THE FERTILIZER ASSOCIATION OF IRELAND

NEW DEVELOPMENTS IN THE FERTILIZER INDUSTRY

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NEW DEVELOPMENTS IN THE FERTILISER INDUSTRY

Ingrid Steén, Group Agronomist, Kemira Agro Oy.

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Introduction

This paper discusses environmental constraints in the future and whether this might limit Europe's ability to produce all its own food requirements. It also outlines the most recent European ideas on taxation on fertilisers or their use, limits on N, P and K usage, and any legislation that may affect blended fertilisers compared to complex fertilisers. Moreover, some views on new types of fertilisers or methods of application are presented. Furthermore, it includes some reasoning on possible future changes in Europe, which may affect Ireland. In addition, some other European issues that are relevant to the fertiliser and other agri-industry are also considered. These are the implementation of the Nitrate Directive, the Water Framework Directive, the future changes of the Common Agricultural Policy CAP 2000, and finally, some assumptions regarding global food requirements and its effect on European agriculture.

Fertiliser product and consumption development

Agriculture's choice of fertilisers has changed notably during this century. The major practice in the developing fertiliser industry was the separate production of straight fertilisers, each containing only one primary nutrient. However, changing farming practices, crop rotation, improved soil fertility and conditions, higher yields and greater productivity have led to an increasing popularity of compound fertilisers. Over the last 50 years the manufacture of mineral fertilisers developed towards crop and soil specific products. Higher nutrient concentration of fertilisers was requested and compound fertilisers became more and more common. The increased use of mechanical application equipment called for improved physical quality and, as a result, chemically mixed and granulated fertilisers became increasingly popular amongst farmers in Europe.

The International Fertiliser Industry Association's (IFA) suggests that the world's leading nitrogen products are Urea and Ammonium Nitrate, which together hold a third of the total nitrogen consumption globally. The most used phosphate containing fertiliser is Ammonium Phosphate; almost 40% of the phosphate used in global agriculture is in the form of Ammonium Phosphate. For potash there is one leading product, Potassium Chloride, whose total use is about 60%. Generally, for nitrogen and phosphate, 2/3 is used as compound fertilisers and the global N:P2O5:K2O ratio seems to have stabilised at 20:8:5. The west European N:P2O5:K2O ratio is around 21:8:9. In Ireland Urea and Calcium Ammonium Nitrate hold some 55% of the nitrogen market. Phosphate and potash are used almost entirely in the form of compound fertilisers and the average Irish N:P2O5:K2O ratio is approximately 21:7:9.

In Europe the phosphate fertiliser consumption peaked in 1973, potash in 1979 and nitrogen in 1985. Since these individual peaks year the nitrogen fertiliser consumption in tons of nitrogen has gone down by almost 15%, phosphate by around 40% and potash by more than 20%. The statistics reveals that in Ireland the phosphate consumption peaked in 1972, potash in 1978 and the nitrogen consumption levelled out during this decade. Since these individual Irish peaks year the nitrogen consumption has stabilised, the phosphate consumption has gone down by 36% and potash by 24%. The European Fertiliser Manufacturers' Association's (EFMA) fertiliser consumption forecast for the next ten years suggests a continuous decline in the use of mineral fertilisers and in Ireland this would be at a rate of approximately 1% p.a. for nitrogen and potash and more than 2% p.a. for phosphate.

Globally, the mineral fertiliser consumption increased almost tenfold from 13.6 million tons of N, P2O5 and K2O in 1950 to 129.2 million tons of N, P2O5 and K2O in 1995. Over these 45 years this would be an annual growth rate of some 5%. However, the global fertiliser consumption growth rate has levelled out and in 1989 the highest consumption ever was measured, approximately 145 million tons of nutrients. It fell by 17% until 1994 due to a decrease in mineral fertiliser consumption in developed countries, mainly the former Soviet Union, Central Europe and West Europe. According to IFA's consumption forecast for the next ten years, until 2005/6 suggests a continuous annual consumption increase of almost 3%.

The average application rates of nutrients contained in mineral fertilisers in arable farming in Europe today is around 104 kg N/ha, 42 kg P2O5/ha and 49 kg K2O/ha, and in Ireland the figures would be 107, 50 and 97 kg/ha of these nutrients respectively. For grassland that receives mineral fertilisers in Europe the average application rates of nitrogen, phosphate and potash are 83, 20 and 25 kg/ha and in Ireland these are 114, 32 and 43 kg/ha respectively. However, in the interpretation of these data, soil fertility, crop rotation, production levels and many other factors have to be taken into account.

PRESENT AND FUTURE POLICIES HAVING IMPLICATIONS FOR FERTILISER CONSUMPTION

Agricultural policies

Changes and development in agriculture and less than self-sufficient agricultural production in many countries played an important role for the increasing demand for fertilisers. In Europe, for example, the main reason for the foundation of the European Community in 1957 was that the six first Member States of the European Community at that time were far from self sufficient in agricultural produce. The Common Agricultural Policy (CAP) that was adopted aimed at increased agricultural production and yield related subsidies were introduced. The agricultural production did indeed increase, new high yielding varieties were introduced and hence higher application rates of mineral fertilisers were used. Similar developments took place in many parts of the world.

The Common Agricultural Policy remained unchanged until the early nineties; the 1992 reform introduced a number of new measures, all with the objective to reduce agricultural output and to 'extensify' agricultural production. Therefore, amongst other measures, area payment was introduced and yield related subsidies were reduced. In the first half of the nineties the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) brought agricultural products within the scope of the treaty for the first time. It was aimed at bringing more discipline and predictability to world agricultural trade by reducing uncertainty, imbalances and instability. Greater liberalisation of trade was also sought along with substantial and progressive reductions in both agricultural support and protection. The compensatory payments were perceived as being temporary and transitional in nature, forming a bridge between the high market support policies of the past and the market oriented systems for the future. These changes of the CAP and the latest GATT agreement led to a further decrease in European mineral fertiliser consumption.

At present there are discussions within the European Union on the future development of the Common Agricultural Policy. In late 1995 the European Commission presented its Agricultural Strategy Paper in which it outlined the major challenges European agriculture and its rural areas would be facing at the turn of the century. Directorate General VI, Agriculture, also undertook a number of studies to examine the longer-term outlook for agricultural markets, development in rural areas and in world markets. In March 1997 it presented its document 'CAP 2000' where, in short, the European Commission proposes deepening and extending the 1992 reform through further shifts from price support to direct payments, and developing a coherent rural policy to accompany this process. The objectives of the CAP are very similar to past generations of the CAP, i.e. ensuring a fair standard of living for the agricultural community; meeting consumers' demands on food safety and quality; increased competitiveness, integration of environmental goals etc.

Some of the proposed measures are; the cereals intervention price to be fixed in one step in the year 2000 at a level of 95.35 ECU/t (119.19 ECU/t at present); a non crop specific area payment to be established at 66 ECU/t; the reference set-aside to be fixed at 0% etc. For the beef regime it is proposed to reduce the market support and to increase the direct income payment on a per head cattle basis this would mean an increase of some 50% for suckler cows, 100-150% for male bovine and a yearly payment for dairy cows for which there currently is no premium. With regard to the dairy regime the Commission has opted for a cautious approach including minor changes in comparison to present dairy regime. This means that the dairy regime would stay almost intact until 2006. With regard to rural policy a prominent role will be given to agri-environmental instruments to support a sustainable development of rural areas and respond to society's increasing demand for environmental services. Targeted agri-environmental measures may be reinforced and encouraged through increased budgetary means aimed at for instance organic farming, maintenance of semi-natural habitats etc. The majority of EU Ministers have accepted the approach of cutting support prices, although the size of the price cuts is under scrutiny, and increasing direct compensation while EU farmers' organisations opposes CAP reforms. Furthermore, the compatibility with the Blair House commitments has not been evaluated and it might be unwise to cut prices ahead of the next round of WTO negotiations that will commence in about a years time. To achieve any effective and significant liberalisation of agricultural trade over the next twenty years, the new round needs to agree larger cuts for export subsidies and domestic support than agreed in 1994. Other challenges to the CAP are the eastward enlargement and the budgetary prudence. The upcoming WTO round of agricultural talks and the eastward enlargement of the Community is likely to force an economic reorientation of the CAP. However, it is not likely that there will be a WTO agreement before 2005-06. Nevertheless, price cuts on agricultural produce and increased income support as suggested for CAP 2000 will most likely lead to further reductions in the consumption of mineral fertilisers.

For instance, the suggested change of intervention price of more than 20% down to 95.35 ECU/ton cereals is not likely to be approved although there will be income aids that to a certain extent should compensate for the reduced price on farm produce. Further, depending on the development of the world market grain price and the stability of national currencies farmers might be better off than today. However, if world market grain prices does not develop as in the recent past the very low intervention price will lead to a large decline in farm income and, thus, use of mineral fertilisers, nitrogen in particular. Another example could be the oilseed production, most analyses of the development of the oilseed plantings following the implementation of the proposed "oilseed package" shows that this will lead to a great reduction in oilseed production in short and medium term based on the relative profitability between cereals and oilseeds.

There are voices, which claim that the sugar and milk sectors should be included into the revision of the CAP. Some Farm Ministers suggests that the quota system should be abolished and, support prices to be aligned with the world market price as for cereals and beef and, that would avoid the surplus production. The majority of Farm Ministers are not supporting this view at present. Regarding fertiliser consumption, the dairy sector is very important for maintaining the use of mineral fertilisers on grassland, consequently, the fertiliser industry would benefit if the current dairy regime would be maintained.

Further developed and detailed proposal of CAP 2000-06 are to be expected in the coming year and it is not likely that the European Farm Ministers and the European Parliament will be able to reach an agreement on the "reform" of the CAP until during the first half of 1999.

Environmental policies
There are a great number of environmental policies and regulations particularly aimed at reducing nutrient emissions from agriculture. These include losses to air and water, e.g. leaching, run-off, and erosion losses of nitrogen and phosphorus, volatile losses of ammonia and, farm waste discharges. Environmental targets have been set at national and regional levels and measures have been introduced as it has become increasingly clear over the last 10-15 years that modern agriculture has a significant impact on the environment. In the "5th Environmental Action Programme Towards Sustainability", agriculture is one of the target sectors. The framework programme includes the establishment of "ecologically sustainable farming" by extensification and other action points. A key objective is the establishment of an "Equilibrium between the input of nutrients and the absorption capacity of soils and plants".

Within the European Union there are several Directives and Regulations that relate to agriculture and its use of nutrients, the most important being the Nitrate Directive (91/676/EEC) the proposed Water Framework Directive is also likely to have quite significant impact on Europe's agriculture. The objectives of the Nitrate Directive are to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution. Key parameters of this Directive are the national designation of Vulnerable Zones, the development and implementation of Codes of Good Agricultural Practice and, regulations and ceilings for the application of animal manure. A recent report from the European Commission reveals that most Member States have failed to implement it. At present, 13 out of 15 Member States are subject of legal proceedings. Although, not yet recognised by the Commission, there is more and more evidence available that a Nitrate level of 50 mg/l in drinking water will not cause negative health effects even for infants. Furthermore, researchers have discovered that there is a certain need for a daily intake of nitrate via our diet. Also if this were to be appreciated by the European Commission it is not likely that the limits for Nitrate in water contained in the Nitrate Directive will be changed. There are voices that, of various reasons, claim that there is a need for a revision of this Directive. However, the principle reason for the Commission not coming forward with proposals for this is the late implementation of the Directive, which makes it impossible to assess the effectiveness of the Directive.

The proposed Water Framework Directive is not addressing fertilisers as such but to a certain extent eutrophying substances emitted or lost to water bodies. It is aimed at achieving a watertight EU water protection. This proposed Directive contains a combined approach towards pollution emissions to water for to achieve high level of environmental. The implementation of it will ensure that emissions are controlled by Best Available Techniques (BAT) in the first instance, and if this is not sufficient to achieve the goal of good water status set out in the Directive, the controls concerned are tightened as necessary. Part of the necessary controls is already in place, such as the Directive on Integrated Pollution Prevention and Control (96/61/EC), the Urban Waste Water Directive (91/271/EEC) and the Nitrates Directive. These Directives address emissions from both point and diffuse sources.

At present the debate on phosphate and its contribution to the negative consequences of eutrophication of fresh water bodies is increasing. The main sources of phosphate are sewage discharges and diffuse inputs from agricultural land. Currently, phosphate from agricultural/diffuse sources is supposed to be controlled by the Nitrate Directive and a Phosphate Directive would therefore not be required. Further, as phosphate is on the Commission's grey list of dangerous substances contained in the Directive on Discharges of Certain Dangerous Substances (76/464/EEC), this Directive should indirectly control other sources. In these discussions this Directive and the Waste Water Treatment Directive (91/271/EEC) are linked. Nevertheless, there is no EU regulation directly aimed at the use of mineral fertilisers.

In Europe and Ireland, in particular, there is an increasing concern about phosphate's contribution to the negative consequences of eutrophication. At present there are many different organisations engaged in the discussions about causes and effects. Hopefully, the involved parties jointly will try to seek solutions to the deterioration of fresh water bodies and not try to define a scapegoat.

Measures to reduce nutrient use and improve its efficiency
Measures that have been discussed and still are under discussion with the objective to limit or reduce the use of fertilisers are economic instruments. Levies, taxes and financial incentives have been regarded as possible means to achieve both certain environmental goals and reduction of production levels. This type of measures could be used as complement to other production regulating measures. Many such measures could be quite easily administered. At present this type of measures are hardly used in the European Union. Several studies on the technical, environmental, economic and social consequences of economic systems for nitrogen control and features of systems that can be implemented regionally, nationally or internationally in an EC context have been done over the years. The economic systems for nitrogen control can be divided in three categories: levy systems, with or without reimbursement; tradable permit systems and; subsidy systems. The choice of system that are discussed in the report are levies on input, on nutrient surplus, manure production, ammonia emissions, tradable input permits, tradable surplus permits, tradable permits for manure production, tradable permits for ammonia emissions, reimbursements and finally subsidies. Many voices claim that levies on input or surplus nutrients would reduce agriculture's impact on the environment. However, an analysis of the success/failure of this type of taxes on fertilisers that have been and to a certain extent still is in place has shown that there have not been any environmental benefits of these levies. At present Sweden has an environmental tax on nitrogen containing mineral fertilisers and a levy on Cadmium in phosphate containing fertilisers. Norway also has an environmental tax on nitrogen fertilisers. In both cases, the environmental tax is around 20% of farmersí price on the nitrogen content of fertilisers. In addition to this the Netherlands will introduce a mineral balance administration system on January 1, 1998. During 1998/1999 there will be a general fee, large for those who utilise the standard mineral declaration, 182 ECU, and a small fee of 46 ECU for those who prepares a detailed declaration. The fine for mineral surplus, over a certain agreed balance, will be 0.7 ECU per kg of nitrogen per ha. In the year 2000 there seems to be solely a fee on mineral surplus of 2.3 ECU per kg of nitrogen and 9.1 ECU per kg of P per ha. In the Flemish region of Belgium a similar system is already in place, here the farmer pays a fee on surplus production of phosphate and nitrogen. Farmers have a permit to produce a certain volume of manure on their farm, the nutrient content of the manure is assessed. The farmer pays a fee if the on farm production of phosphate is greater than 1500 kg P2O5 and the nitrogen production is exceeding 3000 kg N. The fee is relatively small but means in practice that most farmers are obliged to pay some money to the regional manure bank. If the farm produces, as an example, 12.000 kg of phosphate the fee would be 40-45 ECU and in addition 24.000 kg nitrogen per year the fee would be 80-90 ECU, in total approximately 130 ECU.

Compulsory fertiliser planning was introduced in Denmark in 1993. It includes the preparation of a nutrient balance calculation, which lays particular stress on the efficiency of utilisation of nitrogen in farmyard manure. A levy on surplus mineral balance is currently discussed also in Denmark. It is being considered to introduce a levy on surplus nitrogen at the beginning of next year, however, no decisions have yet been made. In 1996 some farmers at the Jutland peninsula was fined for excessive use of animal manure. It was argued that the fine should be of some 3 ECU per kg nitrogen but it was finally reduced.

During 1997, ten years after the implementation of fertiliser legislation in Denmark the outcome of it was evaluated. In general, assessments by the Danish Research Centres, the Ministry of Agriculture and Advisory Centres on nutrient balances showed that most farmers comply with the nutrient book keeping scheme. Further, losses of nitrogen has been reduced significantly and that the consumption of nitrogen from fertiliser had been reduced by nearly 30% despite a change from spring sown to winter sown crops with higher yields and thus nutrient requirement. Finally, the nitrogen losses from agriculture due to leaching had been reduced by 30% since 1987. However, the target to reduce nitrogen losses by 50% between 1987 and 1997 was not met, consequently, the Ministry of Agriculture decided in August-September that some modifications of the legislation would be required. New actions will be suggested and these are likely to include some type of fertiliser tax, catch crops, N-quotas, increased efficiency of nitrogen contained in manure, penalty on nitrogen surplus etc.

Limits or ceilings on nutrient use are part of the Nitrate Directive. However, this is aimed at animal manure and not at mineral fertilisers. So, currently there is more legislation that indirectly influences fertiliser use than legislation that controls it directly. The legislation that exists mainly concentrates on achieving improved utilisation of animal manure. The likely future development is that nutrient balance calculation systems will be further developed and introduced in other European countries.

Legislation aimed at fertilisers as products

As for any other industry, there are a number of regulations aimed at industrial production, safety, health and environmental protection, transportation and storage that the manufacturers of mineral fertilisers must comply with. In response to the proposal for a European Union Directive on Integrated Pollution Prevention and Control, IPPC, (96/61/EC) the European fertiliser industry jointly prepared eight Booklets on Best Available Techniques for fertiliser manufacturing (Best Available Techniques for Pollution and Prevention and Control in the European Fertiliser Industry, vols. 1-8, 1995). The industry has agreed on emission levels for the manufacture of fertilisers and Kemira Agro's fertiliser plants already meet these requirements or national regulations, this is more than ten years before the IPPC Directive will enter into force. Altogether, these policies have raised the awareness of the need for sustainable development within the agri-industry

Recent activities within the European Union are the discussion on harmonisation of EU legislation for mineral fertilisers and "Simpler Legislation for the Internal Market" (SLIM), in particular. The European Commission in May 1996 launched the SLIM initiative in the context of the Commission's Confidence Pact for Employment. It is also to be seen as part of the programme to simplify Community legislation within the "Action Plan for the Internal Market". It has been decided that SLIM will cover VAT, banking services, the combined nomenclature for foreign trade and fertilisers. The mandate of the SLIM exercise is to develop broad proposals for simplification of the Community legislation on fertilisers.

At the present time, no distinction is made between blended and complex fertilisers in European fertiliser directives. Further, the major fertilisers are already "harmonised" with regard to rules for the marketing of fertilisers within the internal market. At present the working group on SLIM within the Commission has provided its view on the proposed adapted Directive. The main components of the suggested simplification are harmonisation in the respect of adding new fertilisers and fertiliser groups to the legislation. Further, provisions should be made for addition of new groups of fertilisers based on mixtures of existing EC fertilisers of the same nutrient types and agreed test methods should be implemented possibly involving CEN (Centre Européen du Normalisation). Possibly, there will be new criteria for slow release fertilisers and minimum rules for bulk blends might be included. Further, the proposal includes the possibility to call for labelling indicating the physical form of fertilisers, e.g blended fertilisers to be labelled "Blended" and this to be supplemented by appropriate codes of practice. At the blended fertiliser conference in Beaune at the beginning of November this year the Blender's Association presented its Codes of Practice for Blend Fertilisers. Furthermore, organo and organo-mineral fertilisers should be

added after intermediate periods. The consequences for blended fertilisers of good quality will be limited to labelling and the introduction of codes of practice that has already been suggested by the industry. Finally, it should be kept in mind that no decisions has yet been made and first will these proposals will be discussed in the European Parliament and by the competent bodies.

Food demand

For more than a century, modern fertiliser practices have been instrumental in increasing the quantity and quality of agricultural output in the world. The use of mineral fertilisers has made it possible to provide enough food to feed the worldís growing population. A balanced use of mineral fertilisers has shown to be an effective means of improved crop production and has contributed to a substantial improvement in human and animal health.

There are discussions among various groups in Europe about Europe's future as a food producer. Europe's agriculture is one of the most competitive in the world due to good climate, fertile soils and, modern technologies and farm management. At present the total quantity of farm produce in Europe can feed many more millions of people than the current population of Europe. Globally some 800 millions of people are under nourished and starving and the population growth in the world according to current estimates is some 85 millions of people annually.

Cereals, rice, wheat, maize etc are the main source of nourishment for the world's population. Being the world's most important staple nutrient source for humans and animals the current consumption is about 1.9 billion tons per year. The average cereal production is around 2.8 tons per hectare, 3.0 in developed countries and 2.6 in developing countries. Cereal production has kept slightly ahead of population and over the last 25 years the global cereal production increased by some 65 %. Much of the growth in global cereal production occurred in developing countries. These countries increased their production of cereals by more than 85 % between 1970 and 1995. Taking the population growth into account during this period the per capita cereal production in developing countries has gone up by 15 % to about 260 kilograms per person each year. In the industrial countries the figure is 10 per cent and approximately 600-650 kilograms. However, over the last few years there has been a slowdown in the growth of global per capita cereal production.

The present world cereal production can in itself feed the world's population, however, large volumes of cereals are converted into more high value diet, containing more meat. To convert cereals into meat is rather inefficient with the conversion factors cereals to meat of 2:1, 3-4:1 and 5-6:1 for poultry, pork and red meat respectively. These conversion factors are representative for intensive animal husbandry. If future demand is to be met, production must virtually double by the year 2020. At the same time, the available land for agriculture production is decreasing. On the basis of "traditional agriculture", i.e. recycling of organic material as the single source of plant nutrients and no use of mineral fertilisers the planet could feed no more than 2.6 billion people, at present the global population is close to 6 billion. Therefore, it would be unlikely that new policies would be introduced to such an extent that European agriculture would be unable to feed Europe's population or contribute to feeding the global population.

Recent and future developments in the manufacture and use of mineral fertilisers

Developments in the recent past and the near future within the fertiliser industry focus on research on manufacture, quality, composition and the use of fertilisers, moreover, distribution systems, financial, safety and environmental issues are of major importance for today's industry and its customers. To meet future requirements, the industry will continue to focus on the concept of "Best Fertiliser Practice". This would firstly, include improved fertiliser/nutrient efficiency to improve yields and crop quality and reduce any negative environmental impact fertilisers might have. Secondly, the manufacture of mineral fertilisers must be as safe, environmentally friendly and cost effective as possible. Thirdly, the mineral fertilisers should not contain unwanted substances; furthermore, the physical properties must be of excellent quality. Finally, sustainability would also imply good energy efficiency at the plant and improved techniques to manufacture fertilisers and, in the future, to recover and recycle nutrients contained in waste materials.

Kemira Agro Oy is carrying out development and research work, both independently and in close association with universities, research institutes, and extension services. Examples of this are new and improved fertiliser recommendations and advanced computer programmes, soil analysis, new fertiliser products and formulas, development of the precision farming concept, improved nutrient efficiency and physical quality of fertilisers, nutrient recovery and recycling, environmental research and computer aid for improved crop production etc. Effective use of fertiliser management on the farm requires research-based, site-specific recommendations.

The determination of the best fertiliser application rate is based on the results of soil analysis, knowledge of the cropping history, a realistic assessment of the anticipated crop yield and where necessary, plant tissue analysis. Subsequently, effective fertiliser application methods and tillage practices are essential to achieve high levels of efficiency in nutrient use. Improved nutrient efficiency to the benefit of the farmers' economy and the environment is one of the more important issues for today's fertiliser manufacturer. Kemira Agro has invested in research into soil nutrient dynamic modelling and other development activities to improve fertiliser recommendations. Consequently, it is actively involved in the development of the Precision Farming concept aiming at accurate nutrition, in time, composition and amount, of crops. The farmer uses the Global Positioning System (GPS) co-ordinated with Geographical Information System (GIS). The spatial variability on the field is linked to fertiliser recommendations for the actual crop's requirement and, consequently, the accurate nutrient supply can be achieved. This can be accomplished by using Kemira's software LORIS (Local Resource Information System), containing algorithms, correction factors etc. for the field, soil and present crop. Thus, the nutrient efficiency will further improve. A good physical quality of fertilisers is of significant importance so the fertilisers will endure transportation and storage. This is also essential for a precise and accurate distribution of nutrients in the field, both from an economic as well as an environmental point of view. Parameters such as particle size distribution, mass median diameter (d50), bulk density, particle strength, shatter resistance and flow rate are important to achieve an even and accurate spreading. In this respect the coating of fertilisers has a great impact on the fertilisers physical quality and new, and improved coatings and coating aids for different conditions are continuously being developed.

A fertiliser manufacturer cannot guarantee that the physical properties of a certain grade will be the same in the future due to the development in technology, changes in raw materials and processes may differ. Same grades produced by different plants may have totally different physical properties. To give some indication of the spreading properties of a fertiliser, Kemira Agro has developed a unique system for classifying its own products. The classification is based on mass median diameter (d50), particle size range variation coefficient and flow rate. As a result, six different fertiliser types are defined and fertilisers of the same type will require approximately similar spreader settings.

Research is continuously going on to develop new fertiliser products and formulas to meet the requirements of today's agriculture, the food processing industry and consumers. A new idea could be "fertilisers for the food chain". This could mean fertilisers that would lead to improved quality or increased extraction of desired compounds such as sugar, starch, gluten, amino acids etc. As an example, in Finland all Kemira Agro's fertilisers contain Selenium as there is a requirement for a certain concentration of selenium in food from a national human health point of view. Furthermore, for a few

years, all Kemira Agro's products in Denmark have contained sulphur. A continuous development of this type of food chain fertilisers can be foreseen.

Further development of liquid fertilisers is limited due to chemical limitations of how much nutrients a liquid fertiliser can contain. However, the agronomic advantage of liquid fertilisers is the evenness of application. Furthermore, the possibility to combine the application of nutrients and plant protection products at the same time is of interest to farmers. This is, however, mainly to be considered at foliar applications of nutrients and very often the crop is unable to take up large quantities of nutrients by the leaf without any damages to the leaf tissue. At present, the global use of nitrogen containing liquid fertilisers is some 10 % of the total nitrogen consumption. The forecast is that the use of liquid fertilisers will increase slowly at those markets where traditionally this type of fertilisers is being used.

Regarding new technologies for the manufacture of fertilisers, some new patents are pending and few new or amended processes have been installed over the past ten years. As mentioned earlier in this paper, the basic chemistry and principles for making nutrients plant available are still valid. A few new developments will be presented, however, there are some ongoing, new technology developments that cannot be disclosed in this paper. One example of recent development is how the General Electric Environmental Services Inc., developed, patented (1987) and commercialised an innovative process for the production of ammonium sulphate. This unique process produces high quality ammonium sulphate by the removal of unwanted sulphur dioxide from the utility or industrial boiler flue gas by causing a reaction between it, ammonia and air to form ammonium sulphate. In 1992 the Dakota Gasification Company in the USA installed the commercial flue gas desulphurisation system. Another example is the pending French patent from École des Mines de Paris and Grande Paroisse S.A. on urea super phosphate production. This new process provides the possibility to produce a less expensive high water soluble NP fertiliser based on urea, sulphuric acid and phosphate rock. The final example is the Kellogg Advanced Ammonia Process (KAAP) that was commercially implemented by the Pacific Ammonia Incorporated in Canada in 1992. The KAAP represents the first significant advance in ammonia synthesis catalyst technology since the iron catalyst was first used for ammonia production over 80 years ago. The process is based on a ruthenium metal catalyst that makes possible the design of lower cost and lower energy ammonia facilities.

Sustainable fertiliser production includes, besides low energy requiring processes, the tracking of alternative raw material sources to replace the finite sources that are used today. A possible development would be an increased utilisation of nutrients contained in waste and by products from industrial processes, either as recovered elements or by recycling in, for example, organo-mineral fertilisers. A few examples of nutrient sources that could be considered are phospho-gypsum, molasses, vinasse, potato juice, waste water and bio-waste. Kemira Agro uses gypsum as an active filler for complex fertilisers at the plants at Siilinjärvi, Uusikaupunki and, Harjavalta in Finland. At its plant in Nørresundby, Denmark, Kemira Agro incorporates ash from straw from energy recovery into special fertilisers. Furthermore, at its plant at Harjavalta, Finland, Kemira Agro produces organic and organo-mineral fertilisers based on composted bio-waste. Kemira Chemicals in Helsingborg, Sweden, has developed a phosphate recovery technology from waste water. The recovered phosphate may be used in the manufacture of mineral fertilisers or for other applications.

Future fertiliser systems and thereby the fertiliser industry will have to meet many different requirements as there is a great diversity in global agriculture, between and within different regions of the world. Furthermore, in the future, the diversity in agricultural production conditions and methodologies is likely to increase. The challenge for the fertiliser industry is to provide growers with the fertilisers they require, of the desired chemical composition, to contribute to sustainable agriculture which includes minimising any negative impact on the environment from both the use and the manufacture of its products. In the future, increased recovery and recycling of nutrients, fertilisers for extreme conditions, chemical and biological soil nutrient "boosters", fertilisers for toxicity/nutritional disorders, crop geared nutrient release fertilisers, low cost and energy requiring fertigation, fertigation based on both liquid and solid fertilisers etc. might be seen.

Conclusions

The average mineral fertiliser application in Irish agriculture is reasonably higher than the average use in West Europe. In the interpretation of these differences a number of factors have to be considered such as soil fertility, production levels etc. Over the past the fertilisers application rates have decreased, since the individual peaks year the consumption of phosphate in Ireland has gone down by 36%, i.e. since 1972, and potash by 24% since 1978. According to EFMA forecasts a continuous annual decline in the consumption of mineral fertilisers can be foreseen.

At present there are discussions within the European Union on the next revision of the Common Agricultural Policy, CAP 2000. The European Commission proposes deepening and extending the 1992 reform through further shifts from price support to direct payments and developing a coherent rural policy to accompany this process. The consequence of the suggested modifications would most likely be less significant for Irish agriculture than for the agriculture in many other Member States of the European Union. The main argument for this is the structure of Irish agriculture. However, the outcome of the environmental discussions in Europe and Ireland might have greater impact on Irish farming than CAP 2000.

At present Ireland has failed to meet the requirements contained in the Nitrate Directive. The country suggests that there are not any Nitrate Vulnerable Zones in the country and therefore the European Commission considers legal action against Ireland. Because of the phosphate issue there are also discussions on Irelandís difficulty to successfully implement the Waste Water Treatment Directive linked to the Discharges of Certain Dangerous Substances Directive. The debate on phosphate and its contribution to the negative consequences of eutrophication, such as increased algal growth and blooms, is increasing in the community. Nationally involved parties and interests in the phosphate discussion must jointly seek solutions to this issue. Certainly, there will be solutions that are equally acceptable to the different sectors that have an interest in this, agriculture, tourism, industry and the public, furthermore, voluntary action programmes could be more effective than any legislation.

A number of national action programmes for improving the utilisation rate of nutrients used in agriculture have been initiated in some European countries. These action programmes are predominantly related to the Nitrate Directive and are mainly linked to the use of animal manure. These regulations indirectly influence the use of mineral fertilisers and it is likely that, for instance, nutrient balance calculation systems will be further developed and introduced in more European countries. Improved techniques for spreading and utilisation of manure and mineral fertilisers will result in a further consumption decrease of mineral fertilisers. Other pieces of fertiliser legislation are mainly related to the manufacture, transportation and storage of fertilisers. The most recent activities in the European Union are the discussions on harmonisation of EU legislation for mineral fertilisers. At the present time, no distinction is made between blended and complex fertilisers in European fertiliser directives. In short, the discussions on harmonisation are not likely to cause any difficulties for blended fertilisers of good quality on the market. The consequences are likely to be limited to labelling and the introduction of codes of practice that have already been suggested by the Blenders Association.

Finally, it is likely that the development of European agriculture will result in further diversification where nations and regions focus on the best utilisation of their local conditions.

PHOSPHORUS IN THE IRISH ECOSYSTEM - TAKING STOCK

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General awareness of water pollution in Ireland can be said to have originated in the 1970's when a number of Irish lakes, including L. Sheelin and L. Ennell, exhibited symptoms of nutrient enrichment (Anon, 1975). At this time also, L. Leane had been identified as having undergone accelerated enrichment (Bracken et al, 1977) and water quality in Irish rivers had been assessed (Flanagan, 1974). Fish kills (Anon, 1975) and ground water contamination (Mannion, 1977) were other symptoms of deterioration in the general quality of the Irish environment during this period. Industrial expansion, farming operations and intensification of agricultural practices were among the activities said to be related to the decline in water quality. Specifically, land spreading and runoff of pig slurry were causally related to the problems in L. Sheelin (Champ, 1977) while the problems in L. Ennell and L. Leane were largely attributed to discharge of effluent from local sewage treatment plants (Bracken et al, 1977; Toner, 1977).

The significance of sewage, animal manures and silage effluent in the overall question of water quality was reviewed by Toner and O'Sullivan (1977), a distinction being drawn between the relative importance of these pollutants according to the proximity or otherwise of the receiving water to large/medium sized towns. The occurrence of elevated phosphate levels in a number of river stretches below towns, and the lack of a significant contribution of P fertilizers to the P status of water, were other pertinent points referred to by Toner and O'Sullivan (1977).

A perspective on water quality in Ireland for the period 1971-1986 is contained in the report Water Quality in Ireland - The Current Position - Summary Report (Anon, 1986). The report assesses the quality of rivers and streams based on biological and physicochemical measurements for the period 1982-1986, with organic biodegradable pollutants (sewage, farm wastes, wastes from food processing etc.) as the primary focus. Comparative data for 1971 and 1977-1981 are also included in the report. When the results for the three periods were adjusted for the shorter channel length that had been surveyed in 1971 (2900 km), the results (Table 1) showed a steady decrease over time in the 'seriously polluted' category, but an increase in the 'slightly' and 'moderately' polluted stretches.

Table 1. Water quality classification (% of channel length in each category)[1]

Period	Unpolluted	Slightly polluted	Moderately polluted	Seriously polluted
1971	83	5	5	7
1977-1981	78	11	7	4
1982-1986	69	20	8	3

[1] Anon (1986)

In all categories, the greater part of pollution was attributed to wastes discharged directly to water courses from towns and industries (point sources). It was acknowledged however that this view (based on circumstantial evidence) probably underestimated the impact of waste inputs from non-point sources, especially agriculture. Overall, it was concluded that remedial measures would involve/require reduction in nutrient inputs (especially P) both from point and non-point sources of pollution. It was noted (Anon, 1986) that whereas "....conventional treatment of sewage and other wastes has reduced the extent of seriously polluted river channel, the inability of such treatment to remove more than a small proportion of P means that the effluent retains much the same fertilizing value as the untreated waste. It is even possible that the treatment enhances this value by converting phosphorus to a more readily assimilable form for algae and other plants". Clabby et al (1992) have also commented on the implications arising from the lack of P removal technology in sewage treatment plants around the country. In addition, they reported that the trends in water quality shown in Table 1 had continued into the period 1987-1990, the values in the unpolluted, slightly polluted, moderately polluted and seriously polluted categories being 65%, 20%, 13% and 2%, respectively.

The data in Table 2 are selected from published reports on river water quality in Ireland (Flanagan, 1974; Lennox and Toner, 1980; Flanagan and Larkin, 1986; Flanagan and Larkin, 1992). The reports respectively refer to surveys carried out in 1972-1973, 1976-1978, 1983-1985 and 1987-1990 and the data shown are the ranges for each river of the maximum values for P concentration for all sampling stations and all sampling dates. The data are striking because of the magnitude of the P concentrations recorded, especially when set against the P concentration (~0.02-0.04 mg l^{-1} P) that is said to initiate algal growth in surface water. It is pertinent to note however that the scale of the values shown in Table 2 was not the subject of contemporary comment, nor indeed was an association between P fertilizers/P fertilizer use and impaired water quality ever suggested during this period. Nevertheless, there was a general acceptance then that the agricultural sector was implicated in the development of eutrophic conditions in surface waters, the major problems being inadequate management of animal manures, silage effluent and farm-yard effluent.

It appears that the association of P fertilizers/P fertilizer use with poor water quality originated in 1990 when, in the context of discussing the balance between P inputs (incl. P fertilizers) and P outputs in Irish agriculture, a presumed loss of 0.5 kg soluble P ha^{-1} yr^{-1} to water was interpreted as exceeding the level of P necessary to cause eutrophication (Tunney, 1990a). Further, "the average loss in 1950 was probably less than 0.1 kg water soluble phosphorus per ha and now is probably over 0.3 kg per ha. It is likely that the loss is continuing to increase. It is therefore apparent that the high fertilizer use and increasing soil status is contributing to loss to water" (Tunney, 1990b). Subsequently, Clabby et al (1992) referred to the threat of inorganic fertilizer runoff from agricultural land (and forestry) as causal factors of poor water quality while loss of P through application of fertilizers (and animal manures) was regarded by McGarrigle et al (1993) as significantly contributing to the deterioration of water quality in L. Conn. More recently still, unsubstantiated claims linking P

Table 2. Concentrations of phosphorus (mg l^{-1} P) in selected rivers in Ireland

River	1972-1973[1]	1976-1978[2]	1983-1985[3]	1987-1990[4]
Ara	0.29-1.63	0.17-1.45	0.52-1.10	0.32-5.00
Ballyfinboy	no data	0.11-0.17	0.08-0.20	0.04-0.17
Barrow (Athy)	0.10-0.25	0.06-0.23	0.14-1.13	0.05-0.50
Barrow (Carlow)	0.13-0.16	0.09-0.22		
Blackwater (Rathmore)	0.27-0.87	0.03-0.50	0.02-7.10	0.17-0.88
Blackwater (Mallow)	0.13-0.18	0.03-0.21		
Boyne (Edenderry)	0.11-0.95	0.03-0.85	0.03-1.36	0.06-1.22
Boyne (Navan)	0.10-0.13	0.05-0.10		
Broadmeadow	0.16-1.10	0.63-6.10	0.14-10.48	0.78-10.50
Brosna (Roscrea/Birr)	0.08-2.20	0.07-0.97	0.01-0.56	0.02-0.15
Camlin	0.07-1.00	0.05-0.69	0.04-10.00	0.05-0.63
Castlebar	0.42-0.93	0.06-1.70	0.06-1.20	0.05-1.00
Clare (Tuam)	0.05-1.50	0.02-0.29	0.04-0.20	0.07-0.28
Dee/White	0.11-5.43	0.08-0.63	0.07-1.71	0.05-0.78
Deel	0.15-1.10	0.21-0.39	0.04-0.70	no data
Dodder	0.14-0.23	0.02-0.14	0.12-6.60	0.04-0.36
Funshion	0.07-3.30	0.09-1.90	0.22-4.10	no data
Glyde/Proules	0.06-4.60	0.04-2.90	0.04-1.06	0.04-4.31
Graney (Shannon)	no data	0.02-0.05	no data	0.02-0.03
Liffey (Newbridge)	0.04-0.09	0.02-0.10	0.02-2.45	0.03-0.38
Liffey (Lucan)	0.11-0.13	0.07-0.17		
Loobagh/Maigue	0.33-1.10	0.12-1.10	no data	no data
Nenagh	no data	0.18-0.33	0.05-0.48	0.04-0.57
Rye Water	0.10-0.33	0.09-1.10	0.14-0.75	0.17-0.76
Shannon (L. Derg Inflow / Outflow)	0.03 (1 sample)	0.03-0.07	0.01-1.40	0.01-0.12
Suir (Thurles)	0.13-0.21	0.07-0.33	0.10-0.79	0.12-1.30
Suir (Cahir / C. on Suir)	no data	0.06-0.33		
Tolka	0.23-1.60	0.27-1.20	0.58-4.83	0.35-1.08
Triogue	0.11-1.60	0.15-1.80	0.23-1.45	no data
Ward	0.19-0.45	0.33-1.20	0.08-2.52	0.27-1.07

[1] Flanagan (1974); [2] Lennox and Toner (1980); [3] Flanagan and Larkin (1986); [4] Flanagan and Larkin (1992).

fertilizers/excess P fertilizer use with the occurrence of a number of pollution incidents in the southern part of the country have been made in the national press/radio. The question that arises here is the validity of the claim that there is a relationship between P fertilizer use, soil P status and appearance of fertilizer P in water courses. This claim derives from the correspondence between annual average values for Morgan's extractable P in the soils tested by Teagasc and the pattern of fertilizer P use in the country to 1990 (Tunney, 1990a; Tunney, 1990b). But as noted by Tunney (1990a) and Gately (1994), there is little information on the relationship between soil P status and P loss to water, and this position has not altered in the meantime.

In general, water soluble P fertilizers react with mineral soils in such a way as to render the P immobile/essentially immobile. This arises as a result of adsorption reactions between the P fertilizer and iron and aluminium oxide/hydrous oxide materials that are natural constituents of the soil matrix. In addition, some of the fertilizer P undergoes precipitation reactions, the nature of which vary with soil pH, but the effect of which is to contribute to the P retention mechanism. It is worth noting here that the mechanism(s) by which P is immobilized in mineral soils is essentially the same as that which would operate in the treatment of sewage for P removal, the need for which in the context of P loading of surface waters has been emphasised frequently in Ireland (Bowman et al, 1993; McGarrigle et al, 1993; Bowman, 1996).

The extent to which P fertilizer is retained/fixed in mineral soils is highly dependent on 'soil type', the term used to reflect the particular status of the soil in respect of properties such as parent material, hydrous oxide content, texture, structure, hydraulic conductivity, pH, depth, slope, elevation, water table height, drainage status etc. It follows from this that the manner in which a soil will respond/react with P fertilizer is quite individualistic. Equally, the extent to which a soil will release fixed/retained P for crop growth, or for transport, is also quite individualistic.

The P status of soils can be differentiated into two inter-related categories: the intensity-factor (I) which is the concentration of soluble orthophosphate in the soil water, and the quantity-factor (Q) which reflects the amount of P that can be released from the solid matrix to replenish the P removed from solution by crop uptake. Leaving aside the dependence of Q on the volume of soil exploited by roots and the factors that impinge on this, Q is related to the types of adsorbed P-products that form as a result of the fixation mechanism, and on the strength with which the P is held. The quantity-factor (Q) also depends on the types and solubilities of the precipitated P compounds in the soil. It is apparent here that many different sources/types of P contribute to Q, and since there is a multitude of soil types with different compositions and physicochemical characteristics, it is not possible to predict the relative contribution of each to the P buffering capacity of the soil. The significant issue here is that the true relationship between Q and I in a range of soils (i.e., the extent to which there is net desorption of P from Q to I over time) is not/cannot be accounted for by conventional soil testing procedures. And this can lead to a situation where two soils having the same amount of

available P as defined by a particular soil test (Morgan's, say) could respond quite differently to P fertilizer application. This point is illustrated by results from a replicated field plot experiment in which the yield response of herbage to increasing rates of P application on ten major soil types was assessed (Table 3). Superphosphate (8% P) was applied at 0, 20-30, 40-50 or 80-90 kg ha^{-1} P as a single

Table 3. Annual yield (t ha^{-1} d.m.) from control (P_0) and fertilized (P_{80-90}) plots (selected data)[1]

	1967		1968		1969		1970	
Soil[2]	P_0	P_{80}	P_0	P_{90}	P_0	P_{90}	P_0	P_{90}
Clonroche E (2)	9.0	9.4^{NS}	9.8	10.7^{NS}	12.1	13.7^{NS}	8.9	10.5*
Clonroche L (2)	5.7	6.5^{NS}	7.3	8.8^{NS}	9.5	10.9^{NS}	7.1	9.0^{NS}
Meath/Elton G (1)	9.1	10.3^{NS}	9.9	11.7^{NS}	10.1	12.2^{NS}	10.5	12.0^{NS}
Cork/Waterford D (1)	8.4	8.5^{NS}	10.1	12.3*	10.9	13.4*	7.3	11.1*
Meath/Elton H (2)	7.3	8.9*	9.0	13.0*	8.6	11.7*	7.0	10.6*
Coal Measures V (2)	6.4	8.9*	7.3	10.8*	6.3	10.4*	5.6	9.4*
E. Mayo/Galway Q (17)	8.2	9.7*	7.6	10.9*	8.2	11.1*	7.6	10.7*
E. Mayo/Galway R (7)	7.2	8.5*	7.4	9.4*	6.6	10.2*	5.6	9.3*

[1] Ryan and Finn (1976); [2] initial values for Morgan's available P in the soils shown in parentheses

dressing in March of each year. The data for cumulative annual yield from the P_0 and P_{80-90} plots in each year (Table 3) showed no significant response to fertilization among the upper group of soils, whereas the mid-group of soils (Cork-Waterford D, Meath-Elton H and Coal Measures V) did respond. Significantly, the initial Morgan's available P content of the soils in each of the two groups here was 1-2 mg kg^{-1} P. In the East Galway-Mayo soils Q and R, in which available P content at the start was 17 and 7 mg kg^{-1} respectively, significant yield responses to P fertilization were also found (Table 3). Taken together, these observations point to the fact that responsiveness of soils to P fertilizer is not/may not always be predictable on the basis of a soil test value alone. At present, our general knowledge of the manner in which the major soils in Ireland respond to P fertilizer is far from precise, emphasising the need to interpret soil test values for P with some degree of caution.

Notwithstanding shortcomings, soil P tests are used world-wide as the basis for making P fertilizer recommendations i.e., with appropriate delineation of soils into similar groups ("soil types") as well as appropriate correlation and calibration within groups, the test provides an index of the extent to which a soil will release P for growth, and the extent to which the soil should be supplemented with fertilizer P to achieve 'optimum' yield. Conventional soil tests for agronomic availability of P however (even those developed to the highest degree of precision) are not sensitive enough for environmental risk assessment (Sims, 1993; Sharpley et al, 1994; Pionke et al, 1997; Sibbesen and Sharpley, 1997). Because in the most simple scenario, sources (soils) with low soil test values and high runoff potentials could be major sources for P loss whereas soils with high P test values but low runoff potentials could represent minor sources for P loss (cf. Pionke et al, 1997).

This points to the risk of relating soil P test values alone with susceptibility of soils to lose P to water courses.

Generally, measurements of P loss that have been made in Ireland refer to extreme conditions in which the combination of soil and other factors contrived to 'maximize' the loss. Burke et al (1974) assessed P loss by surface and subsurface drainage from a poorly permeable undrained surface water gley to which a total of 464 kg ha^{-1} P had been added for the six-year experimental period. The salient features of the results for surface flow (Table 4) were that 69% of annual loss in 1966 was accounted for by two storm events that occurred in the five day periods immediately after the February and June applications of P. In 1967, likewise, 49% of annual loss was associated with one storm event that

Table 4. Phosphorus loss by surface flow from undrained gley at Ballinamore[1]

Year	Rate of P application (kg ha^{-1} yr^{-1})	Time of P application (month)	Rainfall (mm)	Surface flow (mm)	P loss (kg ha^{-1} yr^{-1})	Characteristics of yearly loss
1966	130	Feb/June/July	1393	637	5.2	69% in two events
1967	70	Jan/July	1173	353	3.7	49% in one event
1968	40	Nov	1269	462	1.9	32% in one event
1969	80	Mar/Oct	964	266	1.8	17% in one event
1970	80	Mar	1177	329	2.5	36% in one event
1971	64	Apr/Oct	906	154	0.9	no significant event

[1] Burke et al (1974)

occurred after fertilization in January. Disproportionate quantities of P were also lost during relatively short periods of rainfall activity in the other years of the study. Most notably though, when the site was dry at the time of fertilizer application in March, April and October, less P was lost in all of 1969 and 1971 than was lost during the single five day storm events in 1966 and 1967 - and this despite the high total application of P applied to the site prior to 1969 (240 kg ha^{-1} P). Large (17-31% of applied P) losses of P from poorly permeable sites were also found by Kiely and Roche (1981), and by Burke (1975) on drained and undrained blanket peat (~32% of applied P). Invariably the significant losses of P by surface flow occurred when the fertilizer was applied to wet land and when the ensueing pattern of rainfall favoured surface flow.

There is general agreement that P loss from land is far more likely to result from surface flow than from subsurface flow. It is also clear that the potential for loss by surface flow is not likely to be uniform across the country - that is, whereas some soils under some circumstances may be highly susceptible to surface flow (such as above), others are less so, while others are not susceptible at all. In this context, Gleeson (1992) has classified Irish soils into eight categories on the basis of their runoff risk potential. Even within a particular catchment, farm or field however, susceptibility to runoff losses can be highly variable as highlighted by Pionke et al (1997) who showed that nearly all

of the bioavailable P exported from a small (~26ha) catchment originated from less than 10% of the land area of the catchment. Generalized and unqualified statements relating to P fertilizer runoff from land such as have been recently made in the Irish literature and media, therefore, are simply not tenable.

Much of the case for the current review of P fertilizer recommendations is based on the P balance approach (Tunney, 1990a), and the fact that 20% (grassland) - 28% (tillage) of the soils tested by Teagasc in 1995-1996 had excessive (Index 4) levels of P (Coulter and Tunney, 1996). The excessive use of any nutrient (incl. P) for crop production is not justifiable, even on economic grounds. And few, therefore, can argue with the approach that seeks to minimize input costs without compromising output returns. To this extent, then, the current review is both timely and welcome. However, the basis on which the proposed new recommendations have been developed is not entirely convincing. Even with the most stringent test procedures, including correlation and calibration for different soil types/associations, soil testing is only an approximation of what the soil-crop-fertilizer response relationship is going to be under field conditions. And in Ireland, there is no formal recognition of the fact that different soils will/may react differently to P fertilization. A precision and interpretation has been applied to soil test values that was never meant to be applied. More so when soil test values are used to assess environmental risk.

The coupling (without qualification) of P soil test values and P fertilizer use with P loss to water is invalid because there is no scientific evidence for Ireland that fertilizer P runoff is of general occurrence or that the extent of fertilizer P runoff to surface water is related to Morgan's soil test values. Sites and circumstances under which surface water flow can occur have been identified here, and are otherwise identifiable. It is possible therefore to devise management strategies for these sensitive situations such that the twin objectives of agronomic benefit and fertilizer P retention on the farm are satisfied. Such an approach is preferable to one based on the questionable argument that P fertilizer applications are continually susceptible to runoff from the whole of what has been referred to as 'the national farm'.

It is hoped that the current debate on P fertilizer use will not shift the focus from what are now accepted as the primary causes/sources of pollution arising from agriculture i.e., animal manures, silage effluent and yard water. Likewise we should not lose sight of the significant adverse impact that municipal sewage and industrial effluents continue to have on water quality in this country. Nevertheless, the need to redress the practice of excess P fertilizer use is entirely defensible. But the substantial majority of farmers do not use excessive amounts of P fertilizer, and in the short-term, the priority objective should be to ensure that the new fertilizer recommendations do not threaten the production potential of this 'compliant' group of farmers. With the current state of knowledge, we can only speculate as to whether tangible benefits to water quality will follow implementation of the new advice. The hope of course is that both objectives wil be realised. The certainty of this, however, is more problematical.

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IRISH AGRICULTURE – LOOKING TO THE FUTURE

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The world for Agriculture and particularly Irish Agriculture, needs serious study with a view to putting in place policies for the future. The signing of the GATT Uruguay round and its implementation has changed European Agriculture in a manner equivalent to the setting up of the CAP. It is the general consensus that the next WTO round will continue this change. An excellent review of likely future trends was presented by Sir Leon Britton at the recent ICOS Conference. In this talk Sir Leon states that the EU will have to adapt and modify its policies in the future. This is in contrast to some EC member states, including Germany who feel that we have a nice semi-protected system and should keep it that way. The Commission does not hold with this view for three basic reasons:

1. We cannot treat the agriculture sector forever as though it was as economic activity separate from all others.
2. The Community is the biggest importer of agricultural produce and the second biggest exporter. We cannot remain involved in activity on this scale without rules. WTO makes the rules and we need to support the system.
3. No sector of the economy can thrive if it kept cocooned and isolated.

In my view the development of Agriculture over the next 25 to 50 years will be influenced greatly by world population and its influence on food demand.

The fact that there have not been major famines in the past few years has tended to let us overlook the inexorable growth of world population which is currently at 88 million extra people each year. The EU-15 has 372 million people so the world gets the population of another EU-15 every 4.2 years. These people must be fed. World population today stands at 5.8 billion. When some members of our illustrious audience were born it stood at a little over 2 billion as seen in Table 1.

Table 1 World Population (billion)

1650	0.55
1750	0.73
1850	1.20
1900	1.60
1950	3,00
2000*	6.20
2010*	7.00
2020*	7.90
2050*	10.00

*Projections

Cereal Demand

Cereals are the most basic of human foodstuffs, when either eaten directly in most societies or fed to livestock which end up in the human food chain.

World per capita cereal production has been in decline since about 1984. It amounted to about 280 kg in 1950 and increased to over 360 kg in 1984. Since then it has been in decline. A detailed evaluation of this topic has been given by Dyson (1996). Suffice it here to restate a few of his findings.

1. To meet demand, based on the assumption that per capita consumption will remain static to 2020 will require an increase in production from 1.923 billion metric tonnes in 1990 to 2.651 billion metric tonnes in 2020.
2. Allowing for an increase in per capita consumption in certain regions brings the demand in 2020 up to 2.960 billion metric tonnes.

3. The area sown to cereals in the world has remained static at about 700 million hectares, for the past 25 years. It is unlikely that substatial additional areas can be brought into production, hence future production to meet growing demand is largely a matter of yield. Yield has increased in a linear fashion (allowing for year to year variations) over the past 50 years and there is every reason to believe that with inputs of genetics, husbandry and fertility, this trend can be maintained.

   It is an interesting sidelight to note the contention that high yield agriculture is saving 10 million square miles of land for wildlife. This extra area would be needed to produce our present crops if technical agriculture had not been developed.
4. Many cereal growing areas however use sub optional quantities of fertiliser and Dyson estimates that will require a doubling of Nitrogen usage to meet cereal production targets for 2020.

An important aspect of cereal production in the year to year variation in yield per hectare. We can all come to terms with variation in yields in individual countries or regions. For examle, in Ireland year to year yield varied by 15% from 1992 to 1993 and by 12.8% from 1994 to 1995. One would assume that on a world scale good yields in one region would tend to balance out bad yields in another region, giving reasonable stability on a global scale.

Table 2 World Population ('000)

	1985	1990	2000	2010
World	4,863,675	5,295,176	6,228,330	7,149,761
Africa	554,508	642,581	856,155	1,116,253
N & C America	395,948	423,676	484,382	538,994
S America	267,689	294,115	344,460	391,685
Aia	2,844,014	3,118,039	3,961,883	4,213,969
Europe	499,391	500,807	515,518	527,579
Oceania	24,619	26,609	30,918	35,312
USSR (former)	277,506	289,350	305,014	325,699

Source: FAO

This is not the case and year to year variation does not vary up and down by up to 10% from year to year. This effectively means that without planned storage, years of plenty and scarcity can follow one another and the commercial consequence is price volatility even when over a five year period the correct amount is being grown and harvested.

I have referred to world population growth. It must now be emphasised that this growth is not evenly divided. The projections from 1985 to 2010 are given in Table 2. If we look at expansion from 1995 to 2010 (20 years) we see the following (Table3):

Table 3 World Population increases 1985 - 2010

	million
Africa	+ 341.3
N & C America	+ 83.4
S. America	+ 77.2
Asia	+ 788.5
Europe	+ 6.4
Oceania	+ 6.3
USSR (former)	+ 12.7

Food Demand

Being totally pragmatic we must look at food markets on the basis of the ability to buy as well as on population. On this basis Africa has a negative per capita GDP growth and thus although it provides a huge potential market, the area south of the Sahara except South Africa cannot be expected to develop in the next fifteen or twenty five years. Instead, it is likely to be an outlet for food aid.

Europe (including EU) presents problems as per capita consumption is high and static. Indeed the main feature of Europe is the growth of fads and food scares. With little population growth in Europe therefore presents a dull picture for an Ireland interested in expanding its food industry. At best we can take market share from our competitors.

While initially one can say that per capita consumption is also static in the USA, it has the expectation of a 13% growth in population in the 1995-2010 period. Other areas, particularly Mexico and Central America, have potential for both population and per capita growth.

South America has more stable political systems, rapid population growth, real GDP growth and so is likely to provide a growing and more sophisticated market for food in the future.

The most exciting area however is Asia. With huge population growth, rapid and consistant growth on GDP and dramatic growth in meat, fish and milk, this is the market of the future. While Europe and the USA suffer falls in beef consumption the story in Asia is as follows:

Period 1992-1996
Per capita growth in beef consumption

China	+ 153%
Hong Kong	+ 42%
Japan	+ 29%
Korea	+ 50%

Source Agra Europe Oct 25th

Similar examples could be supplied for pork, poultry, fish etc. A further feature of many Asian countris is the lack of arable land for expanding food production. There is therefore a major opportunity to export food from Europe.

Where do we stand now?

Ireland is a major exporter of food. In this sense it differs from its EU fellow member states. If one takes self sufficiency within the EU for any product as 100, the relative positions of Ireland and the EU-12 are as follows in 1994

Product	Ireland	EU-12
Beef	880	113
Milk	560	112
Sheepmeat	320	82
Pigmeat	200	103
Poultry	200	106
Cereals	86	126

This shows clearly that while the EU is close to self sufficiency in most major products and thus not involved in major export activity, Ireland has great surpluses in beef, milk, sheep and pigmeat and thus must export to survive.

Many examples can be produced to show the extent of this. Poultry is one where figures are available. From 1985 -1990 exports from the USA and the EU were similar and below 400,000 tonnes annually. By 1994, the EU had grown to 700,000 tonnes but the USA to 1,500,000 tonnes. The USA expects to increase this to 2,5 million tonnes by 1997, but Europe cannot even produce figures for 1995.

Growth in the world's population is presenting and will present, great opportunities for exports of food from Europe to the Far East. The WTO is opening up previously protected markets and allowing efficient and quality producers of food to increase exports to countries with high economic growth, high population growth and limited land resources. Ireland and Europe can participate in these new markets but to do so must get cost of raw materials right as well as developing the desire to expand and participate in these export markets. In my view continuing to attempt to remain self sufficient in a fortress Europe will lead to stagnation. Now is the time to develop our thinking and our policies for the next quarter century.

OPTIMISING FERTILIZER NITROGEN USE IN WINTER WHEAT PRODUCTION

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Research has shown that grain yield in winter wheat is closely associated with the nitrogen uptake of the crop, i.e. high nitrogen uptake levels are required for high grain yields. The high nitrogen uptake levels are required for the development of an optimum crop structure - large leaf size and leaf duration, combined with high ear numbers and good ear size which is the basis of high yield potential.

The key parameter is the cop nitrogen uptake (kg/ha) which is measured as the total nitrogen present in the above ground crop parts at harvest. The crop nitrogen uptake is the sum of the grain nitrogen and straw nitrogen with approximately 70% of the total crop nitrogen being in the grain at harvest.

In commercial winter wheat production the important practical relationship is the grain yield response to fertilizer nitrogen rate, i.e. the nitrogen response curve. As shown in Figure 1, the nitrogen response curves will vary considerably between sites as influenced by soil type and rotation. Data for three contrasting sites is presented in Figure 1, with the heavy textured Lyons soil representing a first wheat in a mixed grass/tillage rotation, contrasting with the similarly heavy textured North Dublin site which is in long term continuous wheat and the light Athy soil site which is also a first wheat crop but in a tillage rotation. The Lyons and Athy soils contrast both in the yield levels without fertilizer nitrogen and in the overall yield potential levels. The North Dublin site is particularly interesting with a low yield level at zero N but a high yield response to fertilizer nitrogen up to 210 kg/ha. Suitable fertilizer nitrogen programmes for such high 'response' sites will be discussed later.

The nitrogen response curve for the North Dublin site indicates low soil nitrogen availability and good yield response to fertilizer nitrogen use up to high total doses of 200-250 kg/ha (160-200 units/acre). When the relationship between fertilizer nitrogen rate and crop nitrogen uptake is examined for this site (Figure 2) we can quantify clearly the soil nitrogen component and the fertilizer nitrogen component of the total nitrogen uptake. Notable here is the high level of recovery of applied fertilizer nitrogen by the crop, averaging almost 60% for fertilizer nitrogen rates in the range 0-210 kg/ha.

When the two components of the total nitrogen uptake, that sourced from 'soil nitrogen' and 'fertilizer' nitrogen respectively are compared over a number of seasons at one location two observations can be made (Figure 3). The first is that the level of soil nitrogen uptake can be very variable between seasons, being very high at Lyons in 1992 but relatively low in 1986 and 1992. The second observation relates to the variation in the recovery in fertilizer nitrogen between seasons with recovery levels over the six seasons varying from a low of 30% in 1992 up to almost 60% in 1987 and 1988. In a 'normal' season it can be expected that 50% of the applied fertilizer nitrogen will be recovered in the crop at harvest. With regard to soil nitrogen supply the Nitrogen Index system used by Teagasc in formulating fertilizer nitrogen recommendations for cereal takes account of expected levels of soil nitrogen supply based on rotation and soil type factors.

While the theory is that high nitrogen uptake levels are required to achieve high yields in winter wheat the practical task for farmers is to alter fertilizer nitrogen programmes to more efficiently utilise the applied nitrogen.

Farmers have very complex decisions to make in selecting fertilizer nitrogen rates to use with decisions based on general nitrogen recommendations combined with other factors including personal experience, specific field history, cultivar characteristics, the season to date and crop condition at the time of application.

The conventional fertilizer nitrogen recommendations for winter wheat are based on a two-split application, while recent UCD trials provide show that where a three or four-split nitrogen programme is used then the optimum total nitrogen rate is higher.

In practice where modest 'total' fertilizer nitrogen rates are being applied to winter wheat up to 150 kg/ha (120 units/acre), then a conventional two-split nitrogen fertilizer programme is suitable. However, where 'high' fertilizer nitrogen rates are being applied, 200-250 kg/ha (160-200 units/acre), then multiple applications are the logical options i.e. a three or four-split nitrogen programme.

In multiple application fertilizer nitrogen programmes the first and second splits at conventional timings are followed by later applications at one or more of the following timings, mid-May (flag leaf), early-June (booting/ear emergence) and early-July (grain-fill). For the May and June timings CAN is a suitable nitrogen source while for the June and July timings a foliar urea spray is an effective nitrogen source.

In UCD trials carried out at two sites, a heavy clay-loam soil at Lyons farm and a lighter textured soil at Castledermot in South Kildare, show a 40 kg/ha nitrogen application at flag leaf giving a yield response of 0.3-0.4 t/ha with a late season application giving an average yield increase of 0.2-0.3 t/ha. Most significantly this yield effect is consistently found when applied following conventional two split applications at recommended rates.

With regard to milling wheat production each 40 kg/ha of 'extra' nitrogen lifts protein content by 0.%. A programme combining a mid-season and late-season application can lift protein by 1% (Figure 4). In this scenario yield increase comfortably covers the cost of the applications and the increase in protein content is a bonus.

Figure 1

Grain yield response to fertiliser nitrogen rate at three sites

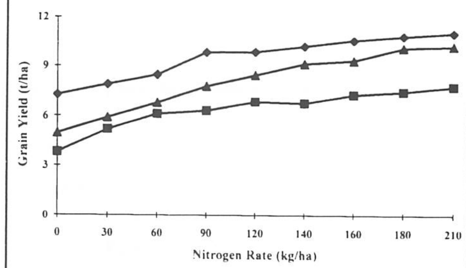


Figure 2

Crop Nitrogen Uptake for North Dublin site– Soil N and Fertiliser N components

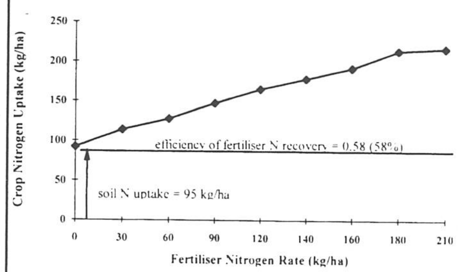


Figure 3

Soil Nitrogen Uptake and Fertiliser Nitrogen Uptake at Lyons over six years fertiliser nitrogen rate = 140 kg/ha

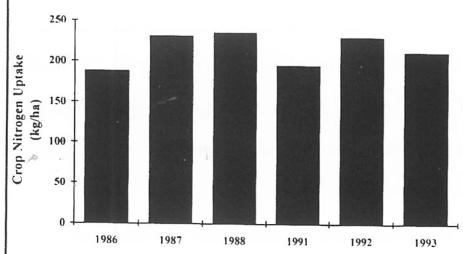
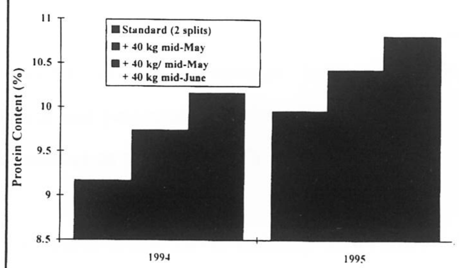


Figure 4

Protein response to 3rd and 4th split N: average of Lyons and Castledermot – 1994 and 1995



FERTILISER USE SURVEY 1995

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INTRODUCTION

The farm management survey data for 1994 and 1995 was used as the basis for a fertiliser use survey. The sample of farms was drawn by the Central Statistics Office on the basis of farm size and farming system. The survey was carried out on 1226 farms.

The data for 1995 is given in the report and the 1994 data is given in an Appendix.

Table 1 shows the trends in total consumption of fertiliser from 1985 to 1995.

Table 1: Use of fertiliser ('000 t per year)

Year	N	P	K
1984/85	327,709	66,028	163,811
1985/85	322,747	58,083	144,690
1986/87	371,646	65,887	165,495
1987/88	339,400	62,446	155,962
1988/89	349,025	64,665	160,718
1989/90	379,311	64,573	158,432
1990/91	375,457	62,573	152,640
1991/92	358,302	59,425	147,824
1992/93	336,814	59,370	146,273
Oct-Sept			
1992/93	377,985	61,451	151,622
1993/94	404,811	59,974	145,320
1994/95	428,826	62,410	150,543
1995/96	416,918	61,945	152,124
1996/97	379,468	53,760	132,114

Over the 10 year period 1984 to 1994, the nitrogen usage has continued to increase. In the 1994-1996 period nitrogen usage was at an all time high. Phosphorus and potassium sales have not changed dramatically, although sales of both elements have declined since the mid-1980's.

The total national consumption was calculated from the figures in this survey and they were compared to the sales figures in Table 1. In 1995, the N, P, K usage's calculated from the survey were 101, 104 and 105%, respectively of the 1994/1995 sales figures in Table 1. In 1994, the N, P, K usage's calculated from the survey were 95, 104, and 105%, respectively of the 1993/1994 sales figures in Table 1.

Table 2: Summary of the results from the survey of the use of N, P and K levels in 1995

	N (kg/ha)	s.e.*	P (kg/ha)	s.e*	K (kg/ha)	s.e.*	Mean Crop Area	No. of Farms in Survey
Spring Wheat	162	7.9	26	2.6	57	4.4	8.9	26
Winter Wheat	170	6.6	30	2.0	82	3.0	25.8	44
Spring Barley	104	2.6	27	0.7	57	1.5	9.5	160
Winter Barley	144	6.7	30	2.0	81	5.2	13.7	49
Malting Barley	107	3.0	23	1.3	57	2.4	13.1	74
Spring Oats	72	5.8	30	1.3	60	2.7	2.6	39
Winter Oats	120	7.9	28	3.4	63	8.2	10.5	18
Potatoes	121	8.5	101	5.0	245	1.7	1.9	84
Sugar Beet	183	5.2	56	1.7	203	5.7	8.5	52
Maize	106	9.3	37	9.7	55	14.3	5.0	10
Oats & Peas	84	16.3	18	4.0	40	7.9	3.0	10
Turnips	83	10.0	76	11.5	182	19.1	1.6	23
Fodder Beet	150	8.8	73	5.1	209	9.4	2.0	62
Kale & Rape	66	8.5	18	2.9	38	5.7	2.0	19
Hay	56	1.8	14	0.5	33	1.2	3.8	705
Silage	117	2.1	20	0.4	57	1.3	10.9	972
Total Grassland	103	2.6	14	0.3	34	0.7	33.0	1219
Grazing (estimate)	93	3.2	11	0.3	24	0.7	22.0	1177

*s.e. = Standard Error

Table 2 shows the levels of N, P and K used on the different crop in 1995. The standard errors (se) associated with values are also shown. This gives an indication of the reliability of the results. The smaller the standard error the better.

CEREALS

Table 3 summarises the fertiliser usage on spring wheat in the various counties where spring wheat is grown.

Table 3: Usage N, P and K on spring wheat in 1995

	N (kg/ha)	s.e.	P (kg/ha)	s.e.	K (kg/ha)	s.e.	Mean Size of sample (ha)	No. of farms
Carlow	189	10.6	24	5.2	56	8.8	10.4	7
Dublin	148	-	49	-	99	-	4.0	1
Kildare	170	16.3	22	2.2	66	10.4	9.5	4
Kilkenny	137	-	25	-	49	-	7.3	1
Laois	135	-	22	-	45	-	3.6	1
Louth	163	38.9	31	3.2	62	6.4	7.4	4
Wicklow	167	2.6	17	17.2	34	34.2	8.5	2
Cork	132	9.3	20	2.0	43	1.3	10.5	3
Tipperary South	155	-	25	-	49	-	8.5	1
Waterford	123	24.8	35	8.9	70	17.9	9.1	2
Mean	162	7.9	26	2.6	57	4.4	8.9	26

The Teagasc, N recommendations for Indices 2 and 3 are 140 and 100 kg/ha on shallow/sandy soils and 110 and 75 kg/ha on other mineral soils. The nitrogen usage would appear to be slightly higher than is recommended. The P recommendations for Indices 2 and 3 are 35 and 25 kg P/ha. The usage was in line with the recommendations. The K recommendations are 75 and 60 kg/ha. The K usage was perhaps a little less than that recommended.

Table 4 summarises the fertiliser usage for winter wheat.

Table 4: Usage of N, P and K in winter wheat

County	N (kg/ha)	s.e.	P (kg/ha)	s.e.	K (kg/ha)	s.e.	Mean Size of sample (ha)	No. of farms
Carlow	193	17.4	20	6.4	74	19.5	23.5	5
Dublin	131	67.1	26	2.5	83	37.2	25.5	2
Kildare	176	7.2	29	2.7	91	6.8	22.6	15
Kilkenny	170	7.9	39	1.8	81	6.7	5.6	2
Laois	176	30.0	19	0.9	71	8.5	6.1	2
Louth	189	8.1	37	3.7	85	5.9	44.7	5
Meath	187	13.7	32	7.4	78	9.2	48.5	5
Wexford	51	-	49	-	99	-	4.0	1
Wicklow	128	60.2	19	19.3	39	38.6	20.0	2
Tipperary North	195	-	24	-	101	-	6.1	1
Tipperary South	166	-	42	-	81	-	69.2	1
Donegal	125	39.9	33	9.2	83	19.7	6.2	3
Mean	170	6.6	30	2.0	82	4.3	25.8	44

The Teagasc N recommendations for indices 2 and 3 are 175 and 140 kg/ha for sandy/shallow soils and 140 and 100 for other mineral soils. The mean N usage was higher than the N recommended.

The Teagasc P recommendations for indices 2 and 3 are 35 and 25 kg kg/ha respectively. The mean P usage was in line with the recommendations. The K recommendations are 75 and 60 kg/ha for indices 2 and 3 and the mean K usage was very close to the recommended levels.

Table 5 summarises the fertiliser usage in winter barley.

Table 5: Usage of N, P, K for winter barley

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	No. of farms
Carlow	165	*16.2*	24	*9.4*	75	*19.6*	10.8	4
Kildare	131	*6.5*	32	*3.9*	111	*9.8*	13.0	14
Kilkenny	161	*4.2*	35	*2.5*	70	*4.9*	6.6	4
Laois	145	*32.4*	23	*3.7*	97	*15.9*	7.9	2
Longford	170	*0*	6	-	12	-	5.4	1
Louth	138	*16.2*	33	*3.0*	65	*6.0*	14.4	6
Meath	148	*10.6*	28	*5.5*	87	*15.2*	28.5	5
Offaly	85	-	39	-	77	-	13.0	1
Wicklow	52	-	0	-	0	-	5.3	1
Cork	163	*21.8*	28	*8.7*	49	*24.8*	14.3	2
Tipperary North	339	-	0	-	0	-	6.5	1
Tipperary South	247	-	39	-	78	-	18.2	1
Waterford	99	-	44	-	88	-	22.7	1
Donegal	130	*22.0*	38	*4.7*	74	*7.8*	12.9	5
Monaghan	105	-	38	-	76	-	10.5	1
Mean	144	*6.7*	30	*2.0*	81	*5.3*	13.7	49

The Teagasc recommendations for indices 2 and 3 are 165 and 125 kg/ha N in sandy/shallow soil and 135 and 100 in other mineral soils. The N usage was broadly in line with recommendations. As with the other cereals, the P usage was broadly in line with current recommendations. The K usage is 75 and 60 kg/ha for indices 2 and 3 and the K usage was broadly in-line with recommendations.

Table 6 summarises the fertiliser usage in spring barley.

Table 6: Usage of N, P and K for spring barley

County	N Usage (kg/ha)		P Usage (kg/ha)		K Usage (kg/ha)		Area	
	Mean	*s.e.*	**Mean**	*s.e.*	**Mean**	*s.e.*	**Mean**	**No. of farms**
Carlow	130	*7.7*	20	*2.2*	41	*4.0*	11.1	15
Kildare	124	*8.0*	27	*3.3*	46	*4.5*	11.0	8
Kilkenny	111	*9.9*	32	*3.2*	74	*9.8*	8.4	6
Laois	99	*9.0*	26	*1.5*	65	*6.0*	6.7	11
Longford	94	*0*	22	-	60	-	6.1	1
Louth	115	*10.8*	34	*2.4*	69	*4.9*	13.2	11
Meath	104	*16.9*	28	*6.7*	57	*13.4*	7.4	5
Offaly	110	*9.0*	29	*2.4*	62	*5.9*	11.2	12
Westmeath	131	-	25	-	49	*0*	4.9	1
Wexford	111	*7.2*	26	*2.0*	47	*3.4*	8.5	18
Wicklow	89	*17.0*	34	*3.6*	67	*7.2*	8.6	5
Clare	78	-	26	-	52	-	12.1	1
Cork	99	*5.9*	27	*1.7*	54	*3.3*	6.9	23
Kerry	80	*21.3*	33	*4.0*	65	*7.9*	6.0	4
Tipperary North	98	*11.4*	25	*1.9*	51	*3.8*	6.5	3
Tipperary South	106	*20.3*	26	*1.8*	51	*3.6*	20.1	3
Waterford	106	*12.4*	29	*3.4*	58	*6.9*	5.9	4
Galway	63	*11.4*	24	*3.2*	47	*6.6*	4.4	8
Mayo	37	-	37	-	74	-	3.2	1
Cavan	67	-	22	-	44	-	3.2	1
Donegal	98	*6.8*	28	*2.5*	56	*4.9*	15.1	18
Mean	104	*2.6*	27	*0.7*	57	*1.5*	9.5	160

The Teagasc N recommendations for Indices 2 and 3 are 125 and 100 kg/ha in sandy/shallow soils and 100 and 75 kg/ha on other mineral soils. The mean N usage was in line with the recommendations. The P recommendations are 35 and 25 kg/ha. Mean P usage was broadly in line with recommendations. Mean K recommendations are 75 and 60 kg/ha. K usage appeared to be a little below the recommended usage.

Table 7 summarises the fertiliser usage in malting barley.

Table 7: Usage of N, P and K for malting barley

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	**Mean**	*s.e.*	**Mean**	*s.e.*	**Mean**	**No. of Farms**
Carlow	118	*14.2*	20	*1.0*	41	*2.0*	8.2	8
Dublin	81	*9.0*	18	*4.8*	71	*3.7*	18.8	2
Kildare	129	*4.9*	10	*3.7*	70	*7.0*	22.2	9
Kilkenny	97	*11.1*	28	*3.6*	55	*7.1*	11.3	5
Laois	102	*12.1*	22	*3.2*	67	*6.4*	9.9	9
Louth	108	*4.7*	31	*7.0*	61	*14.1*	9.0	2
Offaly	126	*25.4*	41	*7.1*	84	*14.8*	21.6	2
Wexford	97	*6.6*	26	*3.2*	51	*6.3*	9.4	11
Wicklow	97	*8.4*	17	*17.1*	34	*34.2*	11.5	2
Cork	104	*5.4*	23	*2.2*	53	*5.6*	11.8	17
Tipperary North	103	*5.1*	15	*1.7*	45	*2.6*	20.0	3
Tipperary South	108	*6.3*	34	*2.5*	68	*5.0*	18.6	4
Mean	107	*3.0*	22	*1.3*	57	*2.4*	13.1	74

The Teagasc recommendations for N indices 1 and 2 are 120 and 100 kg/ha in sandy/shallow soils and 110 and 90 kg/ha in other mineral soils. The mean N usage was broadly in line with recommendations. If barley is grown on Index 3 soils, no N is required. P recommendations for Indices 2 and 3 are 35 and 25 kg/ha. The mean P usage was somewhat below the P recommendations. The K requirements for Indices 2 and 3 are 75 and 60 kg/ha. As in the case of the P, the K mean levels was below the recommendations. If straw was recycled the recommendations were very close to the actual usage.
Table 8 summarises the fertiliser usage in spring oats.

Table 8: Usage of N, P and K for spring oats

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	**Mean**	*s.e.*	**Mean**	*s.e.*	**Mean**	**No. of farms**
Carlow	106	*15.6*	29	*5.0*	48	*4.8*	3.1	5
Kildare	118	*4.6*	30	*7.5*	59	*150*	5.7	2
Louth	148	-	37	-	74	-	8.1	1
Meath	84	*14.8*	32	*0.9*	69	*3.3*	3.8	2
Wexford	62	*21.5*	27	*0.4*	41	*14.3*	1.9	2
Wicklow	41	-	41	*0*	82	-	2.4	1
Cork	64	*10.9*	32	*3.4*	65	*6.8*	1.7	4
Kerry	56	*18.0*	31	*6.6*	62	*13.2*	1.8	2
Waterford	97	-	43	-	86	*0*	4.0	1
Galway	41	*15.4*	32	*4.4*	70	*6.8*	1.6	6
Mayo	53	*14.0*	30	*8.2*	61	*16.4*	2.0	2
Donegal	68	*8.6*	26	*2.2*	52	*4.4*	2.1	11
Mean	72	*5.8*	30	*1.3*	60	*2.7*	2.6	39

Teagasc N recommendations for indices 2 and 3 are 125 and 100 kg/ha for sandy/shallow soils and 90 and 60 kg/ha for other mineral soils. The N usage was significantly lower than the recommended levels in many counties. The P recommendations for indices 2 and 3 are 35 and 25 kg/ha and by and large, the P usage was broadly in line with recommendations. The K recommendations for Indices 2 and 3 are 75 and 60 and the usage was below recommendations in several counties.

Table 9 summarises the fertiliser usage in winter oats.

Table 9: Usage of N, P and K for winter oats

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	**Mean**	*s.e.*	**Mean**	*s.e.*	**Mean**	**No. of farms**
Dublin	74	-	27	-	116	-	9.3	1
Kildare	104	*11.*	30	*3.2*	76	*15.3*	13.6	4
Laois	119	*7*	0	-	0	-	6.1	1
Louth	141	-	36	*1.3*	71	*2.6*	14.9	2
Wexford	151	*7.7*	32	-	64	-	7.5	1
Wicklow	87	-	14	*13.7*	27	*27.5*	8.4	2
Cork	133	*49.*	37	*0.0*	74	*0.0*	9.1	2
Tipperary North	136	*1*	0	-	0	-	6.1	1
Tipperary South	175	*14.*	47	-	93	-	14.2	1
Waterford	125	*6*	36	*5.3*	72	*10.7*	8.9	3
		-						
Mean	120	-	28	*3.4*	63	*8.2*	10.5	18
		14.						
		5						
		7.5						

Teagasc N recommendations for indices 2 and 3 are 125 and 90 kg/ha on sandy/shallow soils and 70 and 60 kg/ha on other mineral soils. The N usage was a little above the recommendations in most counties. However, there was only one farm in the sample in many counties. The P and K usages were broadly in line with recommendations.

Sources of Nutrients in Cereals

It has been possible to determine the sources of the nutrients that were used on the different crops in past surveys and again on this occasion. The changing preferences of farmers for different types of fertilisers for the different crops can therefore be followed.

Table 10: Sources of N for cereal crops

Compound N P K	Spring Wheat	Winter Wheat	Spring Barley	Winter Barley	Malting Barley	Spring Oats	Winter Oats
	Nitrogen - percent supplied from each source						
CAN	62.1	77.8	50.7	75.4	46.3	41.6	75.1
Urea	1.2	13.9	0.1	7.7	1.4	-	10.4
10:10:20	6.6	3.7	9.0	3.7	7.2	17.1	4.6
14:7:14	0.6	-	5.2	2.2	5.4	-	2.2
18:6:12	20.3	2.0	30.3	6.2	23.2	37.7	7.8
High N compounds	9.2	1.9	2.9	3.4	10.7	-	-
16:5:20	-	0.1	0.6	-	0.8	-	-
10:25:22 (N1)	-	0.6	-	1.0	0.3	-	-
15:3:20	-	-	0.5	0.4	4.5	-	-
15:10:10	-	-	0.7	-	-	3.6	-
10:7.5:17.5	-	-	-	-	0.2	-	-

The main point to be made here is the increase in the number of compounds used in cereal crops. In 1989, there were 8 compounds, while in 1995 there were 11. Straight nitrogen, mainly CAN, dominated the markets. 18:6:12 was the most popular compound used for all crops.

Table 11: Sources of P for all cereals crops

Compound	Spring Wheat	Winter Wheat	Spring Barley	Winter Barley	Malting Barley	Spring Oats	Winter Oats
	Phosphorus - percent supplied from each source						
0:7:30	1.5	29.4	1.2	20.7	1.6	0.3	12.3
10:10:20	40.3	25.7	38.1	17.8	31.8	46.4	19.8
14:7:14	2.0	-	11.0	5.2	12.0	-	4.7
18:6:12	14.4	4.5	42.8	9.9	34.2	34.1	11.2
High N compounds	14.8	3.0	1.7	3.8	12.0	-	-
0:10:20	-	32.5	1.9	36.8	1.2	12.6	51.9
16:5:20	-	0.2	0.9	-	0.1	-	-
10:25:22 (N1)	-	4.7	0.1	5.3	1.4	-	-
15:3:20	-	-	0.5	0.5	40	-	-
15:10:10	-	-	1.9	-	0.1	6.5	-
10:7.5:17.5	-	-	-	-	0.6	-	-
18:5:18		-	-	-	-	0.1	-

The increase in number of compounds containing P increased significantly, 18:6:12 remained highly popular as did 10:10:20, 0:7:30. The most popular compound for winter crops was 0:10:20. dominated the winter sown crops.

Table 12: Sources of K for cereal crops

Compound	Spring Wheat	Winter Wheat	Spring Barley	Winter Barley	Malting Barley	Spring Oats	Winter Oats
	Potassium - percent supplied from each source						
0:7:30	3.2	39.1	2.5	31.2	2.8	0.7	23.2
10:10:20	39.2	16.0	36.9	12.5	26.8	47.8	17.3
14:7:14	1.9	-	10.7	3.7	10.1	-	4.1
18:6:12	40.3	2.8	41.6	7.0	28.7	35.0	9.8
High N compounds	15.4	2.4	2.0	2.9	12.1	-	-
Potash 50% K	-	16.8	0.3	12.7	3.9	-	-
0:10:20	-	20.2	1.8	25.9	1.0	13.0	45.5
16:5:20	-	0.3	1.7	-	1.8	-	-
10:25:22 (N1)	-	2.4	0.1	3.1	1.0	-	-
15:3:20	-	-	1.5	1.0	11.2	-	-
15:10:10	-	-	0.9	-	-	3.3	-
10:7.5:17.5	-	-	-	-	0.6	-	-
8:5:18	-	-	-	-	-	0.1	-

Very little K was supplied as a straight or single nutrient fertiliser. While a whole range of compounds were used, 10:10:20, 0.7.30 and 18.6.12 dominated the market.

ROOT CROPS

Table 13 summarises the fertiliser usage in potatoes.

Table 13: Usage of N, P and K in potatoes

County	N (kg/ha) Mean	N (kg/ha) *s.e.*	P (kg/ha) Mean	P (kg/ha) *s.e.*	K (kg/ha) Mean	K (kg/ha) *s.e.*	Area Mean	Area No. of farms
Carlow	130	*29.8*	120	*34.2*	289	*47.1*	0.5	3
Dublin	168	*74.1*	109	*14.7*	217	*29.3*	5.5	2
Kildare	96	-	82	-	233	-	1.8	1
Laois	150	*55.2*	93	*21.8*	218	*53.1*	0.4	4
Longford	237	*193.8*	67	*29.2*	123	*16.7*	0.1	3
Louth	154	-	154	-	309	-	4.9	1
Meath	175	-	150	-	425	-	0.2	1
Offaly	175	-	150	-	425	-	0.2	1
Westmeath	87	-	75	-	212	-	0.2	1
Wexford	129	*28.1*	87	*27.2*	235	*55.9*	2.9	4
Wicklow	173	-	148	-	420	-	0.8	1
Cork	110	*21.7*	101	*19.0*	306	*58.6*	0.5	7
Kerry	185	-	185	-	370	-	0.8	1
Tipperary North	138	-	137	-	275	-	3.6	1
Galway	113	*15.7*	94	*10.5*	247	*23.1*	0.7	13
Mayo	137	*21.4*	122	*21.9*	319	*42.6*	0.1	8
Sligo	70	-	60	-	420	-	0.2	1
Donegal	101	*9.9*	97	*7.4*	204	*13.0*	3.7	30
Mean	121	*8.5*	101	*5.0*	245	*11.7*	1.9	83

The Teagasc N recommendations for main crop potatoes are 125 and 100 kg/ha for Indices 2 and 3. The recommendations for early potatoes are 110 and 85 kg/ha for Indices 2 and 3. Because there is such a variation in the use of different potato cultivars and in the effects of N on timber quality the use of a standard rate of N for all cultivars is incorrect. In the survey no distinction was made between crops or end uses. Counties, like Longford, Meath and Wicklow used higher N than standard recommendations. Several counties would have had Index 1 soils for potatoes and in these the N requirement is 150 kg N/ha for main crop. In this situation, usage was largely in line with recommendations.

The Teagasc recommendations for P for main crop potatoes are 100 and 75 kg/ha for Indices 2 and 3. For early potatoes the recommendations are 115 and 100 kg/ha for Indices 2 and 3. Usage was broadly in line with recommendations.

The Teagasc K recommendations for main crop potatoes are 245 and 185 kg/ha for Indices 2 and 3, and are 120 and 90 kg/ha for early potatoes. The K usage was very generous in many counties. Table 14 summarises the fertiliser usage in sugar beet.

Table 14: N, P, K usage in sugar beet in 1995

County	N (kg/ha) Mean	N s.e.	P (kg/ha) Mean	P s.e.	K (kg/ha) Mean	K s.e.	Area Mean	Area No. of farms
Carlow	187	*6.9*	56	*2.7*	221	*9.1*	11.2	13
Kildare	190	*13.2*	57	*3.7*	227	*17.2*	7.8	10
Kilkenny	125	*18.1*	49	*3.2*	183	*15.2*	3.9	4
Laois	165	*13.1*	71	*6.7*	216	*6.1*	5.3	6
Meath	172	-	56	-	231	-	13.8	1
Offaly	196	-	56	-	222	-	4.0	1
Wexford	183	*18.6*	52	*4.9*	192	*17.7*	5.5	3
Cork	208	*7.3*	46	*2.2*	161	*7.8*	7.8	11
Tipperary North	102	*13.6*	76	*2.3*	191	*5.6*	11.9	2
Tipperary South	241	*0*	61	-	214	-	27.5	1
Mean	183	*5.2*	56	*1.7*	203	*5.7*	8.5	52

Table 15 outlines the Teagasc N recommendations for sugar beet. It is clear from the table that N usages were significantly higher than the recommended rates. The Teagasc P recommendations for Indices 2 and 3 are 55 and 40 kg/ha. Many farms used slightly higher amounts than the recommended rates.

The K recommendations are 270, 180 kg/ha for Indices 2 and 3. The results show that the K usage was very variable between counties.

Table 15: N inputs for sugarbeet (kg/ha)* for combinations of N index, rainfall and soil-texture

Rainfall (mm) April-June	N Index 1	2	3	4
		Sandy Loam		
100	155	90	70	40
160	170	100	80	50
220	180	110	90	60
		Loam		
100	130	60	40	10
160	140	70	50	20
220	150	80	60	30

*For late-sown crops, reduce N by 20% if sown after April

Table 16 summarises the fertiliser usage in Fodder Beet.

Table 16: N, P, K usage in fodder beet

County	N (kg/ha) Mean	N s.e.	P (kg/ha) Mean	P s.e.	K (kg/ha) Mean	K s.e.	Area Mean	Area No. of farms
Carlow	186	*15.9*	63	*9*	205	*12.3*	2.0	12
Kildare	209	*46.0*	68	*3*	261	*21.0*	2.6	4
Kilkenny	160	-	49	-	173	-	0.8	1
Laois	239	*49.8*	75	*12.8*	202	*5.0*	2.9	4
Meath	123	-	135	-	225	-	1.6	1
Offaly	236	-	41	-	148	-	2.4	1
Wexford	142	*20.9*	97	*16.6*	207	*20.8*	1.9	10
Wicklow	82	*2.9*	25	*24.7*	89	*89.0*	8.5	2
Cork	132	*13.5*	74	*10.7*	230	*22.8*	1.9	17
Kerry	85	-	0	-	0	-	0.8	1
Tipperary North	118	*43.5*	97	*27.8*	237	*12.5*	1.7	2
Tipperary South	99	-	62	-	223	-	2.8	1
Waterford	89	*10.5*	77	*11.4*	215	*15.3*	1.6	3
Galway	99	*14.0*	63	*7.8*	182	*72.2*	1.5	2
Sligo	64	-	107	-	193	-	0.3	1
Mean	150	*8.8*	73	*5.1*	209	*9.4*	2.2	62

The Teagasc N recommendation for fodder beet is some 25 kg/ha more than is recommended for sugar beet (Table 15). Usage varied considerably between counties. The P recommendations for Indices 2 and 3 are 55 and 40 kg/ha. While usage was variable, it is obvious that in many counties P usage was well in excess of recommendations. K recommendations for Indices 2 and 3 are 270 and 180 kg/ha. While usage was variable, in general terms K usage was seldom below 180 kg/ha.

Table 17 summarises the fertiliser usage in turnips.

Table 17: N P K usage in turnips

County	N (kg/ha) Mean	*s.e.*	P (kg/ha) Mean	*s.e.*	K (kg/ha) Mean	*s.e.*	Area Mean	No. of farms
Carlow	77	*21.6*	77	*15.4*	194	*27.8*	1.6	2
Kildare	41	-	26	-	93	-	2.4	1
Laois	142	*82.8*	56	*18.9*	142	*8.2*	1.1	2
Louth	83	-	65	-	213	-	1.6	1
Offaly	56	*6.9*	61	*21.4*	145	*2.9*	6.3	2
Wexford	117	*27.9*	107	*51.0*	232	*32.3*	1.0	2
Wicklow	74	*24.6*	46	*15.4*	167	*55.5*	1.8	2
Cork	90	*10.4*	56	*6.5*	202	*23.4*	1.2	2
Galway	78	*16.0*	90	*27.9*	206	*43.8*	0.6	4
Roscommon	47	-	78	-	141	-	2.2	1
Donegal	125	-	125	-	250	-	0.0	1
Monaghan	31	-	34	-	56	-	1.6	1
Mean	83	*10.0*	64	*11.5*	182	*19.1*	1.6	23

The Teagasc N recommendations are 70 and 40 kg/ha for Indices 2 and 3. As there were only one or two farms in most counties the results for the counties were unreliable.

The recommended P levels for Indices 2 and 3 are 60 and 40 kg/ha. Most counties used P above that recommended levels. The recommended K levels for Indices 2 and 3 are 100 and 60 kg/ha. While results were variable, K usage tended to be higher than recommended.

OTHER CROPS

Table 18 summarises the fertiliser usage in maize.

Table 18: N, P, K usage for maize

County	N (kg/ha) Mean	*s.e.*	P (kg/ha) Mean	*s.e.*	K (kg/ha) Mean	*s.e.*	Area Mean	No. of farms
Carlow	126	-	13	-	22	-	6.9	1
Kildare	105	*8.3*	16	*16.2*	32	*32.3*	6.0	2
Kilkenny	63	-	0	-	0	-	7.3	1
Wexford	114	*19.9*	69	*5.2*	92	*21.5*	4.0	4
Wicklow	118	-	12	-	49	-	3.6	1
Waterford	88	-	29	-	41	-	4.9	1
Mean	106	*9.3*	36	*9.7*	54	*14.3*	5.1	10

The Teagasc N recommendations for maize for Indices 2 and 3 are 55 and 40 kg/ha nitrogen usage was considerably above recommended rates in all counties. P recommendations for Indices 2 and 3 are 25 and 20 kg/ha. Apart from Wexford P usage was below the recommended levels. However, it must be remembered that the recommended rates are for total nutrients and in many areas considerable amounts of slurry are probably applied to maize crops.

K recommendations for indices 2 and 3 are 125 and 100 kg/ha. K fertiliser usage was considerably below the recommended levels. As in the case for P, it is assumed that slurry was used to make up the shortfall between fertiliser usage and K requirements.

Table 19 summarises the fertiliser usage in arable silage.

Table 19: N, P, K usage for oats and peas (arable-silage)

County	N (kg/ha) Mean	*s.e.*	P (kg/ha) Mean	*s.e.*	K (kg/ha) Mean	*s.e.*	Area Mean	No. of farms
Kildare	127	-	13	-	27	-	4.5	1
Kilkenny	77	-	16	-	32	-	2.8	1
Offaly	25	-	25	-	49	-	2.0	1
Cork	102	*2.5*	10	*0.8*	31	*12.6*	2.1	2
Waterford	44	*22.2*	9	*2.5*	17	*5.0*	4.3	2
Galway	195	-	13	-	53	-	2.8	1
Donegal	59	*9.2*	36	*13.6*	79	*27.2*	1.4	2
Mean	84	*16.3*	18	*4.0*	40	*7.9*	2.8	10

The numbers of samples recorded in the survey was quite small. The N levels used was very variable. The N recommended for arable silage is indices 2 and 3 are 100 and 75 kg/ha. The P and K usage, although variable were quite low. However, as this is a silage crop, slurry would be used to supplement the P and K requirements on many farms.

Table 20 summarises the fertiliser usage in Kale and Rape.

Table 20: N, P, K usage for kale and rape

County	N (kg/ha) Mean	N *s.e.*	P (kg/ha) Mean	P *s.e.*	K (kg/ha) Mean	K *s.e.*	Area Mean	No. of farms
Kildare	81	*12.7*	0	*0.0*	0	*0.0*	3.8	2
Kilkenny	89	-	9	-	37	-	2.4	1
Offaly	17	*7.6*	17	*7.6*	34	*15.2*	3.4	2
Wicklow	56	*46.0*	3	*3.1*	11	*11.1*	3.0	2
Cork	84	*19.0*	21	*3.3*	43	*6.6*	1.8	6
Tipperary North	67	-	22	-	44	-	1.6	1
Waterford	74	-	25	-	49	-	2.4	1
Galway	50	*8.7*	27	*14.3*	52	*29.9*	0.7	2
Mayo	57	*16.2*	33	*8.4*	66	*16.7*	0.9	2
Mean	66	*8.5*	18	*2.9*	38	*5.7*	2.2	19

Numbers of samples per county in the sample were generally small. In Cork, where six farms were surveyed the N usage was 84 kg/ha, but the *s.e.* was 19.0, indicating quite a wide variation. While the mean P usage was 18 kg/ha, there was considerable variation between counties, K usage also varied widely.

Table 21: Sources of nitrogen for root crops, maize, kale/rape and oats/peas

Compound	Nitrogen - percent supplied from each source						
	Potatoes	Sugar Beet	Fodder Beet	Turnips	Maize	Oats Peas	Kale Rape
CAN	1.7	35.9	34.4	-	9.6	28.5	37.8
S/A 21% N	0.1	0.4	0.8	-	-	-	-
7:6:17	14.1	-	-	-	-	-	-
10:10:20	81.3	-	13.2	8.3	9.5	2.6	6.1
16:6:12	1.5	-	-	-	-	-	-
High N Compounds	0.3	2.3	0.6	-	8.4	41.5	15.6
Urea	-	-	-	-	-	-	0.7
8:5:18	-	0.8	27.9	60.1	-	-	-
9:4.5:18	-	27.2	7.2	-	-	-	-
9:6:15	-	4.8	0.8	-	-	-	-
13:4:14	-	27.1	7.9	-	-	-	-
18:6:12	-	0.8	4.6	14.9	29.1	21.4	39.5
6:10:18	-	-	-	11.7	-	-	-
9:7:23	-	-	-	5.0	-	-	0.2
Urea	-	-	-	-	33.2	-	-
15:10:10	-	-	-	-	10.2	-	-
14:7:14	-	-	-	-	-	6.0	-

Table 22: Sources of phosphorus for root crops, maize, kale/rape and oats/peas

Compound	Phosphorus - percent supplied from each source						
	Potatoes	Sugar Beet	Fodder Beet	Turnips	Maize	Oats Peas	Kale Rape
0:7:30	-	0.7	0.8	1.7	-	-	-
0:10:20	1.1	-	-	-	-	-	-
5:5:10	0.8	-	-	0.2	-	-	-
7:6:17	12.4	0.2	-	-	-	-	-
10:10:20	85.1	-	33.8	11.8	38.5	15.3	28.3
13:6:12	0.5	0.4	3.6	6.5	40.1	42.2	60.7
High N Compounds	0.1	0.6	0.1	-	7.3	24.6	7.1
Super 16% P	-	1.3	-	-	-	-	-
8:5:18	-	1.9	41.0	49.2	-	-	2.1
9:4.5:18	-	51.0	8.5	-	-	-	-
9:6:15	-	12.0	1.3	-	-	-	-
6:10:18	-	-	3.2	25.5	-	-	1.7
13:4:14	-	31.2	5.7	-	-	-	-
8:8:6	-	-	0.1	-	-	-	-
7:7:23	-	-	-	5.1	-	-	-
15:10:10	-	-	-	-	14.1	-	-
14:7:14	-	-	-	-	-	17.9	-

Table 23: Sources of potassium for root crops, maize, kale/rape and oats/peas

Compound	Potassium - percent supplied from each source						
	Potatoes	Sugar Beet	Fodder Beet	Turnips	Maize	Oats Peas	Kale Rape
Potash 50% K	0.8	-	-	-	-	-	-
0:7:30	-	0.8	1.1	2.6	-	-	-
0:10:20	1.0	-	-	-	-	-	-
5:5:10	0.7	-	-	0.2	-	-	-
7:6:17	16.6	0.1	-	-	-	13.1	26.9
10:10:20	80.2	-	19.9	7.1	38.5	36.1	68.0
18:6:12	0.5	0.6	2.4	4.6	40.1	35.5	-
High N Compounds	-	0.8	0.1	-	7.3	-	3.7
8:5:18	-	1.9	51.5	63.2	-	-	-
9:4.5:18	-	57.0	11.9	-	-	-	1.5
9:6:15	-	8.3	1.1	-	-	-	-
13:4:14	-	30.3	6.9	-	-	-	-
6:10:18	-	-	2.0	16.4	-	-	-
8:8:16	-	-	0.1	-	-	-	-
9:7:23	-	-	-	5.9	-	-	-
15:10:10	-	-	-	-	14.1	-	-
14:7:14	-	-	-	-	-	15.3	-

Table 24: N, P, K usage for hay

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	No. of farms
Carlow	61	*6.7*	13	*1.9*	31	*3.9*	4.9	30
Dublin	46	*8.0*	18	*4.6*	36	*9.3*	7.3	8
Kildare	75	*9.6*	15	*2.4*	42	*8.8*	9.2	20
Kilkenny	68	*6.8*	12	*1.7*	28	*3.4*	3.1	24
Laois	53	*7.7*	11	*1.8*	30	*5.8*	4.7	34
Longford	34	*5.9*	12	*2.6*	24	*5.0*	4.7	19
Louth	59	*13.2*	14	*4.2*	31	*8.8*	5.2	11
Meath	51	*6.7*	13	*1.7*	29	*4.1*	4.7	35
Offaly	62	*18.2*	18	*2.4*	47	*7.5*	3.9	27
Westmeath	38	*13.0*	12	*3.5*	26	*6.8*	4.0	6
Wexford	72	*6.6*	12	*2.2*	26	*5.5*	3.6	32
Wicklow	67	*16.6*	17	*3.0*	37	*7.9*	4.8	22
Clare	36	*7.7*	11	*1.7*	27	*4.6*	3.6	39
Cork	75	*6.0*	11	*1.3*	29	*4.1*	2.9	64
Kerry	48	*5.5*	15	*2.7*	30	*5.4*	2.6	36
Limerick	34	*6.3*	10	*2.3*	26	*5.0*	3.6	28
Tipperary North	64	*15.4*	16	*4.2*	42	*11.8*	3.8	14
Tipperary South	63	*9.3*	14	*3.1*	37	*11.6*	3.8	18
Waterford	75	*7.6*	14	*2.5*	34	*5.0*	5.2	16
Galway	47	*4.7*	20	*2.0*	47	*4.8*	3.2	56
Leitrim	31	*7.4*	12	*2.4*	29	*7.2*	3.2	13
Mayo	60	*7.4*	17	*2.3*	39	*5.3*	2.5	32
Roscommon	24	*5.8*	11	*2.6*	25	*6.3*	4.0	25
Sligo	39	*5.3*	14	*2.1*	31	*5.1*	2.9	15
Cavan	44	*6.2*	13	*2.1*	29	*4.2*	3.0	23
Donegal	79	*12.7*	17	*2.3*	40	*4.3*	2.5	42
Monaghan	43	*8.0*	12	*2.4*	27	*4.9*	4.8	16
Mean	56	*1.8*	14	*0.5*	33	*1.2*	3.8	705

The Teagasc N recommendations for hay is 80 kg/ha index 2-4, which is considerably higher than was used. The P recommendations for indices 2 and 3 are 40 and 35 kg/ha. The mean P usage was considerably lower than this. It is not certain that sufficient slurry and/or farmyard manure was returned to the hay fields. The K requirements for Indices 2 and 3 are 150 and 120 kg/ha. As in the case of P, the mean K usage was very low. Unless large quantities of slurry were used, K usage were well below what should be applied to give optimum yields.

Table 25 lists the straights and compounds used for hay, and also gives the N P K percentages supplied from each source. Straight CAN, 18:6:12 and high N compounds dominated the market. 18:6:12 and 10:10:20 were the principal sources of P, while 10:10:20, 18:6:12, 0:7:30 and high N compounds dominated the K market.

Table 25: Sources of N, P and K for hay crops

Compound	% Nitrogen	% Phosphorus	% Potassium
CAN	19.2	0.0	0.0
S/A 21% N	0.2	0.0	0.0
Urea	3.0	0.0	0.0
Super 8%P	0.0	0.3	0.0
Potassium 50%K	0.0	0.0	1.3
0:7:30	0.0	7.4	13.6
0:1020	0.0	4.6	3.9
5:5:10	0.0	0.0	0.0
10:10:20	7.3	27.5	23.6
14:7:14	0.2	0.4	0.3
15:3:20	0.5	0.4	1.0
18:6:12	34.6	43.3	37.1
10:25:22:NI	0.6	2.5	1.8
High N Compounds	34.3	13.5	17.2

Table 26: N P K usage in silage

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	No. of farms
Carlow	128	*10.3*	20	*1.7*	58	*5.2*	12.0	40
Dublin	103	*28.8*	16	*6.0*	37	*14.4*	6.5	5
Kildare	167	*12.4*	24	*3.1*	83	*9.5*	25.7	26
Kilkenny	137	*9.5*	18	*1.6*	56	*6.0*	15.5	30
Laois	120	*10.1*	22	*2.1*	65	*8.2*	15.3	31
Longford	81	*10.9*	20	*2.8*	47	*6.2*	7.3	27
Louth	126	*22.1*	12	*3.0*	36	*10.6*	8.3	14
Meath	130	*11.5*	19	*1.9*	53	*4.6*	17.2	40
Offaly	109	*10.1*	21	*2.7*	64	*9.0*	12.7	26
Westmeath	104	*11.5*	20	*3.3*	55	*7.5*	9.5	12
Wexford	126	*8.1*	17	*2.2*	37	*5.1*	11.6	33
Wicklow	122	*15.6*	25	*2.8*	72	*8.6*	16.7	29
Clare	88	*9.4*	19	*2.2*	62	*8.9*	7.9	40
Cork	156	*5.6*	21	*1.0*	67	*3.8*	11.0	128
Kerry	109	*7.7*	19	*1.3*	53	*4.5*	7.6	61
Limerick	114	*10.5*	16	*1.8*	54	*6.6*	12.7	31
Tipperary North	130	*15.0*	22	*6.3*	61	*12.0*	14.7	17
Tipperary South	148	*14.2*	15	*2.8*	49	*8.3*	15.8	24
Waterford	152	*10.2*	19	*2.2*	56	*6.8*	16.6	25
Galway	101	*7.0*	26	*1.4*	68	*4.2*	7.5	86
Leitrim	49	*4.7*	14	*1.3*	31	*4.3*	6.0	13
Mayo	105	*8.2*	26	*2.7*	66	*6.2*	6.2	59
Roscommon	53	*7.1*	19	*1.7*	48	*5.0*	6.5	31
Sligo	81	*14.4*	23	*2.6*	48	*5.4*	5.4	18
Cavan	78	*7.9*	15	*1.6*	41	*4.5*	6.6	35
Donegal	115	*10.3*	20	*2.4*	51	*5.1*	9.8	61
Monaghan	107	*8.6*	14	*1.7*	45	*4.5*	9.7	30
Mean	117	*2.1*	20	*0.4*	57	*1.3*	10.9	972

The Teagasc N recommendations for 1st cut and 2nd silage's are 125 and 100 kg/ha. The survey data was unable to distinguish between cuts and at a mean of 117 kg/ha, it would appear that N usage was broadly in-line with recommendations. The *s.e.* over the 972 samples at 2.1, is quite small, suggesting that the N usage figures were reasonably accurate. However, no account was taken of slurry applied in early spring which can supply N to the silage crop. The Teagasc phosphorus recommendations for silage are summarised in Table 27.

Table 27: Phosphorus recommendations for silage (**New 1997 Recommendations**)

Index	P (without slurry) kg/ha	P (with 33 m^3/ha of slurry) kg/ha
1	40	20
2	30	10
3	8	0
4	0	0

At Indices 2 and 3 and if slurry is not recycled, the P levels were near the requirements. However, it must be assumed that on most farms the slurry was recycled on the silage land, and in this situation P applications to silage were significantly higher than is now agronomically necessary under the new recommendations.

The recommendations for K in Indices 2 and 3 are 150 and 120 kg/ha for 1st cut silage and 50 and 35 kg/ha for 2nd cut. If it is assumed that slurry is recycled efficiently, the K usage was more than adequate to meet requirements.

Table 28 summarises the amounts of N, P and K that were applied to silage land in differing farming systems.

Table 28: The effect of farming system on N P K use for silage

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	No. of farms
Dairy	154	*4.4*	20	*0.7*	69	*2.6*	13.8	235
Dairy & Other	145	*4.3*	23	*1.1*	69	*3.3*	15.6	210
Cattle rearing	69	*3.6*	18	*1.2*	40	*2.4*	5.0	109
Cattle finishing	88	*3.6*	21	*0.9*	52	*2.2*	8.1	218
Sheep	84	*4.3*	20	*1.2*	50	*3.0*	6.9	142
Tillage	140	*8.9*	17	*1.9*	48	*6.1*	11.0	50
Pigs and Poultry	130	*15.1*	6	*2.2*	18	*8.0*	24.0	8
Mean	117	*2.1*	20	*0.4*	57	*1.3*	10.9	972

Farmers that have dairying as their main enterprise used the most nitrogen on their silage ground. Farmers with cattle and sheep as the main enterprise tended to use less nitrogen. Phosphorus and potassium usage followed similar trends.

Table 29 summarises the sources of N, P and K used for silage. CAN and Urea accounted for 43.3% of total N usage. High nitrogen compounds accounted for 44.7% of total N usage.

High N compounds accounted for 33.5 and 37.3% of P and K used on silage land respectively. 0:7:30 and 18:6:2 made up most of the balance, while small amounts of 10:10:20 were used.

Table 29: Summarises the type and percentages of fertiliser supply N, P and K to silage

	N, P, K percent from each source		
Compound	**Nitrogen**	**Phosphorus**	**Potassium**
CAN	30.0	0.0	0.0
S/A 21% N	0.2	0.0	0.0
Urea	15.3	0.0	0.0
Super 8% P	0.0	0.0	0.0
Super 16% P	0.0	0.1	0.0
Potash 50% K	0.0	0.0	0.2
0:5:5	0.0	0.0	0.0
0:7:30	0.0	27.6	38.1
0:10:20	0.0	7.3	4.7
5:5:10	0.0	0.0	0.0
10:10:20	1.1	7.3	4.7
14:7:14	0.1	0.3	0.2
15:3:20	0.0	0.0	0.0
18:6:12	8.0	18.5	11.9
10:25:22:NI	0.7	5.4	2.9
High N Compounds	44.7	33.5	37.3

Table 30 summarises the N, P, K usage for the total grassland area, *i.e.* hay, silage and grazing. It should be pointed out that lands devoted to rough grazing are not included in this survey. Nationally, there are approximately 450,000 ha of this type of land. By definition this category of land, in all probability, receives little or no fertiliser.

Table 30: N, P, K usage for total grassland

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	No. of farms
Carlow	111	*11.4*	13	*1.2*	34	*3.2*	34	51
Dublin	121	*38.5*	13	*2.9*	27	*5.8*	20	134
Kildare	131	*16.7*	13	*1.6*	36	*4.5*	48	43
Kilkenny	117	*14.0*	14	*1.4*	35	*4.0*	36	41
Laois	134	*16.9*	15	*1.5*	38	*4.5*	41	44
Longford	59	*9.2*	15	*1.7*	32	*4.2*	31	26
Louth	94	*15.1*	16	*2.3*	35	*4.7*	27	17
Meath	116	*11.6*	14	*1.3*	35	*3.5*	55	52
Offaly	83	*10.3*	14	*1.3*	32	*3.5*	33	44
Westmeath	71	*13.6*	13	*1.7*	32	*4.1*	31	18
Wexford	128	*15.7*	15	*1.8*	34	*4.9*	30	37
Wicklow	83	*11.7*	13	*1.4*	29	*3.2*	45	44
Clare	57	*8.5*	13	*1.2*	31	*3.1*	27	53
Cork	173	*8.7*	16	*0.8*	40	*2.2*	33	135
Kerry	102	*10.9*	13	*1.0*	33	*2.8*	27	72
Limerick	110	*14.9*	14	*1.9*	36	*5.0*	34	37
Tipperary North	109	*12.1*	15	*1.8*	39	*5.1*	36	27
Tipperary South	160	*19.2*	15	*2.1*	37	*5.4*	38	30
Waterford	134	*15.9*	15	*1.5*	39	*4.3*	48	29
Galway	80	*7.5*	16	*1.0*	41	*2.6*	29	90
Leitrim	21	*4.3*	7	*1.3*	14	*2.7*	29	20
Mayo	66	*5.8*	14	*1.0*	33	*2.4*	23	74
Roscommon	38	*6.6*	11	*1.4*	27	*3.6*	25	41
Sligo	62	*15.6*	12	*2.0*	25	*3.9*	27	20
Cavan	90	*11.9*	11	*1.1*	28	*2.6*	22	37
Donegal	83	*8.6*	12	*0.9*	27	*2.3*	25	88
Monaghan	111	*12.9*	11	*1.1*	27	*2.8*	31	35
Mean	103	*2.6*	14	*0.3*	34	*0.7*	34	1219

The mean N, P and K usages for grassland were 103, 14 and 34 kg/ha, respectively. There was wide variation between counties in the usage of N ranging from 21 kg/ha in Leitrim to 173 kg/ha in Cork. The phosphorus usage was more consistent between counties. Potassium usage was also reasonably uniform between counties.

Table 31 summarises the N, P, K usage on grazing land. These figures are estimated figures that were derived from the data on total grassland and land for hay/silage. There is an assumption that the silage areas used for grazing received N, P, K at half the rate used on the pasture areas in addition to the N P K for silage. This table also includes fertiliser rates on the varying farming systems and the influences of stocking rates on fertiliser usage.

Table 31: N P K usage on the estimated grazing areas

County	N (kg/ha)		P (kg/ha)		K (kg/ha)		Area	
	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	No. of farms
Carlow	124	*14.7*	12	*2.1*	27	*4.5*	23	48
Dublin	106	*36.4*	6	*2.5*	11	*5.0*	16	10
Kildare	175	*56.3*	8	*1.2*	20	*3.0*	32	39
Kilkenny	119	*14.6*	11	*1.1*	24	*2.9*	25	38
Laois	105	*20.6*	12	*1.7*	26	*3.7*	26	42
Longford	50	*8.8*	12	*1.9*	25	*3.9*	24	29
Louth	83	*16.0*	7	*2.2*	15	*5.2*	22	17
Meath	101	*10.1*	13	*1.6*	27	*3.3*	28	53
Offaly	65	*9.2*	9	*1.2*	20	*2.6*	24	39
Westmeath	51	*12.2*	10	*2.3*	20	*5.3*	23	14
Wexford	103	*13.3*	0	*1.4*	19	*3.6*	21	38
Wicklow	87	*12.7*	12	*1.8*	25	*3.8*	31	45
Clare	49	*6.4*	8	*1.2*	19	*3.4*	20	52
Cork	164	*9.4*	15	*0.9*	33	*2.1*	22	139
Kerry	90	*10.9*	11	*1.1*	23	*2.5*	19	67
Limerick	101	*14.6*	10	*1.4*	22	*3.1*	21	38
Tipperary North	66	*13.0*	9	*1.9*	22	*5.2*	24	19
Tipperary South	137	*15.9*	10	*1.7*	21	*3.7*	25	28
Waterford	152	*14.2*	15	*1.6*	32	*3.5*	34	30
Galway	62	*6.9*	13	*1.4*	27	*3.0*	21	92
Leitrim	19	*4.9*	7	*1.6*	14	*3.5*	20	18
Mayo	50	*6.2*	12	*1.5*	25	*3.6*	15	70
Roscommon	36	*6.8*	11	*1.9*	21	*3.5*	20	41
Sligo	38	*8.9*	9	*1.9*	19	*3.7*	23	19
Cavan	78	*11.3*	12	*1.4*	24	*2.9*	15	35
Donegal	63	*7.0*	11	*1.5*	22	*3.0*	19	84
Monaghan	97	*10.1*	11	*1.4*	21	*2.6*	18	33
Farm System								
Dairy	166	*6.2*	14	*0.6*	30	*1.5*	21	237
Dairy + Other	130	*6.6*	13	*0.6*	29	*1.4*	29	212
Cattle rearing	39	*4.1*	9	*0.9*	19	*2.0*	15	142
Cattle finishing	56	*3.1*	11	*0.6*	22	*1.3*	20	287
Sheep	52	*3.7*	10	*0.9*	22	*1.9*	24	206
Tillage	117	*27.4*	9	*1.2*	22	*2.8*	18	84
Pigs & Poultry	95	*24.9*	4	*1.8*	7	*3.7*	38	9
Stocking Rate								
0-1 LU/ha	32	*2.3*	7	*0.6*	16	*1.4*	20	287
1-1.5 LU/ha	82	*3.4*	12	*0.5*	24	*1.1*	23	439
1.5-2 LU/ha	137	*5.0*	13	*0.5*	29	*1.1*	24	379
2-2.5 LU/ha	179	*31.8*	17	*1.8*	35	*3.5*	20	72
Mean	93	*3.2*	11	*0.3*	24	*0.7*	22	118

The N usage on grazing land was 93 kg N/ha, with a wide use range between counties. Dairying used the highest rates of N, while cattle rearing used the lowest rate of N. Stocking rate was, as expected directly related to N usage. N usage was broadly in line with recommendations. For the purposes of this study, stocking rates above 2.5 LU/ha which were recorded on a small number of farms were discarded, because of the low number. Mean P usage was 11 kg/ha, with most P being applied to the dairying sector. As stocking rates increased P usage/ha also increased. The P recommendations for grazing is given in Tables 32 and 33.

Table 32: P recommendations for grazing (**New 1997 Recommendations**)

P Recommendations for Grazing (1) kg/ha				
Soil P Index	Dairying(2)			
	Stocking Rate LU/ha			
	1.0-1.4	1.5-1.9(3)	2.0-2.5	2.6-3.0(4)
1	16	19	32	36
2	6	9	22	26
3	0	0	12	16
4	0	0	0	0

Table 33: P recommendations for dry stock (**New 1997 Recommendations**)

P Recommendations for Dry Stock(1) kg/ha				
Soil P Index	Dry Stock			
	Stocking Rate LU/ha			
	1.0-1.4	1.5-1.9(3)	2.0-2.5	2.6-3.0
1	13	15	27	29
2	3	5	17	19
3	0	0	7	9
4	0	0	0	0

(1) These recommendations are calculated for the mid-point of each stocking rate range.

(2) Dairy recommendations assume milk yields of 5,000 l/cow/yr. For greater yields, add 1 kg P/1,000 L of extra milk to the figures in Table 32.

(3) If the stocking rate is at 1.9 LU/ha and early grass is required, add a further 5 kg P/ha to the recommendations for Indices 1, 2 and 3.

The recommendations in Tables 32 and 33 are based on replacing the P removed in product with fertiliser P, once target soil fertility levels are achieved. On this basis the mean P usage in many instances was above what is recommended. Potassium usage for grazing is 60 and 35 and 0 kg/ha for

Indices 2, 3 and 4. The mean K usage was 24, suggesting that on many farms K usage was well below the recommended levels.

There were very few pig/poultry farms in the survey, but in the 9 that were surveyed P usage is very low, suggesting that the P strategy on such farms was reasonably responsible, in that there is very little artificial P used.

Table 34 summarises the N P K usage in the farming systems at differing stocking rates.

Table 34: N P K for grazing in differing farming systems

System	SR	N Rate Mean	P Rate Mean	K Rate Mean	N
Dairy	0-1 LU/ha	60	8	15	25
	1-1.5 LU/ha	141	14	30	114
	1.5-2 LU/ha	226	15	33	87
	2-2.5 LU/ha	198	16	36	11
Dairy + other	0-1 LU/ha	57	8	16	17
	1-1.5 LU/ha	92	13	27	82
	1.5-2 LU/ha	161	14	31	101
	2-2.5 LU/ha	232	17	38	12
Cattle rearing	0-1 LU/ha	21	6	14	78
	1-1.5 LU/ha	58	11	21	41
	1.5-2 LU/ha	72	14	29	21
	0-1 LU/ha	27	7	13	81
Cattle	1-1.5 LU/ha	52	11	22	115
finishing	1.5-2 LU/ha	83	13	28	80
	2-2.5 LU/ha	117	21	41	11
	0-1 LU/ha	35	10	22	68
Sheep	1-1.5 LU/ha	36	8	17	59
	1.5-2 LU/ha	67	11	23	54
	2-2.5 LU/ha	106	13	27	25
	0-1 LU/ha	29	4	8	16
Tillage	1-1.5 LU/ha	70	9	22	24
	1.5-2 LU/ha	113	9	22	33
	2-2.5 LU/ha	358	19	41	11
	0-1 LU/ha	0	0	0	2
Pigs &	1-1.5 LU/ha	107	8	17	4
Poultry	1.5-2 LU/ha	143	0	0	3
Mean		93	11	24	1177

Table 35: Sources of N, P and K for grazing

Compound	N P K percent for each source: N	P	K
0	0	0	0
CAN	44	0	0
s/A 21% N	0	0	0
Urea	14	0	0
Super 8% P	0	0	0
Super 16% P	0	1	0
B Slag 6.5% P	0	0	0
R. Phos 11% P	0	0	0
Potassium 50% K	0	0	1
0:4.5:16	0	0	1
0:5:5	0	1	0
0:7:30	0	5	10
0:10:20	0	12	11
5:5:10	0	0	0
8:5:18	0	0	0
7:6:17	0	0	0
8:8:16	0	0	0
10:5:25	0	0	0
10:10:20	2	16	15
14:7:14	0	0	0
15:3:20	0	0	0
15:10:10	0	0	0
16:5:20	0	0	0
18:6:12	10	31	30
10:25:22:NI	1	6	5
High N Compounds	29	26	26

CAN and urea accounted for 58% of total N applied to grazing land, with high N compounds and 18:6:12 making up most of the balance. High N compounds supplied 26% of the P and K, with 18:6:12 making up 31% and 30% of P and K, respectively.