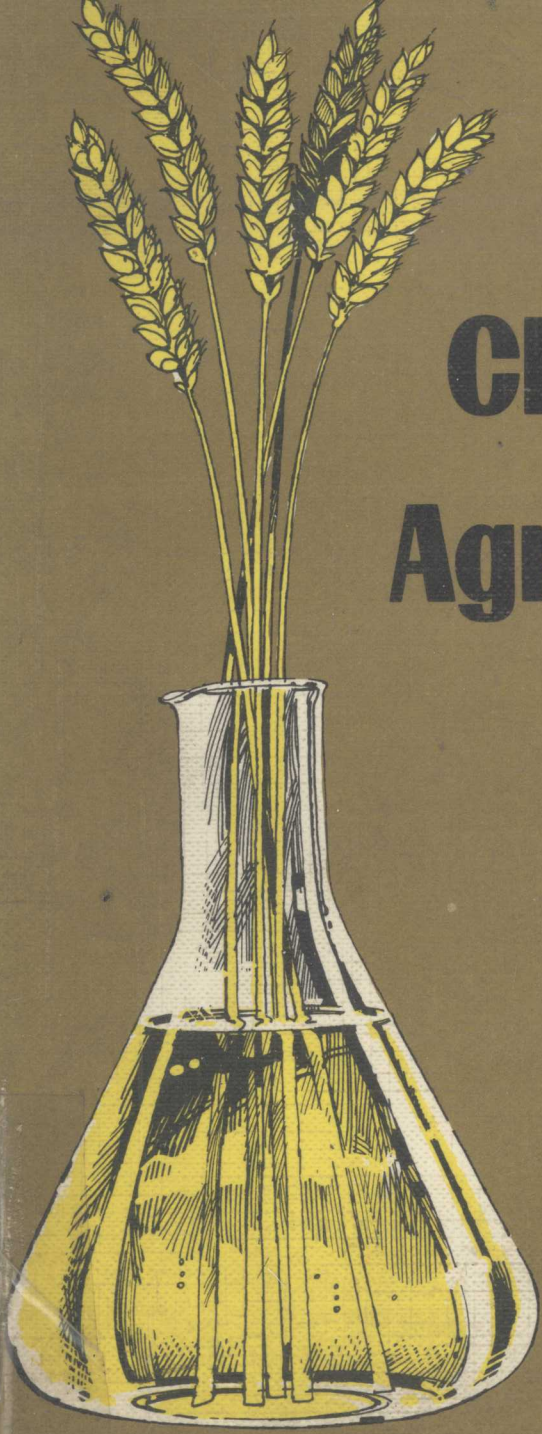

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Introduction

By D. Woodcock, Long Ashton Research Station, Bristol

The problems of feeding a rapidly increasing world population, particularly in developing countries, are enormous. Of the major nutrients N, P and K, whereas the usage of phosphatic and potassium fertilizers is now fairly static, the amount of applied nitrogen continues to increase. This has posed problems not only of efficient usage, but of long term prospects for nitrogen fixation, which is very much the concern of the ARC Unit of Nitrogen Fixation. Apart from current biochemical studies aimed at improving our knowledge of nitrogenase function, the search for a synthetic catalyst for a low-technology dinitrogen reduction process is also in progress and the underlying principles essential to such achievements have been established. The long term solution to safeguarding supplies of fertilizer nitrogen may well involve genetic engineering either to produce more efficient nitrogen-fixing bacteria or to introduce a nitrogen-fixing facility into plants themselves.

The role of trace elements must not be forgotten and this monograph includes an up-to-date comprehensive review paper on their essential nature and fascinating functional aspects of the metallic members.

Even where nutrients and water are not limiting factors, losses of crops caused by pests, diseases and weeds hardly need to be emphasised, and the judicious use of pesticides in addition to promoting agricultural sufficiency by increasing yields often results in improvement in quality. The question of economic importance of plant growth regulator usage on a world scale may still be problematical, but there is no doubt about their efficacy for producing specialized effects in a variety of plant species. The importance of herbicides in modern agriculture continues undiminished, and the concept of promoting selective antagonism in the plant by invoking additional chemicals ('safening agents') is the latest trend in the search for selectivity. In plant disease control the development and widespread use of highly persistent fungicides with single site modes of action has led to rapid onset of resistance and perhaps we now need conceptually different approaches to obviate this problem. Once harvested, crops are still at risk from yet more pests and storage diseases, and it has been estimated that these crop losses in storage are as great as those before harvest. Attempts to prevent such post-harvest losses by the direct application of pesticides to the edible portion of the crop impose severe limits on the nature and amount of chemicals that can be used.

The increased usage of chemicals in maintaining animal health requires continual demands on chemical and pharmacological expertise. The question of residues, as with pesticides, looms large because of the ultimate involvement of meat and dairy products, and the same is true of colouring matters - both natural and synthetic - and flavour additives in beverages.

This dramatic rise in the usage of synthetic chemicals - whether drugs, pesticides or food additives - during the past few decades has led not only to increased public interest and awareness, but inevitably to increased control legislation.

This up-to-date account of chemical involvement in agriculture provides not only a panoramic view of progress and problems, but also some detailed chemical and biochemical facets for the specialist. It should have an appeal to many engaged in agriculture, crop protection and food technology, including research workers and students.

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CONTENTS

The Broad Overview

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To give even a broad overview of current and future problems related to chemistry and agriculture, and to suggest possible solutions, is a substantial task and I will confine myself to some of the principal aspects of the matter. Those which I propose to discuss are fertilisers and pesticides, although I will also touch on feedingstuff additives and say a little about problems created for agriculture by chemical pollutants from industrial and urban sources.

Although I will be concentrating on problems, because that is what I was asked to do, it would give a wholly unbalanced view if I did not first of all say that the application of chemistry to agriculture has made an enormous contribution to productivity in this country and throughout the world. The origins of agricultural science lie in chemistry and indeed at one time agricultural science was almost wholly concerned with various aspects of chemistry. Some of the early chemists in this country such as Bacon, Boyle and Priestley took a keen interest in the scientific basis of agriculture as did the Royal Society from its inception. Coming closer to the present, early work on the analysis of soils was carried out for the Bath and West Society at the beginning of the 19th century, and one particular landmark which could be mentioned is the series of lectures given by Humphry Davy at the Royal Institution. These were sponsored by the Board of Agriculture, the forerunner of our present Ministry, and published in 1813 under the title of "Elements of Agricultural Chemistry".

Without doubt, however, the two men who laid the foundations of modern agricultural chemistry in this country were Lawes and Gilbert who worked in partnership at Rothamsted for over 50 years from 1843 onwards. In this period they explored the principles of plant nutrition (and also carried out some less well known work on the nutrition of farm animals) and established the classical field experiments on manuring which survive to this day.

Their work and earlier work by Lawes alone was the basis of the fertiliser industry in this country.

Over this period of time - say in the last hundred years or so - yields of crops and livestock products have increased greatly and there can be no doubt but that chemistry in its various aspects has played a major part in bringing about these increases. A large part of the improved production shown in Table 1 has taken place since the Second World War because, while much of the necessary science and technology was available before the war, economic conditions were unfavourable for agricultural expansion.

Table 1

Yields of Crops & Livestock Products

		1900	1977
Wheat	Tonne/ha	2.0	4.9
Barley	" "	1.9	4.4
Potatoes	" "	12.3	28.5
Milk	Litres per cow per annum	2000 ?	4452
Eggs	Per laying bird per annum	100 ?	241

Source: MAFF Statistics.

It would require a paper in its own right to discuss the relative importance of the different factors which have led to these yield increases, but certainly better fertiliser practice, better pesticides, increasing knowledge about animal nutrition and improved genetic material have all been of great significance in this respect. There is, of course, still plenty of room for further yield increases given favourable economics. In the ICI "Ten Tonne Club", 27 fields yielded over 10 tonne/ha of wheat in 1978.

Fertilisers

The use of fertilisers over the period 1874-1974 is summarised[1] in Table 2. This shows that not only has use increased greatly with time, and particularly since the Second World War,

but that there have also been changes in the balance of the plant nutrients nitrogen, phosphorus and potassium. Whereas at one time phosphatic fertilisers were dominant, this position is now held by nitrogenous fertilisers, reflecting in part the improved phosphorus status of our soils. The use of phosphatic and potassic fertilisers is now fairly static whereas nitrogen use continues to increase, although the rate of increase has slowed down

Table 2

Use of Fertilisers in the UK 1874-1974
(thousands of tons)

	N	P_2O_5	K_2O
1874	34	90	3
1913	29	180	23
1939	60	170	75
1959	321	383	375
1969	768	460	440
1974	1100	490	453

considerably. Making predictions about future fertiliser consumption is difficult, influenced as this is by UK prices for agricultural products and other factors, but there is reason to believe that while only small increases are to be expected for arable crops, there is likely to be a further increase in nitrogen use on grassland over the next decade or so.

In 1974 I made some estimates[1] of the gross monetary returns from the then current fertiliser use on the four principal arable crops in this country and these are shown in Table 3.

Table 3

Estimated Gross Returns from Fertilisers (UK)
(£ millions)

	N	P_2O_5	K_2O
Wheat	104	7	6
Barley	140	10	10
Potatoes	53	15	23
Sugar Beet	28	2	5
Total	325	34	44

Although there is a great deal of evidence on the responses of crops to fertilisers, estimates of this sort are not easy to make for various reasons. However, it will be seen that the large returns in financial terms are related to nitrogen use with much smaller returns from phosphorus and potassium.

Now all the evidence suggests that the effects of improved fertiliser practice on the yield and quality (although this last is often difficult to define) of agricultural products are very largely beneficial but, on first principles, it is not to be supposed that big additions of plant nutrients to soils would be completely free from undesirable side effects. These are of two main kinds and each is described briefly in the following sections.

Effects of Fertilisers on Crop Composition. In what is rather a complex subject, it is possible to distinguish firstly the effects of adverse balance of fertilisers on crop composition of which a good example would be the magnesium deficiency in both crops and livestock which can be induced by excessive dressings of potassic fertilisers. Secondly, excessive dressings of nitrogenous fertilisers or of organic manures supplying nitrogen can give rise to accumulations of nitrates in plants. On occasions, this can produce "nitrate poisoning" in livestock and may be undesirable in human nutrition (see below).

Effects of Fertilisers on Water Quality. High levels of nitrate-nitrogen are undesirable in potable waters mainly because such waters may give rise to a condition known as methaemoglobinaemia in very young infants. This is an extremely rare disease in the UK but is most likely to occur when high nitrate waters are given to infants which, at the same time, are suffering from gastrointestinal upsets. Water Authorities in this country are usually able to supply water below the WHO standard of 11.3 mg/litre of nitrate-nitrogen, but there has been a tendency for levels to rise in some parts of the country and, in particular, in areas where public supplies are derived from groundwaters in strata such as chalk and certain sandstones. A second reason why high nitrate waters (or high nitrate foods) may be undesirable is that carcinogenic N-nitroso compounds may be formed in the human gastrointestinal tract. However, there seems to be no