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## THE FUTURE OF FERTILISERS

By J. C. Andrews, Epsom, Auckland.

It is with some considerable doubt in my mind that I have agreed to give a talk on the future of fertilisers. It is always difficult to be a prophet, but I agreed in the end because one can see certain trends in the fertiliser industry which are likely to develop as time goes on and as more knowledge concerning fertilisers develops. At the outset, our present knowledge of the soil sets limitations on what one can do in regard to fertilisers and advances in the future must depend to a large extent on increased knowledge of the soil itself.

While today the soils of New Zealand can be roughly classified into various types and the Soil Bureau is actively engaged in increasing our knowledge regarding the soil, when it comes to a question of fertilisers one is immediately confronted with a lack of knowledge on a number of soil factors. The most important of these are:-

(1) Soil Structure<sup>7</sup> - Soil may be roughly defined as rock degraded into small particles and incorporated therewith compounds of organic decay, and containing moisture and life in the form of micro-organisms, nematodes and other invertebrates. Not only are there active changes being brought about by the micro-organisms of the soil, but also the state, nature, and conditions of the rock particles themselves may have a very distinct bearing on what will happen when fertilisers are applied to such a system. The small particles involve a large surface area capable of adsorbing both moisture and fertilising substances. Different soil types are composed of different types of broken down rock particles, the chemical nature of which varies from type to type. While undoubtedly certain common factors may be present in most types, there are many others which vary according to the type of soil. Considerations concerning the structure of soil must involve further studies in the realms of soil chemistry, soil physics, soil moisture, and soil micro-biology. When a fertiliser is added to a particular soil type some of the fertilising substance is adsorbed on to soil particles and held there until some other agency is able to remove it. In other cases, the fertilising material re-acts directly with some chemical substance in the soil to produce an insoluble material which is not available to the plant. When such a re-action occurs to a large extent, the soil is said to have a high "locking" value. In other cases a similar type of re-action may occur but the resulting product may still be available to the plant. Furthermore, certain compounds of the fertiliser with soil ingredients may not be available to plant life but may be made available per medium of some other agency - for example, micro-organisms. Further, the ability of a soil to become a medium of fertility is known to be bound up with its state of aeration.

(b) Soil Moisture - It goes without saying that unless the moisture content of a soil is adequate, it cannot support plant life satisfactorily, inasmuch as moisture constitutes by far the greatest component of the plant by weight. Consequently, a supply of moisture in the soil is necessary. So far we have very little knowledge concerning soil moisture. We do know, of course, the effect of drought where an under-supply of moisture is obviously demonstrated, and water logging of the soil as occurs in swamp areas where an over-supply of moisture is available, but taking ordinary soil conditions we should like to know exactly what are the optimum moisture conditions for maximum plant growth. Again, we would like to know more accurately, exactly what happens when rain falls on a soil. We know that it is generally absorbed and eventually finds its way to lower levels to strike a water level and that by making bores we are able to create wells, also that on slopes there is a certain amount of run-off moisture finding its way into the lower lying areas forming streams. Of considerable importance is the question as to what happens when moisture falls on a soil and gradually finds its way to the water level. In passing through the upper layers of the soil

which have received an application of fertiliser to what extent does such water dissolve and carry the fertilising ingredients out of reach of the plant rootlets? Admittedly, the type of fertiliser applied will no doubt have some effect upon the amount to which it is dissolved and removed to the water level. So far no satisfactorily controlled experiment has been conducted on a piece of soil under ordinary climatic conditions to determine exactly (a) the fate of all the moisture received by that area, and (b) the fate of all the fertiliser applied to such a soil. A study along these lines must inevitably give results which will be of considerable interest to the farming community. While it is no doubt impossible to control soil moisture at an optimum in farming practice, I believe that there would be some gain in knowing what constituted optimum conditions and having obtained those conditions one could then study the effect of various methods of farm husbandry and no doubt could eventually arrive at methods of farming which would give the greatest possible conservation of soil moisture for the benefit of the plant.

(c) Micro-organisms - It has been clearly demonstrated that the micro-organisms of the soil play a very important part in the final returns possible from a good soil. Parrish (Chemical Age, 56, No. 1437, 55) estimates that in a soil containing  $5 \times 10^9$  bacteria per gram, some 4 tons of bacterial substance may be present per acre. We do know, for example, that if a soil is too acid, the micro-organism population is suppressed, and this accounts to some extent for the lack of fertility of this particular soil. Again, in soils which are highly alkali the same repression of useful micro-organisms occurs. It is known that the more neutral types of soil allow of their maximum development to give figures of the order quoted by Parrish (Ibid.). Again, the chemical composition of the soil itself effects micro-organism population.

Soil Fertility - Of considerable interest is the mechanism whereby soil nutrients become available to and are absorbed by the plant rootlets. The concept that plant nutrients have essentially to be soluble in soil water for utilisation by the plant can no longer be considered tenable. While one can instance much experimental evidence to show that plants can and do use fertilising substances dissolved in water, it should be pointed out that this mechanism, while true in itself, does not preclude the possibility of other mechanisms for the absorption of nutrients by the plant. On the other side of the picture, it is known that fertilising materials can inter-act with components of the soil to form compounds which are not available or, in other words, have formed such stable compounds with the soil as to be termed "locked". Such locked fertiliser may be made available to some extent by the application of another element. MacIntyre and his co-workers (Knoxville) have suggested that magnesium can function in such a manner in the case of certain soils with a high phosphate locking capacity. Intermediate between these two extremes, it is suggested that the soil may form compounds with nutrients which, while water insoluble - that is, insoluble in the soil waters - can provide the plant with nutrients, or, to put it in another way, absorption of the nutrients by soil colloids has occurred. Colloidal systems have properties peculiar to themselves so that water solubility and its properties do not account for all the properties of colloidal systems which may be said to depend rather more on ionisation than on the independent molecule, and such systems will depend more on the base exchange status of the soil than water solubility. For example, Albrecht (Commercial Fertiliser Year Book, 1946-1948) has shown (in the case of marigolds) that nutrients absorbed on colloidal clay in dilute suspension and poured over zonolite, grew better marigolds than the same nutrients used in water cultures. Soluble fertilisers also tend to hinder germination on account of high concentration even in the case of the so-called "neutral" fertilisers. Albrecht has summarised the position as follows:-

(1) Water soluble nutrients, like the nitrogen, phosphorus, and potassium of fertilizers, are not taken up by the plant as water solutions. They react, rather, with the soil to become adsorbed on the colloidal clay and humus. High solubility of fertilizers means

more rapid reaction with these colloids. It is often not rapid enough in drier soils, however, to be without salt injury to germinating seeds if they and the fertilizer are put simultaneously into the same soil area.

(2) Nutrients adsorbed on the clay are taken by the plant root mainly as it exchanges hydrogen or acidity for them.

(3) Calcium probably plays an important role in the root conditions by which nutrients are taken, or moved, from the clay into the root.

(4) These beneficial effects by calcium are seemingly greater if some hydrogen or acidity accompanies it.

(5) Consequently, soil acidity is beneficial not only in making the calcium more efficient but also in mobilizing other nutrients into the exchangeable forms, including those in the silt mineral reserves.

(6) The complexity and number of the chemical reactions and interactions within the soil emphasize the insufficiency of considering only the inorganic aspects of them, and suggests that the soil organic matter may represent benefits not yet well understood.

With the above background it is now competent for us to consider fertilisers and what their future place in agriculture is likely to be. I propose in the first place to deal with nitrogen. Nitrogen is one of the three major fertilising agents and it can be applied to the soil in a number of forms both organic and in-organic. Where cropping is practised extensively it is usual to find fairly large quantities of nitrogen being applied, whereas in the case of pastoral farming the demand is very much less. The reason for this is no doubt quite evident to all of you inasmuch as in pastoral farming nitrogen demand is to a large extent supplied by certain plants themselves by fixation of nitrogen, and also the fact that the animal returns large quantities of nitrogen together with other fertilising materials to the soil, whereas in cropping neither of these sources of nitrogen is necessarily available. In a pastoral area where crops, such as turnips, are grown by farmers for supplementary feed one notices that the farmer often applies fertiliser of the same composition as he would normally apply to his pastures. Consequently, the nitrogen available for the crop is often at a sub-optimum level and better results would have accrued had some form of nitrogen been added as a fertiliser when crops were being grown.

At the present time the main in-organic forms in which nitrogen is available are the sulphate and nitrate, both of which are derived from fixed nitrogen from the air. Consequently, the supply is only limited by the facilities available for the fixation of atmospheric nitrogen. Other forms of in-organic nitrogen such as urea and cyanamide are unlikely to develop much in the future, whereas the use of sulphate and nitrate can both be expected to become more important as time goes on. The successful utilisation of ammonium nitrate is really a development of the past war when surplus supplies of ammonium nitrate from the explosive industry had to be disposed of. It was known to be a very good source of nitrogen, the only problem remaining being to condition it in such a form that it could be utilised successfully. This was achieved by granulation and treatment of the granules.

With regard to the use of organic sources of nitrogen, it will be evident that this will depend on the supply of material available from the meat industry and the fish industry. With regard to the former, the development of stock food in the form of meat meal has depressed the amount of fertiliser available in the form of blood and bone and this tendency can be expected to continue. Bone dust will, of course, be available as fertiliser, and with better development of the fishing industry, fertiliser in the form of fish meal should increase to some extent.

A.L. Mehring of the U.S. Department of Agriculture (Industrial and Engineering Chemistry, March, 1945) shows how organic forms of nitrogen have decreased in importance and how ammonia and its compounds have increased in popularity over the 15 year period, 1925 to 1940:-

TABLE 1.

	1925	1940
Solid Nitrates .. .. .	38	32
Solid Ammonium Salts .. .. .	31	35
Natural organic .. .. .	25	12
Synthetic organic .. .. .	5	8
Ammonia & its Solutions .. .. .	0	13
	<u>100%</u>	<u>100%</u>

With regard to New Zealand, I feel that the use of nitrogenous fertilisers is bound to increase slowly because as the population grows, cropping and vegetable growing must extend, and in these two fields the need for nitrogenous fertilisers has been demonstrated. However, as yet, the consumption of nitrogenous fertilisers in New Zealand has remained at a relatively low level on account of the large pastoral industry, and some considerable increase in demand will be required before it will justify the installation of a synthetic ammonia plant in this country. Such small supplies as are required are imported in the form of nitrate or sulphate.

Phosphates - Still by far the most important form of phosphatic fertiliser is superphosphate and for various economic and other reasons, is likely to remain so for a very considerable time. M.H. Lockwood, (American Fertiliser, 106, 7, 1947) compares the production of phosphatic fertilisers in the United States for the years 1929 to 1944:-

TABLE 2.

Year	Ordinary Superphosphate		High Analysis Superphosphate		Total tons of P <sub>2</sub> O <sub>5</sub>
	Tons P <sub>2</sub> O <sub>5</sub>	% of Total	Tons P <sub>2</sub> O <sub>5</sub>	% of Total	
1929	710,700	95%	34,900	5%	745,600
1934	477,500	94%	31,300	6%	508,800
1939	632,600	83%	125,500	17%	758,100
1944	1,219,500	91%	124,900	9%	1,344,000

I do not propose at this stage to discuss the advantages and disadvantages of superphosphate as a fertiliser, but it will necessarily remain the most important form of phosphatic fertiliser. Other types of fertiliser which have developed to some extent are the so-called double or triple superphosphates where phosphoric acid made from phosphate rock is used to acidify a further quantity of the phosphate rock. This results in a highly concentrated form of fertiliser and is useful under certain conditions. The production of ammonium phosphates has been developed by certain large chemical companies, they enjoy a reasonable popularity, and are useful inasmuch as they provide a concentrated form of both nitrogen and phosphate. To such a material it is simple to incorporate potash to form a concentrated NPK fertiliser. Heat treatment has been used to a limited extent for the production of phosphatic fertilisers but the quantities produced have only been of an experimental nature and cannot be considered as important in the commercial field, and it is somewhat doubtful whether such products will ever be able to compete with superphosphate. Most interest in the phosphate field lies in the development of neutralised or "reverted" types of superphosphate. Such materials have been produced to a limited extent for a considerable period of time. Mixtures of lime and superphosphate have been used in New Zealand over a considerable number of years and in the United States of America the mixing of superphosphate with other substances is of fairly general practice, one of the more important substances used in forming these mixtures in certain areas being dolomitic limestone. The introduction of serpentine super to New Zealand during the war is another step in this direction and has created considerable interest throughout the world. While mixing of

magnesium silicate materials with superphosphate has been practised to some extent elsewhere, it was left to New Zealand to exploit the neutralisation of superphosphate with magnesium silicate material. In practice, it has been found to be an efficient form of fertiliser with a number of practical advantages and I think that one can confidently predict an increase in the utilisation of this type of fertiliser. It should be pointed out, however, that not only is soil type likely to be found important in connection with this fertiliser, but it does seem reasonably apparent that it will only find favour in those parts of the world where there is a reasonably satisfactory rainfall. New Zealand is fortunate in that connection and subsequently the fertiliser has been used to good advantage under New Zealand conditions. Generally speaking, it seems fairly evident that superphosphate and neutralised compounds made from it will constitute the major form for the application of phosphates to the land for a considerable time to come.

Potash - The use of potash is relatively unimportant under New Zealand conditions, but it is suggested that the time will come when New Zealand soils are depleted of potash reserves and larger applications of potash will be necessary. Some indication that this state of affairs is fast approaching is given by the fact that certain areas of land which have had only restricted applications during the war, now respond well to the application of potash fertilisers. Potash will continue to be distributed mainly as the impure chloride and to some extent, as sulphate.

One of the most important substances in the fertiliser field is calcium or lime. Work has shown that the liming of soils is generally necessary in most areas and that in order to obtain optimum results from the application of other plant nutrients it is desirable for the soil to be brought by means of lime to a condition of somewhere in the region of 60% of the base exchange saturation. A considerable amount of lime can still be used with advantage in many areas in New Zealand and one feels that it will always occupy an important place in agriculture for that reason. In this country it is the practice to apply lime in the form of the finely ground limestone and it is interesting to note that in those countries such as Great Britain where it was usual to apply burnt lime, a change-over to the application of ground limestone is rapidly taking place.

Apart from the major elements involved in plant growth numerous minor elements required in very small quantity have become increasingly important as our knowledge of plant and animal requirements has increased. The spectacular results obtained by the use of cobalt in many areas in New Zealand is a good illustration. Many other elements are required in more or less small quantities and one can foresee the day when it might be possible to supply such elements in optimum concentration to any particular soil type, and to that extent, one feels that the fertiliser industry is likely to develop more truly into a chemical industry for the supply of such elements.

Mixtures of Fertilisers - The blending of fertilisers into mixtures has not been extensively practised in this country inasmuch as the major demand has been for phosphatic fertiliser, but in countries where the demand for all three major elements is greater the use of NPK mixtures is usual and a considerable quantity of "straights", such as sulphate of ammonia, superphosphate, muriate of potash, are blended together to produce mixtures. In some countries the number of mixtures produced is almost astronomical. In Britain, for example, at the outbreak of war many hundreds of mixtures were produced and sold there, but owing to war conditions the mixtures were reduced to three in number and from all accounts served the purpose reasonably satisfactorily. In South Africa a definite limit is placed on the number of mixtures, while in the United States the percentage of the active ingredients has to be shown on the package. Insofar as New Zealand is concerned, the use of mixtures may develop as the demand for nitrogen and potash increases, but it would seem wise to contain the mixing of fertilisers to a relatively small number of definite agricultural value. The

granulation of fertilisers has created considerable interest, and in the United Kingdom granulation of mixtures of fertilisers is largely practised. It is not nearly so popular in the United States, though a small amount of fertiliser is granulated in that country. Unfortunately, the processes of granulation at present known are costly and granulation has been used rather more as an advertising medium than as a process intrinsically valuable in itself. One is prepared to admit that there are arguments for and against granulation, but so far one cannot see any particular advantage in the granulation of superphosphate as distributed in New Zealand, except for special cases, such as where hand broadcasting is necessary, and the possible exploitation of the distribution of fertilisers from the air.

In regard to the utilisation of fertilisers, I think that it is generally safe to predict that they will increase. The rate of increase will, of course, depend on the world demand for agricultural products. The Rt. Hon. Richard Law suggests that the world needs something approaching 20% more food than was grown before the war and if some of the altruistic ideas for the future of the human race are realised, it is safe to suggest that even with the existing population some 50 to 100% more food will be required than is at present being produced. Apart from food products, many other materials used by mankind come from agriculture. One has only to instance fabrics, twines, to mention a large field with an ever widening demand. So I think it is reasonable and safe to predict that on this score alone, namely the greater requirement of food and other materials, the amount of fertiliser used in the world will increase at a reasonably steady rate. Superimposed on this, is the gradually increasing age of areas which have been under production for a considerable period and where natural fertility of the soil has been lowered to such an extent that production has fallen off. Here again, increased fertiliser remains the only answer to the retention and development of fertility of such areas. Furthermore, large areas of land in most countries of the earth are now being developed for the first time. Such so-called virgin country in many cases is deficient in one or more of the plant nutrients and this again must increase the total world consumption of fertilisers. It has been estimated that the pre-war requirement of New Zealand of about 600,000 tons of superphosphate has now grown to approximately 800,000 tons, and it is safe to predict that within the next decade the country should be able to use something of the order of one million tons of fertiliser per year.

#### DISCUSSION ON DR. ANDREW'S PAPER:

DR. CUNNINGHAM: I would like to ask Dr. Andrews why he did not deal with the possibility of making high analysis materials available in a suitable form for distribution from the air? That is of very real importance to hill country farmers.

DR. ANDREWS: The position is that there are two requirements for a fertiliser to be used for such a purpose. It should be concentrated in itself so as to reduce the weight of the load to be carried and it has to be in a form suitable for distribution by that method. Production of high analysis material is possible at a cost. The per unit cost of  $P_2O_5$  in this form would probably be 50% more than in the form of superphosphate as made in this country so that you would have to pay more for  $P_2O_5$ . The increased cost is due to the necessity for putting the material through a number of additional treatments of a fairly costly and difficult nature. The second point on which we have no conclusive evidence as far as I know is this: In what form should such material be produced to distribute it from the air? I have heard it suggested that it should be in lumps the size of pigeons' eggs. Some have an idea that it should be granulated. A commonly held view is that it must be of such a size that it is not carried far by the wind. None of the answers to this question have been properly substantiated and for this reason I did not discuss this subject more fully in the paper.

DR. ANNETT: The New Zealand farmer has been very fortunate in the quality of super available to him and has been able to obtain it more cheaply than farmers in most countries. But one problem attached to super is the low proportion of the phosphate that is taken up by plants. When serpentine super came into use I consider that it resulted in a greater uptake of the applied phosphate. Personally I may say that I have used serpentine super for several years and I would use nothing else. Dr. Andrews stated that overseas exponents have shown that it is not efficient in countries with low rainfall. I do not remember hearing of many experiments being done with serpentine super and I would like to know whether Dr. Andrews' conclusions on the matter were drawn from a sufficiently large number of experiments. Secondly, the farmers' criticism of serpentine super has been directed against its quality. They say it varies considerably in condition. I would also like Dr. Andrews to say how far the rainfall of 30 ins. affects the use of serpentine superphosphate?

DR. ANDREWS: The production of serpentine super requires expensive and complicated plant, and manufacturers were more or less unable to obtain proper plant during the war. I think you will find that this condition is gradually disappearing. I know that all companies are trying to put in proper equipment for the production of serpentine super so I think I can predict that the quality of serpentine super should improve in the future. In reply to the question of rainfall. Work has been done at Rothamsted on this problem and then I found more evidence during a visit to South Africa. The general opinion held there was that on the drier areas superphosphate would not be displaced because it was a hygroscopic material in itself and that helped to draw extra moisture into the soil whereas serpentine super under similar conditions was very disappointing. That is the only direct evidence I have, but there is the American trend that in the higher rainfall areas you get neutral type phosphates being used much more extensively than in the drier areas.

DR. COOP: I would like to ask Dr. Andrews whether he could answer the question of what reserves there are of phosphate in the world and how many years can we expect to use it? In relation to fluorine, I was wondering whether by removing fluorine during the manufacture of superphosphate we deprive the soil of an essential element and whether it would not be more profitable to convert it into a salt and apply it in that form.

DR. ANDREWS: The reserves of phosphate in the world are quite great. The Russians recently found a large deposit in Southern Siberia, and the main reserves are, I think, conservatively adequate for at least the next three thousand years. As regards fluorine, fluorine is always present to a greater or lesser degree in superphosphate and although some of it comes away during manufacture there is always a considerable quantity left. At TVA they reduce the amount of fluorine to a negligible amount so that the resulting product can be used as a stock feed. In South Africa I found that in low rainfall areas it was a general practice to put superphosphate in drinking water for stock.

SIR THEO. RIGG: I have listened with great interest to the talk. I think we all can see that New Zealand agriculturally has benefited immensely by the use of superphosphate and other smaller quantities of potassic and nitrogenous manures. But the point insofar as the future is concerned is whether we can get a greater return from a given amount of phosphate because although there may be reserves of phosphates which may last three thousand years, unfortunately they are not distributed well throughout the world. There may be competition for those supplies which are nearer to hand. One can foresee for example in China the need for thousands and thousands of tons of phosphate over a period of years. I do feel that one of the questions that must be answered is that of dealing with the best utilisation of a given amount of phosphate and I here fully support Dr. Andrews in his statement that much more information is required concerning the processes of the soil and the

fate of various manures when applied to the soil. Unfortunately we have only one or two long term experiments available in which records have been taken concerning the fate, for example, of lime and phosphate in nutrition in the soil and their subsequent loss from the soil. One would like to see permanent plots established in areas with a higher rainfall to accurately measure the losses of phosphate and lime and to get a much more exact picture of what happens when we topdress our pastures and to indicate whether it is necessary to use such dressings of phosphate as are now recommended. In our tomato plots we find that after a period of years we get very little response from the use of manures until soil sterilisation is undertaken. Then suddenly we get a magnificent response. Obviously there must be some soil factor which is detrimental to growth. We do not know what factors operate in soil which has been under one crop for a long time. It may be a question of soil fungi producing anti-biotic effect or may be the accumulation in the soil of harmful residues through the growth of one particular crop over a period of years. If we take, for example, the question of orchard soil we have had great results from the use of super and it is only by the use of those manures that we are able to maintain production at a satisfactory level but when we come to analyse the soils we find that most of the phosphate is in the 0-6 inch layer. Only a very small proportion of the phosphate is utilised. In that case we would think that a basic phosphate which could be ploughed in would be more suitable for use under orchard conditions where the vital thing is to get the phosphate down to the roots. I suppose one could instance numerous cases like that where we have not got the facts to enable us to make a right decision.

MR. WILSON: I was interested in the question of nitrogenous fertilisers and I think that from Dr. Andrews' experience in the U.S. he has not dealt with the electrolytic production of calcium cyanamide, which has steadily increased and I think of all the methods of synthetic production of nitrogen it would be most suitable for New Zealand because it does not need so much skill. If farmers could be induced to use it there are prospects for making it here. The table is not fair to high analysis super because the reason it does not increase from 1939 to 1944 is because it depends on electric power.

DR. ANDREWS: I would like to make a comment on Mr. Wilson's remarks. While I was not decrying calcium cyanamide as a fertiliser, I was pointing out that it had not developed to the extent of the sulphate of ammonia. Only a percentage of high analysis super is produced electrolytically, the main quantity being produced by the wet process. So far as I was aware, there was no shortage of power in most parts of U.S.A. during the war period.

MR. COONES: On the question of the use of serpentine super in dry areas, in the Western Australian Journal of Agriculture fairly extensive field trials are described.

MR. CANDY: I feel that I have had very good service from serpentine super. I was interested in the remarks about the manufacture and the probable improvement in the method in the future. In this country, as far as fertilisers for farms are concerned, we have a serious transport problem. What is the minimum quantity of serpentine required with phosphate to make a good crop?

DR. ANDREWS: In answer to that particular point, it depends on what you want. At present serpentine super is largely converted into a neutral and water insoluble condition. It is possible that the addition of approximately 10 per cent. of finely ground serpentine to super would produce a phosphate which can be classified as neutral in as much as the acidity of the material has been neutralised. But there would still remain a large percentage of water soluble phosphate. As you gradually increase the amount of serpentine added from 10% to 25% then gradually the water soluble material transfers over to a water insoluble condition and it is a question of deciding just how much water soluble material you want in the final product.