THE FERTILISER ASSOCIATION OF IRELAND

SOME FUTURE PROSPECTS FOR EXPANSION IN FERTILISER USE

D.P. Collins

WINTER MEETING – NOVEMBER 22nd, 1985

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W.A. Jackson and M.A. Morgan

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INTRODUCTION

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Because of the present situation facing our farming economy the Council for the Fertiliser Association of Ireland asked me to read a paper which would discuss the following points:

a) The present restraints on farmers and the sale of their produce
b) what will be the effects of those restraints on farming?
c) what can farmers do to overcome the restraints?

Keeping these points in mind what are the future prospects for expansion in fertiliser use? Finally to suggest what the Fertiliser Industry could contribute in the present crisis and in turn help itself.

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DAIRYING

It is unnecessary to discuss the E.E.C. milk Super Levy. Suffice it to say that the "freeze" on milk production is a real tragedy for young farmers and is, of course, a major disappointment to the Fertiliser Industry. The further suggestion of an extra 3 percent cut in milk output, if imposed, would offset all our national efforts in 1984 in achieving a 4.6 percent special derogation for Ireland.

The report by I.C.I. Dairymaid on 165 creamery milk producers for 1984–85 makes interesting reading and the following data produced from it (Table 1) suggests the direction the milk industry should take:

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Milk price	74p/gallon
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Meals cost	12.3p/gallon
Total feed costs (Fert., Meals, Silage)	26.0p/gallon

The total feed cost per cow was £270 and meals accounted for almost half this cost (47%) and only contributed 16% of the total energy used by the cow. Grass silage is a cheaper feed and it is, of course, an excellent consumer of fertilisers. The amount and quality of silage fed per cow is vital. The I.C.I. report shows that farmers who made 8 tonnes of silage/cow rather than 6 tonnes increased the profit margin over feed and forage by £75/cow, or 7.5p/gallon. The report showed once again the importance of cutting silage in time. Even silage cut at the end of May but only one week late, from a quality point of view, cost £60/cow more. In margins over feed and forage cost the top 25% of producers out-performed the bottom 25% by £65 per 1,000 gallons of milk produced. This is equivalent to 6.5p/gallon. These findings at farm level confirm the research results at Moorepark presented to the association by Donal McCarthy in 1982 in which he showed that meal feeding was at least four times the cost of silage feeding.

So the evidence is that dairy farmers should concentrate on doing what they do best. They should make superb quality silage and plenty of it, and reduce meal feeding to a minimum, before looking for an alternative enterprise for the land released as a result of reducing cow numbers. However, we never know when concentrates might again be competitive to high quality silage and this could leave farmers in a new situation.

THE FUTURE FOR MILK

What happens when the milk surplus is brought under control? Will Ireland get an increased milk quota? New comments of recent days certainly suggest that the country will be lucky to hold its quota. Will the purchase of milk quotas from small farmers occur? If this happens what enterprise will develop on those farms?

Money costs and inflation will be lower and this should benefit farming but the cost/price squeeze is getting worse. Milk quotas have not removed the imbalance between supply and demand for dairy products in the E.E.C. "The future possibility could be the reduction of milk prices towards world price levels, with less market support, thus increasing risk and responsibility involved in dairying". These are the words of L. Blake, Chief Agricultural Officer of the Allied Irish Bank.

BEEF INDUSTRY

There are no limitations yet within the E.E.C. in regard to beef production but increasing prices for this product are unlikely, so production must become more efficient. The E.E.C. spent £1,542 million supporting beef prices in 1984 and this is very unlikely to be increased. Increased added value to beef products, which is happening, must be the norm rather than the exception, and this in turn can contribute to an increased price for the raw material, i.e. beef sides. In return for this increased price, farmers must make some guarantee to have a continuity of supply of beef. This in turn requires a commitment to a system of production and a personal relationship with the factory to help underpin the farmer's confidence.

EFFICIENT BEEF SYSTEMS

Two systems of beef production practised in Ireland and having a potential for major improvements are (a) summer grazing with finishing cattle and (b) calf to beef system. Outlined in Tables 2 and 3 are some details from Grange where both those systems were efficiently managed.

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	4.32	5.55	5.55
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TABLE 3

Performance of Friesian steers on a calf to beef system at Grange (kg)

Initail weight	45
Weight at 10 weeks	104
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To justify the present high prices of stock, be they calves or store animals, the beef farmer must achieve high individual performance with his animals. Both systems highlighted here show that this is possible through proper fertiliser usage and good management while achieving high output/ha at the same time. Reliability in supply of the type of animal produced in those systems is what the meat factories and the markets want.

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So the support systems in the E.E.C. are being changed or removed. Such changes make a mockery of planning as, indeed, does the exclusion of two further carcase grades from intervention, i.e. U3 and U4. It is ironic that the better carcases, such as, U3 and U4, are ineligible and so are penalised, plus the fact that there are not many cattle coming into these categories.

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Fundamental changes are required, therefore, such as a deficiency payments system which would guarantee the farmers a decent income, the consumer cheaper food and overall either increase or maintain a high level of consumption of quality food which Ireland is producing. There is an E.E.C. prediction however, that beef supplies in 1986 will be only 0.6% above requirements and that in 1987 the supply will equal demand. If this occurs then the prospects for beef production should improve.

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Human food imports to Ireland in 1982 were worth £750m. Processed foods accounted for £425m. and 70% of this was in direct competition with Irish products. Some 25 to 50% of the present imports could reasonably be taken up by Irish producers. This represents a market opportunity of £155m. There must be some place for the fertiliser industry to find sales in that market.

Horticulture, i.e. vegetable and fruit producers have been poorly organised and lack a professional marketing approach, with the result that market requirements have not been properly predicted and there has been a failure to supply the consumer's needs.

Taking potatoes as an example, the decline in the area of this crop must be the biggest indictment of our agricultural economy. In 1948 Ireland had 155,000 ha of potatoes but to-day it is less than 32,000 ha. In the past, the country had in international name for both ware and seed potatoes, both of which were exported in large volumes, but to-day we are potato importers. The fact that the Dutch find potatoes to be their best paying field crop and that Ireland finds potato production declining, reflects our failure to organise this crop for efficiency in production and innovation in its marketing. There must be a place for the Fertiliser Industry to encourage a reversal of trends and in return obtain expansion of fertiliser use in a crop demanding high fertility.

Irish market gardening acreage is declining and so increasingly potatoes, cauliflower, onions, carrots and tomatoes are being imported. What is the fertiliser industry doing to stop this decline?

For home gardeners the small amounts of fertiliser required by them are either unavailable or at such exorbitant prices that it is off putting. Some fertiliser wholesaler must start supplying this market with appropriate fertilisers in handy amounts, e.g. 25 kg bags, at a reasonable price.

In the case of animal feedstuffs it is estimated that one million tonnes are imported annually in Ireland and that the potential exists to produce at least half of these imports, i.e. 500,000 tonnes within the country. With a conservative estimate of a 5 tonne/ha cereal yield this means an outlet exists on the home market for the produce of 100,000 ha of extra tillage. This would certainly provide a major market for increased fertiliser usage. It may be that some co-operation between the Fertiliser Industry and the Animal Feed Compounders could give this type of development an impetus which would have benefits for both industries and for farming.

DEVELOPMENTS LIKELY TO AFFECT FERTILISER USE

A general observation on agriculture, which I think we all can accept, is that a major restructuring is taking place but that nationally there is no worthwhile change in productivity. Now in making any projection about the future one must keep in mind that it is only one small step from simple surmising to ridiculous projections. One has only to remind you of the previous animal feed crisis year in 1980 when dire consequences were forecast for the cattle population of the country or the 1973 projection of the 4 million cows by 1984.

Within the E.E.C. at present the major demand is job creation for the people of the cities or towns and not those of rural areas who are either partially or fully employed. The resources of the E.E.C. will be directed away from agriculture. In Ireland this will mean a slow reduction in the price of agricultural goods and in turn a reduction in output of milk and meat products. Less milk means less dairy cows but more efficient cows will reduce the dairy herds still further. Indirectly, this will reduce the supply of calves for the beef industry which will only be partially compensated by having more beef cows. Dairy farmers will rear to slaughter weights more of their own calves and this will mean more efficient beef production because there will be no middle man.

There should be a swing to more silage but also to better quality silage and as far as the fertiliser industry is concerned this will help to maintain fertiliser usage at approximately its present level. The tillage sector, if it is not too shocked after 1985, may swing marginally towards import substitution and this will certainly increase outlets for fertiliser use but the tillage land on the heavier soils in the later districts will probably revert to grassland.

The age structure of our farmers is such that reduction in numbers will occur naturally but dramatically in the next 10 years and opportunities for enlargement of individual units will arise more widely but the resources may not be available to achieve it. With a down turn occurring and having occurred in the national populations of Europe and the populations being generally older, there can only be a reduced demand for foods and this means agriculture trimming its production to the requirements.

SUGGESTIONS FOR DEVELOPMENT

What practical contribution can members of the Fertiliser Association make to help farming at present?

1. Each Fertiliser company could select 10 to 20 farms and give them intensive advice, direction, encouragement and financial reward to help develop the poorer type of farm systems — get them aware of the importance of producing a commodity and having a proper understanding of what the potential is in using fertilisers and finally having a personal relationship with their market outlet. In other words, take a page from the renowned Dutch Nitrogen Demonstration farms and aim to achieve somewhat similar results. Do not select farms already well along the road to success but the ones needing the most initial pushing, urging and encouragement. Almost all companies have both the personnel and the resources to make big contributions to changing the attitudes and outlook among the weakest farmers.

2. Fertiliser companies should, instead of spending large amounts of money on advertisement, endeavour to achieve a more tangible result with such funds. For example, why not allocate a large part of such funds to run competitions for different categories of farmers and different systems of farming. The prize might be a foreign trip to an appropriate farm region, e.g. Dutch small farms for dairy farmers, Brittany for beef farmers or even within the country, such as,

Western farmers visiting regions in Munster and Ulster. There are numerous choices and the end result would certainly be longer lasting than a full page "Ad" in a weekly paper that is left aside on Saturday evening and forgotten about.

3. Could the Fertiliser companies in association with members of the Fertiliser Association of Ireland not set themselves a target to organise within each county in the country a Grassland Club? I make this suggestion because so much of our country is in grassland and such a large percentage of the fertilisers are used on grassland. I would not wish to see such clubs as elitist but a place to encourage individuals to take an active part and get to know their native counties in greater detail. Club meetings organised on the basis of farm category might be the best manner to encourage participation.

As an example, Co. Fermanagh has a thriving Grassland Club and its activities and efforts have had a reasonable influence on developments at individual farms and the key to the success has been the use of fertilisers.

REFERENCES

1. ***S. Mansholt (1972).*** European Economic Policies. J. Irish Grassl. and Anim. Production Assoc.
2. ***Inter-Departmental Committee on the Problems of Small Western Farms,*** Report on Pilot Area Development. Dublin, 1963.
3. ***Dairymaid Report I.C.I. (1985).*** Creamery Milk Herds.
4. ***McCarthy, D. (1982).*** Fertiliser Use for Dairying. Fertiliser Assoc. Ireland. Dubl. No. 21.
5. ***L. Blake (1985).*** Work effort reward within production and market constraints. Agricultural Science Association Conference. Cork.
6. ***D.P. Collins (1985).*** Beef Production from White Clover/Grass Swards. Comm. European Communities, Workshop on White Clover, Wexford.
7. ***F.J. Harte (1985).*** Calf management at grass. ACOT Seminar, Grange.
8. ***Industrial Development Authority, Ireland (1984).*** Consumer Foods: Ideas for Development.
9. ***Expansion of the Livestock Industry (1973).*** Publ. Irish Farmers' Assoc. Livestock Committee.
10. ***Walshe, M. (1972).*** Grassland Production and Utilisation. Jr. Ir. Grassl. Anim. Prod. Assoc. Vol. 7. pp. 36–63.
11. ***An Expansion and Investment Plan for Irish Agriculture (1972).*** Publ. Irish Grassl. and Animal Prod. Association.

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Within the E.E.C. at present the major demand is job creation for the people of the cities or towns and not those of rural areas who are either partially or fully employed. The resources of the E.E.C. will be directed away from agriculture. In Ireland this will mean a slow reduction in the price of agricultural goods and in turn a reduction in output of milk and meat products. Less milk means less dairy cows but more efficient cows will reduce the dairy herds still further. Indirectly, this will reduce the supply of calves for the beef industry which will only be partially compensated by having more beef cows. Dairy farmers will rear to slaughter weights more of their own calves and this will mean more efficient beef production because there will be no middle man.

There should be a swing to more silage but also to better quality silage and as far as the fertiliser industry is concerned this will help to maintain fertiliser usage at approximately its present level. The tillage sector, if it is not too shocked after 1985, may swing marginally towards import substitution and this will certainly increase outlets for fertiliser use but the tillage land on the heavier soils in the later districts will probably revert to grassland.

The age structure of our farmers is such that reduction in numbers will occur naturally but dramatically in the next 10 years and opportunities for enlargement of individual units will arise more widely but the resources may not be available to achieve it. With a down turn occurring and having occurred in the national populations of Europe and the populations being generally older, there can only be a reduced demand for foods and this means agriculture trimming its production to the requirements.

SUGGESTIONS FOR DEVELOPMENT

What practical contribution can members of the Fertiliser Association make to help farming at present?

1. Each Fertiliser company could select 10 to 20 farms and give them intensive advice, direction, encouragement and financial reward to help develop the poorer type of farm systems — get them aware of the importance of producing a commodity and having a proper understanding of what the potential is in using fertilisers and finally having a personal relationship with their market outlet. In other words, take a page from the renowned Dutch Nitrogen Demonstration farms and aim to achieve somewhat similar results. Do not select farms already well along the road to success but the ones needing the most initial pushing, urging and encouragement. Almost all companies have both the personnel and the resources to make big contributions to changing the attitudes and outlook among the weakest farmers.

2. Fertiliser companies should, instead of spending large amounts of money on advertisement, endeavour to achieve a more tangible result with such funds. For example, why not allocate a large part of such funds to run competitions for different categories of farmers and different systems of farming. The prize might be a foreign trip to an appropriate farm region, e.g. Dutch small farms for dairy farmers, Brittany for beef farmers or even within the country, such as,

Western farmers visiting regions in Munster and Ulster. There are numerous choices and the end result would certainly be longer lasting than a full page "Ad" in a weekly paper that is left aside on Saturday evening and forgotten about.

3. Could the Fertiliser companies in association with members of the Fertiliser Association of Ireland not set themselves a target to organise within each county in the country a Grassland Club? I make this suggestion because so much of our country is in grassland and such a large percentage of the fertilisers are used on grassland. I would not wish to see such clubs as elitist but a place to encourage individuals to take an active part and get to know their native counties in greater detail. Club meetings organised on the basis of farm category might be the best manner to encourage participation.

As an example, Co. Fermanagh has a thriving Grassland Club and its activities and efforts have had a reasonable influence on developments at individual farms and the key to the success has been the use of fertilisers.

REFERENCES

1. *S. Mansholt (1972).* European Economic Policies. J. Irish Grassl. and Anim. Production Assoc.
2. *Inter-Departmental Committee on the Problems of Small Western Farms,* Report on Pilot Area Development. Dublin, 1963.
3. *Dairymaid Report I.C.I. (1985).* Creamery Milk Herds.
4. *McCarthy, D. (1982).* Fertiliser Use for Dairying. Fertiliser Assoc. Ireland. Dubl. No. 21.
5. *L. Blake (1985).* Work effort reward within production and market constraints. Agricultural Science Association Conference. Cork.
6. *D.P. Collins (1985).* Beef Production from White Clover/Grass Swards. Comm. European Communities, Workshop on White Clover, Wexford.
7. *F.J. Harte (1985).* Calf management at grass. ACOT Seminar, Grange.
8. *Industrial Development Authority, Ireland (1984).* Consumer Foods: Ideas for Development.
9. *Expansion of the Livestock Industry (1973).* Publ. Irish Farmers' Assoc. Livestock Committee.
10. *Walshe, M. (1972).* Grassland Production and Utilisation. Jr. Ir. Grassl. Anim. Prod. Assoc. Vol. 7. pp. 36–63.
11. *An Expansion and Investment Plan for Irish Agriculture (1972).* Publ. Irish Grassl. and Animal Prod. Association.

SOME CURRENT CONCEPTS UNDERLYING NUTRIENT ACQUISITION AND UTILISATION BY CROPS

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INTRODUCTION

Plants absorb essential nutrients from the solution phase of the soil. The concentration of each nutrient in the soil solution is determined by various exchange and precipitation reactions, as well as by various biological transformations. The result of all these reactions, however, must be the maintenance in the soil solution of a concentration from which the roots can absorb the nutrient rapidly enough to meet the demands of the plant for optimal growth. Soil scientists have examined intensively the chemical, physical and biological properties of soils which influence soil solution concentrations. By relating these properties to nutrient acquisition and crop growth rates on various soils, they can reasonably well predict the soil conditions under which specific nutrients in the soil solution will be sustained at the necessary concentrations. Appropriate soil amendments and fertiliser treatments thus are based on reasonably well established soil characteristics.

But plants themselves play a role in the acquisition and efficient utilisation of nutrients. One way they do so is by altering the chemical, physical and biological attributes of the thin layer of soil immediately surrounding their root tissue (the rhizosphere), thereby altering the concentration of nutrients in the soil solution to which they are exposed. Plants also are able to adjust their capacity to absorb nutrients from a given soil solution concentration. Both alterations in root morphology and capacity for absorption by a given root mass can be brought about as the plants undergo nutrient stresses. Finally, plants differ substantially in the amount of a given nutrient which needs to be absorbed to produce optimal growth rates of specific plant parts such as forage, grain, tubers or roots. These plant attributes have not yet been characterised in the detail necessary to incorporate them into precise recommendations for specific soil conditions. But the magnitude of the effects are so substantial that it can be anticipated that they may be able to be utilised in future in ensuring maximal nutrient use efficiency. The hope is that ultimately they may be defined and manipulated precisely enough to be used for soil and fertiliser practices. It is the purpose of this paper to describe briefly some of these plant-related attributes which are involved in the efficient acquisition and utilisation of nutrients.

RHIZOSPHERE ACIDITY CHANGES

The hydrogen ion concentration in the soil (as measured by the soil pH) has a pronounced effect on the precipitation and exchange reactions which control the concentrations of various nutrients in the soil solution. As the soil acidity becomes greater (the pH decreases), the solubility of some trace elements tends to increase as does that of the toxic element aluminium. Within a certain range, the solubility of phosphorus (P) also tends to increase. Soil acidity also influences the microbial populations and the biological transformations which take place and thereby greatly influences the amounts of nitrogen (N) and sulphur (S) available for absorption. Hence, a knowledge of the soil pH is fundamental in assessing the fertility and productivity of a given soil. However, it has been known for a long time that plants have the capacity to alter the acidity of their rhizosphere and that whether this was increased or decreased depended upon the source of N to which the plants were exposed (Jackson, 1967; Nye, 1981). The magnitude of these pH changes in the vicinity of roots and the marked diversity among plant species in the response have only recently been demonstrated in soil systems. Likewise, concepts of how such changes in the hydrogen (H) ion concentration at root surfaces are brought about are only now commencing to emerge.

Rhizosphere pH changes have been clearly illustrated by Marschner and Römheld (1983) using a technique of embedding a dye onto the surface of a soil in which roots of plants were growing. The colour of the dye depended upon the acidity of the soil with which it came in contact. The effects were dramatic; when maize was grown in a soil at pH 6 with N supplied as ammonium (NH_4) a pronounced acidification (to pH 4.5 or below) was evident in the soil within a few mm of the root surface. When the soil was dressed with nitrate, (NO_3) precisely the opposite occurred, the thin soil zone near the roots became more alkaline than the bulk soil, increasing to greater than pH 7.0. Because the soil pH affects the solubility and mobility of many essential nutrients, such dramatic pH changes must have influenced greatly the concentration of these nutrients in the soil solution of the narrow zone of soil surrounding the roots and at the absorbing surfaces of the root cells.

These experiments (Marschner and Römheld, 1983) and other studies indicate that the acidifying effect in the rhizosphere accompanying the supply of NH_4 occurs with all species so far examined. Moreover, leguminous plants relying on N fixation also tend to acidify their rhizosphere, although to a lesser extent than occurs with NH_4. When NO_3 is the N source, however, the rhizosphere pH change is highly dependent upon the plant species. So far as is known now, all cereals and grasses when exposed to high NO_3 supplies tend to cause the rhizosphere pH to increase. When the NO_3 supply is low the tendency is less marked and some decreases in rhizosphere pH can occur in certain parts of the root system. Many broad-leaved species tend to exhibit relatively little pH change with NO_3. But, even at high NO_3 supplies, one species (chickpea) has a markedly acidic rhizosphere whereas the rhizosphere of maize growing in the same container becomes alkaline relative to the bulk soil. Thus, it is clearly evident that plants, within limits, can modify the soil environment to which their root systems are exposed. The effect is highly dependent upon the N source and is, at least in the case of NO_3, also highly species dependent.

A few examples suffice to illustrate the importance of these rhizosphere changes in acquisition of nutrients. Increases in P uptake in the presence of NH_4 as compared to NO_3 have been associated with the differences in rhizosphere acidity developing from the two N sources (Riley and Barber, 1971) although other effects involving root development and capacity to absorb P may contribute to such observations (Soon and Miller, 1977). On sandy, low exchange-capacity soils of Western Australia, marked alterations in soluble manganese (Mn) and aluminium (Al) were shown to result from the differential N sources supplied to subterranean clover (Jarvis and Robson, 1983a; 1983b). The acidifying tendency in legumes dependent upon N fixation has been shown to enhance the solubility of rock phosphate (Aguilar and van Diest, 1981) and may contribute significantly to soil acidification under long-

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It is not yet known with certainty how metabolic events in plant root tissue are altered such that the marked rhizosphere pH changes occur. Nevertheless, physiological and biochemical evidence supports a model which can accommodate most of the observed responses (Israel and Jackson, 1982). This model (Fig 1) envisages a series of proteins embedded in the root cell membranes which facilitates transfer of the essential elements from the soil solution into the root cells. Another protein has the capacity to utilise energy to secrete H ions into the ambient solution, thus resulting in a pH gradient across the membrane, with the cell interior becoming alkaline relative to the surrounding soil solution. The action of this H ion secreting protein also results in an electrical gradient across the membrane, with the cell interior being negatively charged relative to the exterior solution. The electrical gradient serves as an attractive force for entry of positively-charged nutrients such as potassium (K), calcium (Ca), magnesium (Mg) and NH_4 across their specific protein carriers. Entry of negatively charged nutrients such as phosphate (PO_4), sulphate (SO_4) and NO_3 is viewed as occurring across their specific carriers in exchange for the hydroxyl (OH) ions generated in the root cells by the original outward secretion of H ions. Thus, for each H ion excreted, a positively charged nutrient can enter the tissue and a negatively charged nutrient can also enter as it exchanges with the internal OH ion. If this equivalent transfer occurs, there will be no change in pH of the rhizosphere because the outwardly-secreted H, and the OH ions undergoing exchange for the anions, neutralize each other. If, however, there are few negatively charged nutrients present in the soil solution, such as may occur when NH_4 and a nitrification inhibitor is added to the soil, or when the uptake systems for these particular nutrients are not fully active, then less OH ions leave the tissue, the secreted H ions are not fully neutralized, and the rhizosphere becomes acid. Under these conditions the internal OH ions are consumed in the synthesis of organic acid anions which serve to balance the entering positively charged nutrients. Because the carrier systems for PO_4 and SO_4 do not operate nearly as rapidly as those for NO_3, it is the inward movement of NO_3 which largely determines how much OH ion secretion takes place. Carrier systems for NH_4 also operate quickly so that when this positively charged nutrient is present it is absorbed rapidly and contributes to the large net H ion secretion.

In order for the net inward movement of negatively charged nutrients to exceed that of positively charged nutrients, an additional way of generating OH ions in the root tissue has to occur. This is visualized to take place as a result of the reduction of NO_3, the OH ions so generated being used to supplement those generated by the H ion secreting mechanism. Under conditions where the soil mineral N supply is low and nodulated plants are relying largely on N fixation, the activity of the carrier systems for uptake of the positively charged nutrients exceeds that of the systems for uptake of negatively charged nutrients such that rhizosphere acidification takes place. Differences among plant species in their tendency for rhizosphere acidity-changes where NO is present may be viewed as resulting from differences in the efficiency with which their uptake systems for NO_3 operate relative to those responsible for uptake of the positively charged nutrients. The evidence for this model will not be described here, but a number of the predictions to be made from it have been verified (e.g. Israel and Jackson, 1982), and it serves as a useful way to visualise the dramatic changes that plant roots can make in modifying the acidity to which they are exposed.

ADJUSTMENTS IN NUTRIENT TRANSPORT

Plants undergo a number of adaptive responses when the soil nutrient supply is too low to sustain good growth (Chapin, 1980; Clarkson and Hanson, 1980). The nature of these responses differs to some extent for the various nutrients but the general tendency is to increase both the surface area of the roots for absorption and the capacity of the tissue to absorb nutrients. With N and P deficiencies, for example, there is a marked increase in the growth of the roots relative to the growth of the shoots. With cereals, shortly after a N deficient condition is imposed, there may be an actual temporary increase in the root growth rate as that of the shoot slows down (Morgan and Jackson, 1984). As the deficiency becomes more severe, root growth declines but the roots still continue to grow relatively faster than the shoots. Similar observations have been made with plants undergoing P deficiency, and in both instances there can be significant changes in the morphology of the root system. The consequence of these changes is an increase in the root surface area relative to the mass of the shoot tissue i.e. relatively more soil mass per total plant mass is permeated by the root system. An additional increase in volume of soil exploited in the case of P deficiency is brought about by the development of mycorrhizal associations where the fungal hyphae permeate the soil and increase the surface area for absorption.

In addition to these growth and morphological adjustments, there is a marked change in the capacity of root tissue to absorb the nutrient. As noted in Figure 1, each nutrient is viewed as having a specific transport system or carrier which facilitates its movement into the root tissue from the soil solution. When a plant becomes P deficient, for example, the capability of the plant to absorb PO_4, if it becomes available, increases appreciably (Clarkson and Scattergood, 1982). This alteration in capability for absorption has been demonstrated with a number of plant species by growing them in nutrient solutions at PO_4 concentrations ranging from an inadequate to an excessive supply. The plants are then transferred to a standard concentration which is labelled with the radioisotope P-32, and the entry of the labelled PO4 measured over a short time period. Such experiments consistently have shown that plants which are deficient in P have a much greater capacity to absorb P than plants which have been adequately nourished with P. This means that plants have a negative feedback control over the absorption mechanism for PO_4. A specific internal P compound, or a metabolic consequence of P nutrition, apparently exerts an influence over the PO_4 absorption mechanism.

It is not yet clear whether the differences in absorption rates are brought about by changes in the activity of the carrier systems or whether the control is exerted by altering the rate at which carrier systems are synthesised and degraded. Nevertheless, there is a significant, finely-tuned, internal control exerted over the absorption of a number of the essential nutrients. The pattern has been demonstrated with K, SO4 and NO_3 as well as more recently with NH_4. In these instances the absorption systems for a given nutrient have the capacity to operate at a rapid rate when the root system of a plant deficient in that nutrient is exposed to an adequate soil solution concentration, or when a portion of the root system of a deficient plant strikes a

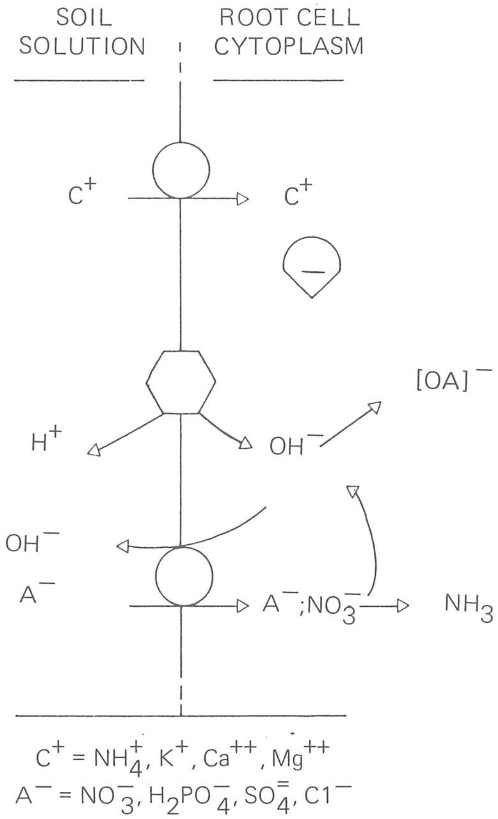

Fig 1: Schematic of metabolic processes which result in differential acidification of the rhizosphere of plant roots. C^+ represents positively charged nutrients such as ammonium, potassium, calcium and magnesium. A^- represents negatively charged nutrients such as nitrate, phosphate, sulphate and chloride. Separate and specific transport systems are envisaged for each nutrient.

zone of soil enriched in that nutrient (Drew **et al.**, 1984). Precisely how this adaptation response to nutrient stresses can be used in fertilisation and management practices has not yet been worked out. It seems reasonable to expect, however, that appropriate genetic manipulations could result in plants that are highly efficient in absorbing nutrients from very low soil solution concentrations.

NUTRIENT USE EFFICIENCY

Plants differ in the amount of growth produced per unit of absorbed nutrient (Chapin, 1980; Clarkson and Hanson, 1980). This may result from differences in the concentration of the nutrient at functional sites required for optimal metabolic rates, or from differences in the effectiveness of redistribution within the plant from storage locations to regions where the nutrient participates in essential processes. Hence, overall efficiency in the use of a given nutrient involves considerations of both efficiency in acquisition (uptake from the soil) and efficiency in its utilisation for the production of dry matter or specific plant parts after it has been absorbed.

For a given genotype, the relative contributions of uptake efficiency and utilisation efficiency for a given nutrient can vary between soils or nutritional conditions. Relative contribution of each attribute to overall nutrient use efficiency can also differ among cultivars of a single species growing in the same soil. This concept has been illustrated by Moll **et al.** (1982) with eight experimental maize hybrids growing on a sandy loam soil at either low or high N supplies. Because grain was the plant part of interest, N use efficiency was defined as grain weight produced/unit N added to the soil (Gw/Ns). Nitrogen uptake efficiency was defined as the total amount of nitrogen absorbed by the plant at physiological maturity per unit of nitrogen supplied (Nt/Ns), and N utilisation efficiency was defined as the amount of grain produced/unit N absorbed (Gw/Nt). Nitrogen use efficiency is thus the product of uptake and utilisation efficiency (Gw/Ns = Nt/Ns x Gw/Nt). Hence, by simple measurements of grain weight and total plant N, the two components of N use efficiency can be delineated.

A comparison of these two traits and their relative contribution to N use efficiency indicates the advantages of the approach. Data for four hybrids at two levels of fertiliser application are shown in Table 1. At the low N level, a significant range (from 120.2 to 72.8g grain/g N supplied) in N use efficiency occurred among the hybrids. The difference between the highest (No 7) and lowest (No 5) was totally a result of ineffective grain production/unit N absorbed (utilisation efficiency) by No 5; they did not differ significantly in their capacity to absorb N. On the other hand, hybrid No 8 was relatively ineffective in absorbing N although its utilisation efficiency was equal to that of hybrid No 7. Differences among the genotypes in N use efficiency were also evident at the high N supply, but the genotypic rankings were not the same as at the low N supply. Thus, at the high N supply, hybrid No 2 compensated for a low utilisation efficiency with a high uptake efficiency. Hybrid No 5 had a low N use efficiency at both levels of N but for different reasons. At low N supply it was ineffective in N utilisation whereas at high N supply it was ineffective in N uptake.

Both uptake efficiency and utilisation efficiency can be sub-divided into further components which tend to reflect specific plant processes. Uptake efficiency (Nt/Ns), for example, can be described as the product of total root mass/unit N supplied (Rm/Ns) and the amount of N absorbed/unit root mass (Nt/Rm). Thus, Nt/Ns = Rm/Ns x Nt/Rm. As noted in the previous section, both components of uptake efficiency may be altered as plants undergo nutrient stresses, and significant differences in each may occur among various genotypes. However, evaluating the relative contribution of each component to uptake efficiency under field conditions is very difficult. There is less difficulty in ascertaining experimentally the component traits of N utilisation efficiency (Gw/Nt) because measurements can be made on the above-ground part of the standing crop. Nitrogen utilisation efficiency can be described as the product of grain weight produced/unit N in the grain (Gw/Ng) and the fraction of the total plant N that is translocated to the grain (Ng/Nt). Thus Gw/Nt = Gw/Ng x Ng/Nt. The first component is the inverse of the N concentration in the grain and the second reflects the ability of the plant to redistribute absorbed N for vegetative to reproductive growth. In the eight experimental hybrids examined by Moll **et al.** (1982), significant independent variation in each component of N utilisation efficiency was observed, and the hybrids ranked differently at the different levels of N supply.

Overall, the data illustrate appreciable genetic variation in N use efficiency, in the two main traits whose product results in N use efficiency (i.e. uptake and utilisation efficiency) and in the individual components which contribute to N utilisation efficiency. It is important that these various attributes tended to vary among the hybrids independently of one another. This implies that genotypes with specific desirable traits can be selected, or combined with material having other desirable traits, for significant improvement in N use efficiency in their progeny. It is equally important that there were distinct differential responses in each of the attributes to variations in N supply. Some hybrids, for example, were able to absorb N efficiently at a low supply but were not especially efficient at a high supply (Table 1). Moreover, one hybrid (No 5) actually had a higher utilisation efficiency at high N supply whereas the others all tended to be lower.

TABLE 1

Nitrogen use, uptake and utilisation efficiencies in four experimental maize hybrids at two fertilizer nitrogen applications (Moll et al., 1982)

	NITROGEN EFFICIENCY		
HYBRID	*USE (Gw/Ns)*	*UPTAKE (Nt/Ns)*	*UTILISATION (Gw/Nt)*
Ns = 2.47 g/plant			
7	120.2	2.04	58.9
8	103.0	1.75	58.7
2	88.4	2.12	41.6
5	72.8	2.08	35.0
Ns = 9.88 g/plant			
7	27.9	0.58	48.0
8	26.0	0.57	45.2
2	27.8	0.77	36.0
5	19.7	0.43	46.0

The differential responses in the component traits to variations in N supply implies that superior genotypes can be developed to meet specific soil and management practices. This possibility is further emphasised by recent information indicating a distinct difference among maize hybrids in their capacity to absorb N as NH_4 or as NO_3 during the grain-filling period (Pan **et al.**, 1984). Finally, it would seem possible to evaluate use efficiencies of other nutrients and with other crops using the concepts of Moll **et al.** (1982). The approach is relatively straight-forward and provides information which has a bearing on performance under varying soil conditions as well as the development of genetic materials specifically adapted to them.

REFERENCES

Aguilar, A. and A. van Diest (1981). Rock phosphate mobilization induced by the alkaline uptake pattern of legumes utilizing symbiotically fixed nitrogen. Plant and Soil 61:27–42.

Chapin, F.S. (1980). The mineral nutrition of wild plants. Ann. Rev. Ecol. Syst. 11:233–260.

Clarkson, D.T. and J.B. Hanson (1980). The mineral nutrition of higher plants. Ann. Rev. Plant Physiol. 31:239–298.

Clarkson, D.T. and C.B. Scattergood (1982). Growth and phosphate transport in barley and tomato plants during the development of, and recovery from, phosphate deficiency. J. Exp. Bot. 33:865–875.

Drew, M.C., L.R. Saker, S.A. Barber and W. Jenkins (1984). Changes in kinetics of phosphate and potassium absorption in nutrient deficient barley roots measured by a solution-depletion technique. Planta 160:490–499.

Israel, D.W. and W.A. Jackson (1982). Ion balance, uptake, and transport processes in N_2– fixing and nitrate-and urea-dependent soybean plants. Plant Physiol. 69;171–178.

Jackson, W.A. (1967). Physiological effects of soil acidity. In: Soil Acidity and Liming, pp 43–124, ed R.W. Pearson and F. Adams, publ. American Society of Agronomy, Madison, Wisconsin, U.S.A.

Jarvis, S.C. and A.D. Robson (1983a). The effects of nitrogen nutrition of plants on the development of acidity in Western Australian soils. I. Effects with subterranean clover grown under leaching conditions. Austr. J. Agr. Res. 34:341–353.

Jarvis, S.C. and A.D. Robson (1983b). The effects of nitrogen nutrition of plants on the development of acidity in Western Australian soils. II. Effects of differences in cation/anion balance between plant species grown under non-leaching conditions. Austr. J. Agr. Res. 34:355–365.

Marschner, H. and V. Römheld (1983). In vivo measurement of root-induced pH changes at the soil: root interface: effect of plant species and nitrogen source. Zeit. für Pflanzenphysiol. III: 241–251.

Moll, R.H., E.J. Kamprath and W.A. Jackson (1982). Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agron. J. 74:562–564.

Morgan, M.A. and W.A. Jackson (1984). Unpublished data. Department of Agricultural Chemistry and Soil Science, U.C.D., Belfield, Dublin.

Nye, P.H. (1981). Changes of pH across the rhizosphere induced by roots. Plant and Soil 61:7–26.

Olsen, R.A., R.B. Clark and J.H. Bennett (1981). The enhancement of soil fertility by plant roots. Amer. Sci. 69:378–384.

Pan, W.L., E.J. Kamprath, R.H. Moll and W.A. Jackson (1984). Prolificacy in corn: its effects on nitrate and ammonium uptake and utilisation. Soil Sci. Soc. Amer. Jour. 48:1101–1106.

Riley, D. and S.A. Barber (1971). Effect of ammonium and nitrate fertilisation on phosphorus uptake as related to root-induced pH changes at the root-soil interface. Soil Sci. Soc. Amer. Proc. 35:301–306.

Soon, Y.K. and M.H. Miller (1977). Changes in the rhizosphere due to NH_4^+ and NO_3^- fertilisation and phosphorus uptake by corn seedlings (Zea mays L.) Soil Sci. Soc. Amer. Jour. 41:77–80.