NEW ASPECTS OF LAND FERTILITY IMPROVEMENT

BY

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I am greatly indebted to my friend, Dr. P.V. Sukhatme, your worthy President, and the Council for inviting me to inaugurate this Session.

I am very happy to be with you all and to take part in your activities.

You know perfectly well that Agriculture is an extremely difficult profession as there are so many variables determining crop production. Hence, accurate knowledge regarding organisms including micro-organisms, soils, crops, fertilizers, manures, insecticides, pesticides, etc. is urgently needed for feeding the teeming millions of human beings which are fast increasing. Your Science has contributed a great deal in the development of Agriculture but more intensive work in our tropical conditions is urgently called for.

Fixation of Atmospheric Nitrogen in World Soils by Organic Matter Oxidation is the Chief Source of Soil Nitrogen

In the famous Rothamsted experiments started by Lawes and Gilbert in 1843, half an acre plot formed the basis of their field trials. But, later on, Yates introduced statistical methods for obtaining more precision. But Rothamsted workers could not explain why the crop production by the application of cake dung was the same as that obtained by corn dung and that farmyard manure increased the total

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nitrogen content of the land whilst the factory nitrogen decreased the total nitrogen content in their fields.

These have been explained by researches carried on in the Allahabad University and the Sheila Dhar Institute of Soil Science for nearly 45 years. It has been experimentally observed that all organic materials like weeds, municipal waste, grasses, water hyacinth, cereal straw, finely-divided coal, lignite, peat etc., when mixed with soil or sand, undergo slow oxidation in air with liberation of energy which is utilized in the fixation of atomospheric nitrogen and makes the soil or the sand nitrogen-rich. This process of nitrogen fixation is markedly accelerated by light absorption and application of calcium phosphate, rock phosphate, bone meal, basic slag (Thomas phosphate). That light markedly improves soil fertility has been discovered by the Allahabad workers for the benefit of mankind.

This discovery is being utilized in India and other parts of the world. The thermal and photochemical fixation of atmospheric nitrogen taking place in the world soils by the slow oxidation of organic matter created by photosynthesis and markedly aided by solar light absorption and phosphate, is the chief source of nitrogen for world agriculture.

Nitrification Causes Nitrogen Loss

Moreover, experimental results have been obtained showing that when nitrogenous fertilizers or manures are applied to land, the unstable substance—ammonium nitrite (NH_4NO_2) – is always formed in the process of nitrification, and, it breaks up according to the equation: $NH_4NO_2 = N_2 + 2H_2O + 718$ k. cal., with large evolution of heat and marked loss of applied nitrogen. This is the explanation of the marked loss of nitrogen in practical agriculture all over the world and the low recovery of nitrogen in crop production observed by agriculturists, the recovery being of the order of 25-50% of the applied nitrogen.

It has also been shown by the Allahabad workers that this loss of nitrogen can be retarded or even stopped by large applications of organic matter or calcium phosphates. By applying organic matter including cereal straw, water hyacinth etc.+rock phosphate or basic slag, which is cheap, large quantities of cereals and vegetables have been produced not only in different parts of India but also in the U.K., Brazil and other parts of the world.

Another very important observation in the field of the Science of Nutrition is that the crops produced by organic matter+phosphates are more nutritive containing more proteins, minerals, vitamins A, B and C than those obtained in the unmanured or in the N-P-K treated fields.

In this communication some aspects of these observations are put forward for your consideration and adoption.

It is well known that animal life depends on slow oxidation of food materials by the inhaled oxygen. Through the process of evolution, a group of animals has become warm-blooded, i.e., their body temperature is maintained at a constant level of 37°-40°C all the year round. But the cold-blooded animals maintained the temperature of the surrounding air, *i.e.*, in the cold weather, their temperature goes down and the oxidations in their bodies slow down considerably and they become much less active. On the other hand, the activity of warm-blooded animals is created by the oxidation of food materials which is controlled by their constant temperature as the amount of oxidation and hence energy liberation is the same throughout the year. The greater the temperature of the oxidation, the greater the energy liberation.

The chemical changes taking place in the soils are controlled by the temperature of the surrounding air, *e.g.*, at Allahabad, the average soil temperature is 26°C whilst in Uppsala (Sweden) the average soil temperature is 5°C, at Paris it is 10°C and at Rothamsted 9°C. Hence, the soil oxidation processes are much faster in Allahabad than in the colder parts of the world. Organic matter is created on soil surfaces by photosynthesis and gets mixed up with the soil, as in cultivation. This organic matter, being rich in energy-producing substances chiefly carbohydrates including celluloses, lignins, small amounts of fats and proteins, forms the soil humus. In hot countries, the soil humus is oxidized much faster than in cold countries. Thus, in Sweden, the soil humus is of the order of 3% whilst in India it is 1%. The humus is the source of soil nitrogen as humus is believed to be ligno-phospho-protein. On oxidation this material liberates plant nutrients like ammonium salts, nitrates, phosphates etc. Humus being acidic can adsorb lime, magnesia, potash soda etc. which are also available on the oxidation of humus. Consequently, land fertility depends a good deal on its humus content and on temperature of the soil.

Available Nitrogen is greater in Indian Soils than in Temperate Countries

In India the average soils contain 0.05% total nitrogen, which in Rothamsted soils is of the order of 0.12%, at Uppsala it is 1.47%. But the total nitrogen, consisting chiefly of proteins, amines, amides etc., is not available for crops, which require available nitrogen which is a mixture of ammonium salts and nitrates formed from protein oxidation. In our Indian soils, available nitrogen is of the order of 10-30% of the total nitrogen whilst in the Rothamsted soils it is of the order of 1-2% as repored by Russell. In Uppsala the available nitrogen is only ½% of the total nitrogen. It is clear, therefore, that in the Indian soils the total nitrogen is of the order of 1100-1200 lbs. per acre of land upto a depth of 4-5 inches. In Rothamsted the total nitrogen is approximately 2200 lbs. per acre. In Uppsala it is of the order of about 3000 lbs. per acre. But as the available nitrogen in India is not less than 10% of the total nitrogen, the available nitrogen is of the order of 100-150 lbs. per acre whilst in Rothamsted it is of the order of 25-50 lbs. and at Uppsala it is only 15 lbs. per acre. Hence, in Indian soils, for centuries, 10-12 mds. of cereals like wheat, paddy etc. have been grown *without any manure or fertilizer*. But in cold countries, as the available nitrogen is much lower, the land without fertilizer or manure produces smaller crops. Moreover, after harvesting of the cereals, about 1-1.5 ton of roots and stubbles are left in the land and these, when mixed with soil by ploughing, undergo slow oxidation with liberation of energy fixing atmospheric nitrogen and making the land fertile. On an average, 1 ton of organic matter, like roots and stubbles when ploughed in the land, can fix 30-50 lbs. of nitrogen and this is the source of the steady production of crops in India *without fertilizer*.

Lord Linlithgow invited me to Simla for a discussion as he became highly interested on reading a very appreciative comment on our researches published in NATURE (April 1936) on the application of molasses and pressmud in crop production and was thoroughly satisfied by the explanation given in the preceding lines.

Organic Matter vital in Crop Production, specially in India

There is not the slightest doubt that Agriculture developed by the application of animal dung as man has always been utilising domestic animals. By trial and error he observed that animal dung does good to the crop. Hence for centuries past till 1900 animal dung mixed with straw formed the basis of crop production all over the world. It is only in recent years that ammonium sulphate, urea, nitrates, potash, superphosphate etc. have been introduced in agriculture.

In the subsequent pages it will be discussed that the nitrogenous fertilizers appreciably decrease the humus content of the soil by enhancing its slow oxidation. Also acidity is created which helps in the loss of the vital nutrient, lime. Consequently, world experience has completely established that fertilizers increase crop production no doubt but cannot maintain a steady crop yield and destroy the vital substance – humus. Hence for permanent agriculture, which is certainly your aim, artificial fertilizer is no solution. Also the production of artificial nitrogenous compounds in the whole world today is only less than 10% of the world requirement for agriculture. Hence our discovery that a mixture of organic matter+phosphates, which fixes atmospheric nitrogen in the soil itself and can supply all plant nutrients, is highly suitable for permanent agriculture all over the world.

It has been clearly proved that without organic matter the soil fertility can never be maintained. The slow oxidation of organic matter creates plant nutrients in our soils much more quickly than in cold countries and this is a very important factor in maintaining land fertility in India by the application of organic matter and phosphates which have been found by us to retard and even stop the loss of nitrogen from soils. Hence greater incorporation of organic matter aided by calcium phosphate in tropical soils can maintain the soil fertility permanently and is of more supreme importance than in cold countries.

Population Explosion and Food Shortage

Hunger is the oldest enemy of man. In the early days of human civilization, procurement of food was difficult. At the present time due to population explosion, the world food situation is causing anxiety to every body.

In 1941, undivided India had a population of 385 millions and in 1951 it was 431 millions. This shows an annual increase of 1.19%. Sir John Russell, in his book *World Population and World Food Supplies*, has correctly stated that the increase of Indian population by over 40 millions in 10 years, which is practically the population of France, makes the food situation of India almost impossible.

Out of a world population of 3,500 millions, only 500 millions are well off. Even in the U.K. with a present population of 55 millions, thoughtful people are declaring that their country is over-populated and the population should be brought down to 30 millions for a proper standard of living.

Very recenty the U.S.A. Congress has become highly concerned with the population growth of this rich nation. One of the witnesses examined stated:

> "One hundred millions would be a nice figure for the U.S.A. population, but, this population was 100 millions in 1917 and rose to 200 millions in 1967 and may go up to 300 millions by the end of this century."

The world population is expected to pass the 4000-millions mark by 1975 and may rise to 7000 millions by 2000 A.D. Currently, world population grows at about 2% per year with regional growth rates varying from less than 1% in Europe to more than 3% in Latin America. The world's quickest growing country is Costa Rica in Central America where the population has doubled in 18 years. The smallest rate of population growth has been recorded in Belgium, East Germany and Luxemburg. Demographers have estimated that it took 6,00,000 years for the human population to reach 1,000 millions about 1800 A.D. and it reached 2,000-million mark in 1930. The increase in the rate of human population gains has continued since then at an alarming rate. The effect of this is being felt even in the industrially advanced nations like the U.S.A. This is evident in the statement of President Nixon:

> "This growth will produce serious challenges for our society. I believe that many of our present social problems may be related to the fact that we have had only 50 years in which to accommodate the second 100 million Americans."

Lord Boyd Orr, the first Director-General of the F.A.O. and an excellent expert on the Problem of Nutrition and Ex-Vice-Chancellor of the Glasgow University, has urged the European nations to help the people of the developing countries in Asia, Africa and South America who have declared war against hunger and poverty.

He has stated that the expert knowledge available in Europe for creating prosperity should be utilized by Europeans in advising the industrially backward nations. Lord Boyd Orr is optimistic about the value of the application of science offered by the advanced nations in improving the standard of living of backward people. This may remove want in the whole world, which may be converted into one 'Brotherhood' of mankind. Prof. Blackett, President of the Royal Society and a Nobel Laureate, is also helpful that the existing knowledge acquired by the scientists of the world for food production, when properly applied, may meet the world food crisis.

The high hopes expressed by Lord Boyd Orr and Prof. Blackett have not been realized because modern technology has not been able to meet the world food situation due to population explosion.

Failure of Western Technology in meeting World Food Shortage

After the first World War in many countries of Europe, Agricultural Universities were organised for the expansion of agriculture, production of more food, fodder and fibre. As there was acute shortage of food during the war period, even in rich countries like Norway, Sweden, U.K. and Germany, it was reported that whenever the learned men and even Nobel Laureates of these countries met, they talked mainly about food, drinks and their substitutes.

About 50 years ago, during the First World War, I was a student in the University of London where I had to depend on a very thin slice of bread during lunch or dinner. We could get fair amount of boiled potato, cabbage etc. and a small piece of meat or fish. The United Kingdom during this period was producing only 20 to 25% of its food requirement and the unlimited German submarine campaign prevented the inflow of food materials in the U.K. After spending very large sums of money for agricultural education and research, the U.K. is producing 40% of its food requirement at the present moment. In Paris, in 1917, I found the food position much better as French agriculture is very sound and produces practically the whole food requirement of France. Even in 1926, in Berlin, I found scarcity of good bread and meat. The Berliners depended mostly on boiled potatoes for nourishment.

In Madrid, in 1958 and 1968 and in Yugoslavia in 1960, difficulty in obtaining food was noticed. In the International Fertilizer Congress held in Opatia (Yugoslavia) in 1960, the Chemical

Industry of the country arranged for a lunch meant only for the foreign Members of the Congress. But the Yugoslav Members insisted and stayed on for the lunch. This shows the uneasy food situation in the Balkan States. In 1964 I spent 10 days in Bucharest, Rumania, for the International Congress of Soil Science and observed that the factory workers there breakfasted on very sour curd and course bread without butter. Moreover in the evenings it was very difficult to obtain hot food or drinks. It appears, therefore, that the food situation in many countries is more difficult than in India.

Prof. R. H. Bradfield of Cornell University, President of the VII International Soil Science Congress of 1960, took exception to my statement that "No nation, certainly no large nation has ever truly conquered hunger, the oldest enemy of man." I had to point out to him that as the population of the U.S.A. is increasing fast the surplus of 10% food may not last long and that various parts of this great country are still poor as will be evident from the following lines :

> "New England crop farmers by and large have had a struggle just to get along almost from Colonial times. The Southern Appalachians seem to be a permanent poor house. Topography, obsolete method, lack of capital and possibly lack of diet adequate to supply the requisite energy and thought, all conspire to make this region sad indeed. Throughout the South, where cotton and tobacco have depleted the soil, rural poverty is rampant. In New Mexico and Arizona particularly amongst the Spanish Americans in Indians, poverty is the rule. Before World War II, we stood arraigned as the most wasteful people in all history. Nowhere else had a people taken such a rich virgin territory and in short three centuries ruined large parts of it for all time and semi-destroyed other parts, while busily trying to do away with the rest" (L. Haystead & G.C. Fite, 1958). Similarly in Oklahoma, Virginia, Alabama, Georgia, (Kentuchky, north and south) Carolina, farmers are not well off. In a recent article, Prof. W. B. Bollen has stated that more crops are being produced in the U.S.A. but lands are losing fertility.

Although great progress has been achieved in technology during the past 100 years, shortage of world food has not been avoided. F.A.O. figures of the Food Balance Sheets of various countries clearly show that Eastern countries, South America and the Balkan States of Europe suffer from food inadequacy. Hence, we have to face the baffling fact that we have not been able to meet the first need of the common man, that is, food and help him to maintain health and it is no wonder therefore that he is now revolting.

It is tragic that the majority of human beings in the world is still poor, ill-fed, ill-clad and uneducated. In India, Pakistan, Ceylon, Burma, China, Japan, most parts of South America, Egypt, Turkey, Italy and Greece, the caloric intake per capita per day varies from 1,500 to 2,500. The daily animal protein consumption ranges from 5.6 to 20.5 grams per person while the normal physiological need is 2,800 calories and 40 gms. of animal protein. Also in the U.S.S.R. the average animal protein intake is below the standard. Even today, the economics of the majority of nations, specially in the East and South America, is the science of human misery as stated by Karl Marx a century ago. Countries like the U.K., Belgium, Holland, Switzerland, Finland etc. are unable to produce the food required by them but they have the means of importing their requirements. Only during war periods there is food shortage in these countries.

Failure of Nitrogen Industry in Solving Food Crisis

The Indian Council of Agricultural Research has reported that on an average the rice production in India is 10 times the amount of the nitrogen applied when the dose is not very large.

It is well known that 1 kg. of available nitrogen normally produces 10 kgs. of food or fodder. Today, in the whole world, approximately 1,200 million tons of cereals, 800 million tons of other food materials and 2,000 million tons of fodder are produced annually. Hence, for the production of 4,000 million tons of food and fodder, approximately 400 million tons of available nitrogen are actually consumed. In the nitrogen factories of the world, not more than 20-25 million tons of nitrogen are annually produced and hence not more than 4% of the world food and fodder production has to be attributed to industrial nitrogen. After the British Association meeting of 1949 presided over by Late Sir John Russell, *Nature* reported as follows:

> "At present only some 3% of the world food production can be attributed to the use of nitrogenous fertilizer. To raise the food by 10% it involves a fourfold increase in the supply of fixed nitrogen costing 1,500 million pounds and this would take a minimum of 15 years to achieve."

In India, the Planning Commission has recommended the production of 120 million tons of cereals annually. This will require 12 million tons of fixed nitrogen, while the actual production of factory nitrogen in India today is approximately 0.55 million tons per year.

Europeans and Americans have laid great emphasis on the growing of legumes like Sunnhemp, clover etc. for nitrogen fixation in soils, but in the U.S.A. 2 million tons of nitrogen are added by legumes and in other parts of the world 3 million tons of nitrogen are fixed by legumes, making a total of 5 million tons. Consequently, the contribution of industrial nitrogen and legumes in world crop production does not exceed 6% of the total nitrogen requirement of the world crops. It is clear, therefore, that Mother Earth is supplying nearly 94% of the total nitrogen for the world food and fodder production. The great reliance of the Europeans on legumes and factory nitrogen appears to be misplaced. Chemical industry has completely failed to cope with the world's food situation. Moreover when nitrogen fertilizers are added to land, the majority of the added nitrogen is lost as nitrogen gas without any benefit to the crop or the soil and hence the nitrogen recovery in crop production is low and the soil fertility decreases with time.

Sunlight and Organic Matter add Nitrogen in Soils

In order to improve land fertility permanently by fixation of atmospheric nitrogen in the soil itself, we have carried on systematic research work at Allahabad for over 45 years with the help of more than 100 research scholars and we have discovered that by ploughing down all types of organic materials (like grasses, leaves, straw, municipal waste, lignite, water hyacinth, peat, powdered coal etc.) marked nitrogen fixation takes place in the soil with a consequent increase in crop yield. These organic materials not only improve the physical properties of the soils, add colloids to the soils and improve the tilth and crump formation and water-retention capacity of soils but these organic substances also undergo slow oxidation in the soil and liberate energy which is utilized in fixing atmospheric nitrogen and enrich the soil from the nitrogen viewpoint. Moreover, the carbohydrates in the soil preserve the nitrogenous compounds present in the soil or added to it just as carbohydrates and fats act as protein sparers in the animal body. Nitrogen fixation is greatly increased by sunlight absorption and also by applying bone meal, calcium phosphates, basic slags etc. This mixture of organic matter and phosphates supplies plant nutrients for an excellent crop growth and shows residual effect to the next crop.

By ploughing down cereal straw mixed with basic slag (Thomas phosphate) we have been able to fix over 100 kgs. of nitrogen per hectare of land and excellent crops are produced in these lands without any other fertilizer or manure.

This is the reason why Lady Eve Balfour of the Soil Association, Suffolk, England, working at my suggestion, obtained 20.5 cwt. of barley grains per acre of land by applying 100 lbs. of P_2O_5 (phosphate) as Thomas phosphate on barley straw whilst by applying 112 lbs. of nitrogen as ammonium sulphate, she obtained 20.3 cwt. of barley grains per acre and the 'Control' plot produced only 14 cwt. per acre. Consequently, it appears that the cheap materials—basic slag (Thomas phosphate)—when applied to straw, fixes more nitrogen and produces more crops than the heavy dose of 112 lbs. of nitrogen as ammonium sulphate per acre.

These researches have drawn considerable attention worldwide. Dr. Alf Aslander of the Royal Institute of Technology, Stockholm, Sweden, writes: "Your discovery of this kind of nitrogen fixation will ceriainly be counted among the most important ones regarding soil fertility. When you get the Nobel Prize for your discovery of the nitrogen fixation, you are very welcome to inspect the results."

Lady Eve Balfour has recorded as follows: "Dr. Dhar's work on behalf of soil fertility is known in many countries. Particularly valuable to world agriculture is his discovery that crude organic matter such as straw left by combine harvesters can be safely ploughed in with it. Dr. Dhar is deeply concerned at the declining humus status of so much of the agricultural soils of the world, which is at its worst of course in the big grain producing areas, and it is there that Dr. Dhar's discovery is of such special importance in that it provides a practical alternation to the burning of straw. Here at Haughley we use Dr. Dhar's method when ploughing in straw on our stockless section. We have done so regularly since our first experiment with it in 1957-58."

Dr. A.C. Hildreth, Superintendent, U.S. Department of Agriculture, Agricultural Research Service, Crops Research Division, Cheyenne Horticultural Field Station, P.O. Box 1250, Cheyenne, Wyoming, U.S.A., has stated thus: "The copy of your Presidential Address

Calcium Phosphates and Their Importance in Nitrogen Fixation and Alkali Soil Reclamation has just been received. This work is a great contribution to agricultural science. Your experiments on photochemical fixation of nitrogen are most interesting. They do much to explain the continued productivity of land in parts of Asia that have been farmed for thousands of years. More important, they offer hope for the future. Thank you very much for making the results of this valuable research available to me."

Nitrogen Industry Costly

Although synthetic nitrogen factories have been started in industrially underdeveloped countries, like Brazil, Philippines, Colombia, Egypt, Finland, Iceland, India, Isreal, Mexico, Peru, Pakistan, Portugal, South Korea, Taiwan, Trinidad, Turkey, Venezuela, Yugoslavia in recent years, these countries find it difficult to meet the heavy capital investment. Different types of ammonia synthesis plants for producing 100 tons of ammonia per day cost as follows in dollars as capital investment:

	Natural gas	*Fuel oil*	*Coal*	*Coke oven gas*	*Catalytic reformer gas*
Capital investment in $	39,50,000	40,98,000	42,48,000	36,20,000	29,80,000

In a recent study on "Observations on the Planned Provision of Nitrogen Fertilizer", Prof. Tinbergen, a Nobel Laureate, and others of the Netherlands Economic Institute, Rotterdam, have reported that the world demand for nitrogen fertilizer in 1960-61 was expected to be 8.1 million tons (Europe 3·1 million tons, U.S.A. 2·4 million tons and other area 2.6 million tons). They concluded that the consumption of nitrogen per acre of land is directly proportional to the density of the country. Moreover, in a recent publication (1957) on "Industrial Uses of Nitrogen" by the European Productivity Agency of the O.E.E.C. the following lines occur "As world nitrogen production is outstripping the expansion of demand for traditional purposes (particularly for nitrogenous fertilizer) all producers are looking round for new outlet". Hence the amounts of chemical nitrogen used as fertilizer are still inadequate as the quantitites of fertilizer nitrogen applied per acre in lbs. per year in 1937 were as follows: Belgium (28 5), Holland (24·8), Germany (15·6), Denmark (10·3), Norway (6·0), Sweden (5·24), Italy (4·3), France (4·0), U.K. (2·5), U.S.A. (1·36), Poland (0·73) and Hungary (0·15).

At present the consumption of nitrogenous fertilizers has increased in many countries and this is evident from the following figures indicating the nitrogen used in kgs. per hectare of land under cultivation in 1956-57.

Australia (11·5), Belgium (52·5), Denmark (29.6), France (14.4), West Germany (35·1), Greece (12·1), Iceland (85·9), Ireland (3·2), Italy (14·7), Luxemburg (28·0), Netherlands (79·0), Norway (38.1), Portugal (10·5), Sweden (22·4), Switzerland (10·1), Turkey (0·4), U.K. (23·5), Spain (9·5) and U.S.A. (9·2).

It has been reported that there is a shortage of chemical fertilizers in the U.S.S.R. although there are 71 plants producing fertilizers. The following figures show the nitrogen utilization in kgs. per hectare of land in some East-European and Eastern countries: East Germany (31·6), Poland (10), Czechoslovakia (5), Japan (109·6), Taiwan (86·7), Republic of Korea (54·1), Ceylon (18·4), Philippines (5·6), China (2·3), Indonesia (2·0), India (1·0) and Pakistan (0·3).

Industrially Backward Countries Neglect Phosphate Fertilisation

It has been emphasised in our publications that for permanent agriculture it is profitable to increase the phosphate status of land under cultivation, because, phosphates help markedly in the fixation of atmospheric nitrogen by the oxidation of plant residues and other organic substances present in the soil. Moreover phosphates maintain soil neutrality. In the following table the ratios of N/P_2O_5 consumed in various countries of the world have been tabulated. The results show that the economically backward countries do not pay attention to the enrichment of land with phosphate fertilizers, but, for producing more cereals, nitrogen fertilizing is carried on. This practice does not improve land fertility at all. On the other hand, many economically advanced countries utilize more phosphatic fertilizers than nitrogenous ones:

		$\frac{N}{P_2O_5}$			$\frac{N}{P_2O_5}$
Germany	$\frac{571384}{964117}$	1 : 1·7	Peru	$\frac{19392}{16408}$	1·2 : 1
U.S.A.	$\frac{334603}{675223}$	1 : 2·01	Eire	$\frac{6765}{26717}$	1 : 3·9
France	$\frac{154770}{353274}$	1 : 2·2	Switzerland	$\frac{3911}{24219}$	1 : 6·2
U.S.S.R.	$\frac{139892}{386731}$	1 : 2·7	Norway	$\frac{7191}{14369}$	1 : 1·99
Japan	$\frac{252824}{232909}$	1·07 : 1	Lativa	$\frac{3667}{22923}$	1 : 6·08
Italy	$\frac{116229}{219486}$	1 : 1·9	Dutch East Indies	$\frac{18864}{11413}$	1·6 : 1
Netherlands	$\frac{62081}{100858}$	1 : 1·6	Puer-to-Rico	$\frac{14446}{4626}$	3·1 : 1
U.K.	$\frac{57790}{180472}$	1 : 3·5	China	$\frac{27035}{480}$	55·4 : 1
Spain	$\frac{103727}{165565}$	1 : 1·6	Hawaii	$\frac{13612}{32}$	425 : 1
Australia	$\frac{12550}{249595}$	1 : 19·8	Austria	$\frac{5184}{12832}$	1 : 2·4
Belgium	$\frac{52181}{81087}$	1 : 1·5	Lithuania	$\frac{1319}{18085}$	1 : 13·7
Poland	$\frac{26109}{32872}$	1 : 1·2	Ceylon	$\frac{8468}{9119}$	1 : 1·07
Denmark	$\frac{40542}{67163}$	1 : 1·6	India	$\frac{16288}{1612}$	10·1 : 1
Sweden	$\frac{27690}{50917}$	1 : 1·8	Algeria	$\frac{3145}{12134}$	1 : 3·8
Korea	$\frac{93690}{21017}$	10.4 : 1	Greece	$\frac{5211}{7376}$	1 : 1·4
New Zealand	$\frac{4276}{101903}$	1 : 2·3	Estonia	$\frac{911}{10396}$	1 : 11·4
Czechoslovakia	$\frac{24852}{48646}$	1 : 1·9	Hungary	$\frac{2333}{10371}$	1 : 4·4
Egypt	$\frac{73733}{8955}$	8.2 : 1	Canary Island	$\frac{4521}{2653}$	1·7 : 1
Canada	$\frac{14738}{33953}$	1 : 2·3	Philippines	$\frac{6649}{108}$	61·5 : 1
South Africa	$\frac{9112}{41383}$	1 : 4·5	Yugoslavia	$\frac{1668}{4397}$	1 : 2·6
Finland	$\frac{7866}{28741}$	1 : 2·6	Mexico	$\frac{2802}{0}$	
Formosa	$\frac{34180}{13970}$	2·4 : 1	Brazil	$\frac{1938}{0}$	
Portugal	$\frac{15928}{32865}$	1 : 2·06	All others	$\frac{30947}{25764}$	1 : 0·8

In this connection, it will be interesting to examine the actual position of world production of fertilizers and their applications in various countries.

Year	Total amounts of Fertilizers used in world Millions of tons		
	N	P_2O_5	K_2O
1913	1·3	2·0	0·9
1938/39	2·6	3·6	2·8
1953/54	5·2	6·3	5·7
1959/60	9·7	9·7	8·6
1964/65	16·8	13·8	12·1
1966/67	21·3	16·2	14·4

In the U.K. the consumption of nitrogenous fertilizers has increased to a much greater extent than P_2O_5 and K_2O during the last 10 years as is evident from the following figures:

	1000 tons		
	N	P_2O_5	K_2O
1957/58	315	386	348
1967/68	748	468	441

The following tables show that even now industrially advanced nations use more phosphate and potash when compared to nitrogen than underdeveloped countries.

Year	Plant nutrient ratios P_2O_5 when N-1		
	Europe	North America	Asia
1956	1·22	1·16	0·41
1961	1·05	0·90	0·45
1967	0·85	0·72	0·48

	K_2O when N-1		
	Europe	North America	Asia
1956	1·29	0·94	0·43
1961	1·09	0·72	0·49
1967	0·83	0·57	0·38

	Population and Fertilizer use per hectare of arable land			
	(1965)	*(1965/6kg/ha)*		
Country	*People hectare*	*N*	*P_2O_5*	*K_2O*
Europe	2·9	43	39	37
Bulgaria	1·8	48	22	2
Denmark	1·8	71	47	65
France	2·3	42	60	47
Germany, Fed. Rep.	6·9	106	99	144
Netherlands	12·7	321	119	141
Rumania	1·8	14	11	1
Hungary	1·8	31	22	9
Spain	1·5	19	15	5
Switzerland	14·1	60	113	142
U.K.	7·3	92	56	58
North & Central America	1·1	21	16	12
Barbados	9·4	135	2	74
Canada	0·5	5	9	3
Cuba	3·9	51	41	30
Jamaica	7·7	32	9	28
Mexico	1·8	11	3	0·3
Trinidad and Tobago	5·6	158	5	27
U.S.A.	1·1	26	19	16
South America	2·2	4	4	2
Argentina	1·1	1·3	0·5	0·3
Chile	1·9	7	14	3
Peru	4·5	24	5	6
Venezuela	1·7	5	1·5	1·9
Asia	3·4	7	3	3
Ceylon	6·0	23	0·5	18
Taiwan	14·0	165	42	52
India	3·0	3	0·8	0·6
Iran	2·0	2·1	1·3	1·2
Israel	6·2	58	29	11
Japan	16·3	129	91	101
Jordan	1·7	1·6	0·7	2·2
Korea	12·6	89	42	18
Pakistan	4·3	5·1	0·4	0·1
Viet Nam	4·3	9	19	4
Africa	1·4	3·4	1·6	0·8
Algeria	1·6	1·9	2·1	1·6
Kenya	5·5	8	6	0·5
Mauritius	7·9	96	74	72
South Africa	1·5	8	16	6
U.A.R.	11·1	107	20	0·2
Australia	0·3	2	27	2
New Zealand	3·3	8	431	135

The above table shows that countries thickly populated try to produce food by heavy doses of nitrogenous fertilizers.

Greater Efficiency of Nitrogen in Crop Production in Countries using Small Amounts of Commercial Fertilizers

In the following table the total agricultural areas, total nitrogenous fertilizers used (1956-57), amounts of nitrogen in kg. applied per hectare of land under cultivation and cereal production in various countries have been recorded :

Country	*Total agricultural area in 1000 hectares*	*Nitrogenous fertilizers used in million tons*	*Commercial nitrogen per hectare in kg. applied*	*Cereal production in million tons*	*Cereal/N*
U.S.S.R.	486,400	1·5	3·3	160	214
U.S.A.	444,236	2·0	4·8	140	140
China	287,350	0·120	0·4	100	168
India	169,496	0·154	1·0	72	934
Turkey	53,818	0·006	0·12	11·5	3800
France	33,668	0·403	13·0	19·0	94
Spain	29,549	0·169	6·1	7·8	92
Pakistan	24,404	0·031	1·3	18·3	1202
Italy	20,936	0·268	13·2	13.6	102
Poland	20,404	0·153	8·0	12·2	158
U.K.	19,364	0·311	17·3	8·3	54
Yugoslavia	15,933	0·067	4·2	5·9	176
West Germany	14,416	0·527	39·5	12·0	50
Greece	8,703	0·055	6·3	1·95	72
Thailand	7,793	0·003	0·4	8·4	5600
Philippines	7,588	0·033	4·3	4·26	280
Hungary	7,266	0·025	3·4	5·3	424
Czechoslovakia	7,377	0·021	2·8	5·5	520
East Germany	6,474	0·218	36·4	5·3	48
Japan	6,404	0·587	92·0	17·1	58
Portugal	4,868	0·047	9·5	1·5	64
Ireland	4,726	0·0145	3·0	1·3	176
Bulgaria	4,537	0·081	18·0	3·45	84
Sweden	4,436	0·09	20·0	3·0	66
Austria	4,088	0·037	9·0	1·91	100
Denmark	3,117	0·0978	31·3	3·81	77
Finland	2,869	0·044	15·3	1·27	56
Switzerland	2,708	0·011	4·2	0·44	80
Egypt	2,618	0·123	46·5	5·5	90
Netherlands	2,305	0·189	86·4	1·57	17
Belgium	1,730	0·087	55·1	1·58	38
Ceylon	1,523	0·0212	15·0	0·54	49
Norway	1,032	0·045	48·6	0·54	24
Taiwan	936	0·084	96·6	2·27	54
Luxembourg	141	0·0037	28·3	0·111	60

If we assume that only 50% of the nitrogenous fertilizer applied in the above countries is used in cereal production and divide the amounts of cereal produced by the quantities of nitrogenous fertilizer utilized for growing the cereals, we obtain some interesting figures recorded in the last column of the foregoing table. They show that in countries where larger amount of nitrogenous fertilizers are applied per unit area, small values are obtained as the ratio of cereal: N as recorded in the last column of the above table. These ratios are recorded in increasing order in various countries:

Netherlands (17), Norway (24), Belgium (38), East Germany (48), Ceylon (49), West Germany (50), U.K., Taiwan (54), Finland (56), Japan (58), Luxembourg (60), Portugal (64), Sweden (66), Greece (72), Denmark (77), Switzerland (80), Bulgaria (84), Egypt (90), Spain (92), France (94), Austria (100), Italy (102), U.S.A. (140), Poland (158), China (168), Ireland, Yugoslavia (176), U.S.S.R. (214), Philippines (280), Hungary (424), Czechoslovakia (520), India, Pakistan (1202), Turkey (3800), and Thailand (5600). On the other hand, the decreasing amounts of commercial nitrogen used per hectare of land in kg. under cultivtion in various countries are as follows: Taiwan (96.6), Japan (92), Netherlands (86.4), Belgium (55.1), Norway (48.6), Egypt (46.5), West Germany (39.5), East Germany (36.4), Denmark (31.3), Luxembourg (28.3), Sweden (20), Bulgaria (18), U.K. (17.3), Finland (15.3), Ceylon (15), Italy (13.2), France (13), Portugal (9.5), Austria (9), Poland (8), Greece (6.3), Spain (6.1), U.S.A. (4.8) Philippines (4.3), Yugoslavia and Switzerland (4.2), Hungary (3.4), U.S.S.R. (3.3), Ireland (3), Czechoslovakia (2.8), Pakistan (1.3), India (1), China, Thailand (0.4), Turkey (0.12).

From the foregoing observations, it appears that in countries not using larger doses of commercial fertslizers the nitrogen response to cereals is very marked and that the law of diminishing return, which is often neglected in modern agriculture by applying heavy doses of commercial fertilizers, is in actual operation in countries like Netherlands, Belgium, Norway, etc. But in countries like Japan, China, Taiwan, where a lot of composts, plant and animal wastes are utilized along with commercial fertilizers, better crop yields per unit of nitrogen applied are still obtained. It is of interest to record here that several experiment stations in the U.S.A. have found that yields of wheat and corn are increased by producing greater amounts of organic matter through rotations. If all crop refuse is utilized and if legumes are grown in rotation, the organic matter level is fairly well maintained. But in drier areas legumes have to be replaced by grasses for building organic matter.

Dr. Alf Aslander in his publication on "Nutritional Requirements of Crop Plants in the ***Handbuch der Pflanzen Physiologie*** has stated:

> "Dhar, on the basis of investigations and observations throughout a lifetime, makes the following statements: Practical farmers in many countries prefer to grow good quality crops by the uptake of nitrogen slowly but steadily supplied by the soil humus, dung or straw is a lasting manure and builds up what farmers call 'high conditions' of a soil. The repeated application of municipal waste products increased the nitrogen content of an Allahabad field from 0.04 to 0.25% and bumper crops were obtained. It appears that crops of which the potash requirement is more pronounced than their available nitrogen need are likely to respond well to organic manures. Crop production on a mixture of farm manure and artificials is better than with the use of artificials alone. Land under grass becomes more fertile because grass adds organic matter to soil and improves the physical properties. In France, too, some results supporting the organic view have recently been reported."

H.L. Jensen of Denmark in a recent article has stated as follows:

> "Actually there has for several years in some parts of the country been a tendency to do away with domestic animals and concentrate on cereals and industrial crops. Moreover, with the advent of the combine harvester and under a severe shortage of agricultural labour many farmers find it economically preferable to burn the straw in the fields which means a strongly lessened return of humus-forming materials to the soil. Actually it is realized that changed crop rotations with predominant cereal growing may create new and serious problems, first and foremost consisting in the spread of soil-borne plant pathogens, but eventually also undesirable changes in soil structure that may not be quickly remedied—all important matters to be considered in the planning of future research."

In the O.E.E.C. publication ***The Effective Use of Fertilizers Including Lime,*** April 1957, page 87, Prof. K.A. Bondorff, Director, State Laboratory, Lyngby, Denmark, has reported: "I will only say that the consumption of fertilizers could profitably be increased by 60%, thereby causing an increase in yield of 4%. I think that we can easily agree that there just be such a thing as a maximum profitable consumption.

When it is emphasised that agriculture in future will have increasing difficulties in meeting the demand of food, these people point to the role fertilizers have played and believe that by increasing the use of fertilizers, every demand can be met. Looking backwards, this point of view can be understood. But looking forward the picture is quite different. The possibilities of an increased use of fertilizers are in my opinion, often overestimated, the law of diminishing return too often neglected."

In a recent article, W.B. Bollen has also come to the conclusion that the plant food materials and fertility in the soil of the U.S.A. are decreasing although the use of commercial fertilizers, specially N, has increased markedly in the last ten years.

Oxidation of Organic Matter in Soils is Vital in Land Fertility Improvement and can fix Greater Amount of Nitrogen than Factory Nitrogen

There is no doubt that oxidation is vital for land fertility. Our extensive researches on the slow oxidation of organic substances and concomitant fixation of atmospheric nitrogen in soils show that in plant nutrition also the process of oxidation is as vital as the oxidation of food in the animal body. By utilising straw, grasses, forest litters, weeds, water plants, municipal waste, peat, lignite, waste coals and specially by oxidising them after mixing with calcium phosphates, man can continue permanent agriculture all over the world *without* animal dung, which is replaceable by straw and other organic substances. Hence, permanent agriculture is certainly a practical proposition in all countries *without* animals provided man ploughs down all easily oxidisable organic substances mixed with rock phosphates or basic slags. There is no doubt that the value as a manure of peat, lignite and coals, which are acidic substances, is greatly improved by mixing them with straw, weeds, water plants which are much more oxidisable than the inert humus-rich materials like peat, lignite, coal. Our discovery is that the oxidisable organic matter oxidation is a very good source of soil N, specially when aided by solar light and calcium phosphates. Man must realise that photosynthesis is not only the supporter of life on this planet but the photosynthesised material, when incorporated with soil, is the creator of land fertility required for crop production.

That oxidation is of vital importance in increasing the land fertility has been practically demonstrated by R.H. Eliot in his Clifton Park farming, where he produced better crops than with artificials by repeated ploughing up of the grasslands *without* any fertilizer. Similarly, in the Cockle Park experiments in Northumberland by adding basic slags, which are alkaline and contain iron, manganese, vanadium, molybdenum etc. and help oxidation of cellulose and other organic matter, the fertility markedly increased.

Freshly prepared phosphated composts should be utilised on a large scale specially because all over the world, prairie and czernogem lands which are also highly productive and seem to be created by the slow oxidation of grass materials in soils rich in lime and calcium phosphate, are loosing their fertility by repeated cropping. Also, peaty lands must be ploughed down after mixing them with straw, sea weeds and other easily oxidisable organic matter aided by heavy doses of basic (Thomas) slag or with a mixture of lime and phosphate. This will lead to the greater utilisation of the valuable substance—humus—which is fruitful in increasing the crop yield and in making the land easily cultivable.

Formation of Fertile Soil from Earth's Crust

We have carried on a large number of experiments in the slow oxidation of energy materials when mixed with soils or chemical surfaces like oxides of iron, nickel, aluminium, titanium, silicon etc. These surfaces do not contain any nitrogenous material. We have observed that the efficiency of nitrogen fixation, that is, the amount of nitrogen fixed per gram of carbon oxidised, is greater on the oxide surfaces than in our soil containing 0.04 to 0.05% total nitrogen. Moreover by increasing the total nitrogen in soils by the incorporation of nitrogenous compounds and mixing the nitrogen-rich soil with organic materials, there is nitrogen fixation in the slow oxidation of the energy materials. But the efficiency of nitrogen fixation falls off as the initial N content of the system increases. The higher value of efficiency of nitrogen fixation obtained with oxide surfaces as compared with that obtained in soils, is due to the fact that the phenomenon of nitrogen fixation and nitrogen loss go on simultaneously. The fixation process is opposed to the loss due to nitrification. The unstable explosive substance, ammonium nitrite, which is formed in the process of oxidation of nitrogenous compounds involved in the nitrification of proteins, aminoacids and ammonium salts formed by fixation of almospheric nitrogen or originally present in the system, undergoes rapid decomposition according to the equation: $NH_4NO_2 = N_2 + 2H_2O + 718$ K. cal. This is the main chemical change involved in the loss of nitrogen always observed in the nitrification of nitrogenous compounds. In soils there is always a certain amount of combined nitrogen, that is to the extent of 0.05% in tropical soils. Hence, the loss of nitrogen is more marked in soils than on oxide surface containing no nitrogen and the process of nitrogen fixation on oxide surfaces becomes more productive than in soil systems because the fixation process and nitrogen loss go on simultaneously opposing each other, and when the nitrogen of the system increases, the loss may compensate the amount of nitrogen fixed from the energy obtained from the slow oxidation of energy materials. These observations are of fundamental importance in explaining the evolution of fertile soils from the earth's crust obtained from the parent rocks of geological ages. The earth's crust does not contain any appreciable content of organic matter but may contain small amounts of nitrate or ammonium salts from rain water or snow or dust. These nitrogenous compounds under the influence of solar light and moisture and seeds from the first set of vegetation or plant life or alga on the earth's crust, the nitrogen need of which is met from the inorganic nitrogen present in the earth's crust in small amount. The energy materials photosynthesised containing cellulose, fat, soluble carbohydrate or other energy material formed in photosynthesis, undergo slow oxidation and liberate energy, causing nitrogen fixation which is markedly aided by light absorption and calcium phosphates present in the system. By the fixation of atmospheric nitrogen, the nitrogen store increases. This, in its turn, leads to a more abundant growth of vegetation, and this process goes on by which the carbon and N status of the system is improved leading to the formation of a fertile soil. This nitrogen fixation which, in the beginning is a non-biological surface reaction aided by light absorption as the original earth's crust is poor in the nitrogenous compounds, is more efficient in the beginning but with the storing up of nitrogen, the efficiency falls off and thus the nitrogen and carbon status of the system reaches a maximum limit depending upon the climatic conditions. But the maximum nitrogen increase can be improved by the incorporation of calcium phosphates which stabilise the nitrogenous compounds and avoid the loss of nitrogen.

Till the beginning of the present century, cattle dung or farmyard manure, alone or mixed with chalk, used to be the chief fertilising material in crop production in Europe. It was believed that dung, in its decomposition, supplies the nitrogenous compounds, potash, phosphate, lime, magnesia etc. present in the dung to the crops growing on the land and the chalk prevents the acidification of the land by washing. From our experiments we have established that dung or farmyard manure with C/N ratio of 20 or 22 not only supplies the plant nutrients contained therein but can fix appreciable amount of nitrogen and make the soil fertile, and, in this process, phosphate rocks, basic slags, bones etc. are of supreme importance and are better than calcium carbonate. Moreover, all organic substances leave a residual effect in the soil because of the humus formation and fixation of atmospheric nitrogen. It is clear that whenever a residual effect of a manure is observed, that is, molasses, straw, hay, farmyard manures, grasses, it is chiefly due to nitrogen fixation in the soil. Little residual effect is observed with legumes with a C/N ratio much smaller than that of farmyard manure or straw.

Why Dung from Oil-cake feeding Produces the same Crop as obtained from Corn Fed Dung ?

It is well known that the chief object of starting the Woburn Experimental Station in the United Kingdom was to test experimentally whether the dung obtained from animals fed on decorticated cotton cake has better manurial value on soils than the dung obtained from corn feeding. After 50 years of experiments, Russell and Voelcker stated as follows :

> "A review of the results forces one to the conclusion that the experiments have entirely failed to show any marked superiority of cake feeding over corn feeding on this soil."

These unexpected results have not been yet explained by the workers in Rothamsted or Woburn and will be quite [clear from the following considerations :

In the Woburn experiments, 45 lbs. of NH_3, that is, 37 lbs. of nitrogen were added in the cake per acre whilst with corn-dung 18 lbs. NH_3, that is, 14.8 lbs. of nitrogen were added.

If we assume that the C/N ratio is 20 : 1 in the corn-dung, the carbon added is 296 lbs. per acre, and if 225 lbs. are oxidised per year yielding 30 lbs. of fixed nitrogen, they make a total of 47 lbs. of nitrogen per acre. In the cake-dung, the total nitrogen is 37 lbs. per acre. The atmospheric nitrogen fixed in the cake-dunged plot is approximately 28 lbs. per annum, as the fixed nitrogen decreases with increase in the original nitrogen present.

The soil contains nearly 0.156%, that is, 3500 lbs. of total N upto a depth of 6 to 7 inches. Hence, the total nitrogen in the cakedunged field is 3500+37 lbs.+28 lbs.=3565 lbs. and in the corndunged field it is 3500+14.8 lbs.+30 lbs.=3544.8 lbs. per acre. If we assume that about 2% of the total nitrogen is in the available form, then the available nitrogen becomes 71.3 lbs. per acre in the cake-dunged field and 71 lbs. in the corn-dunged field and thus the crop yield should be almost identical.

Even when the total nitrogen of the soil drops to 0.093% after continuous cultivation, the total nitrogen in the soil becomes 2082 lbs. per acre and if 2% is in the available form, then the available nitrogen becomes 41.6 lbs. per acre. But if we add the cake-dung or the corn-dung, the total N in the cake dung becomes 2082+65 lbs.= 2147 lbs. producing 42.9 lbs. available nitrogen per acre whilst with corn the total nitrogen and available nitrogen per acre become 2082+50=2132 lbs. and 42.6 lbs. respectively. This also should produce about the same crop. On the other hand, if N is added in the form of ammonium sulphate or sodium nitrate instead of the cake or corn-dung, the position becomes different at once as will be evident from the following lines:

The original available nitrogen present in the soil is 70 lbs. per acre whilst the available N added is 37 lbs. (equivalent to the cake-dung) and this makes 107 lbs. per acre. When the corn-dung, equivalent of N is added as ammonium sulphate or sodium nitrate, the total available nitrogen comes up to 70+15 lbs.=85 lbs. These amounts of available nitrogen should produce better crops than with dung, more so in the first case than in the second case, but, both the crops should be better than with dungs. This is corroborated by the Woburn experiments.

There is another very remarkable fact that oil-cake, containing 4-5% total nitrogen and gram (pulse) containing 2.74% nitrogen when incorporated in soil or sand, loses its nitrogen after 50 or 60 days while wheat straw and paddy straw, containing smaller amounts of nitrogen, continues to fix atmospheric nitrogen in the system to a much longer period, upto even 150 days. This is due to the fact that when the initial nitrogen of the system undergoing oxidation is high, the nitrification of the proteins and aminoacids and the consequential loss of nitrogen in the gaseous state, develops more quickly than in the system containing smaller amounts of nitrogen as in wheat straw. These experimental results clearly explain why nitrogen-rich dung obtained by feeding oil cakes does not produce more crops than the dung obtained by corn feeding. The nitrogen-rich cake dung loses nitrogen when incorporated in the soil and thus the whole nitrogen of the system is not available to the crops but corn-dung fixes atmospheric nitrogen and enriches the soil, which can produce bigger crops.

Recovery of Nitrogen in Crop Production

World experience shows that the amount of nitrogen recovered in crop is approximately 25-50% of the nitrogen applied as fertilizer. In Sweden the recovery is of the order of 30%, as reported by O. Frank. Sir John Russell has recorded the following results of nitrogen recovery in Rothamsted experiments by application of fertilizer, *e.g.* ammonium sulphate at 112 lbs. per acre:

Wheat ...	39%
Barley ...	47%
Oats ...	46%
Swedes ...	35%
Potatoes ...	50%

On the other hand, Russell has recorded the following results on the residual effect of farmyard manure in Rothamsted experiments and the recovery of nitrogen from farmyard manure:

> "Plot 11A had received in the preceding 5 years 40 tons of farmyard manure containing about 525 lbs. of nitrogen and its yield, while falling, remained always above than that of Plot 10A, which indeed showed no sign of approaching. Both plots kept step with each other, and with the unmanured plot for 25 years, and the difference in yield corresponded with the differences in original manuring.

A similar persistence of farmyard manuring is, however, shown on Hoos Field at Rothamsted. One of the permanent barley plots—7-1 received farmyard manure annually from 1852 to 1871 while an adjoining plot received no manure. From 1872 onwards 7-1 has also been left without manure. Its yields have fallen but have always been well above those on the adjoining unmanured plot. If the effects are to be attributed to farmyard manure, the nitrogen balance sheet becomes very striking:

	Plot 10a lb./acre		*Plot 11a lb./acre*	
Total nitrogen supplied in farmyard manure, 5 years, 1877-1881	265	...	...	525
Nitrogen removed in crops, excess over unmanured.				
Direct effect, 5 years, 1877-1881	23	...	80	...
Residual effect, 25 years, 1882-1906	200	223	420	500
Balance not accounted for lb.	...	42	...	25
per cent	...	16	...	5
percentage recovery	...	84	...	95

In these experiments approximately 13-14 lbs. of nitrogen are fixed from atmospheric nitrogen. Even if this correction is made, the recovery of nitrogen from farmyard manure in crop production is higher than from artificial fertilizers.

Similarly, Lohnis and Fred have reported the following recovery in field experiments lasting for 4 years in the U.S.A. :—

Nitrogen	P_2O_5	K_2O
7.8 to 46.1	10.1 to 75.6	22.4 to 85.1

The recovery of nitrogen is less than that of phosphate or potassium.

For a number of years Dhar and co-workers have studied the problem of nitrogen loss from soils and have explained the low recovery of nitrogen from nitrogenous fertilizers and manures from the following considerations:

Under ordinary conditions of cultivation, the proteins, aminoacids and ammonium salts present in the soil or added to it as fertilizers and manures undergo slow oxidation by air as in the following scheme:

$$\text{Proteins} \longrightarrow \text{Aminoacids} \xrightarrow{+O_2} \text{Ammonium salts} \xrightarrow{+O_2} NO_2 \xrightarrow{+O_2} NO_3.$$

These are oxidation reactions which are accelerated by increased aeration, absorption of radiation and increase of temperature. In these processes of oxidation, an intermediate compound—ammonium nitrite—which is unstable and explosive, is always formed and it readily breaks up into nitrogen and water with evolution of heat : ($NH_4NO_2 = N_2 + 2H_2O + 718$ K. cal.) The formation and composition of this explosive substance cannot be avoided in land cultivation and crop production on application of nitrogenous fertilizers and manures.

Nearly 70% of the added nitrogen is said to have been lost when wheat plots have received 14 tons of farmyard manure containing 200 lbs. of nitrogen per acre.

Fate of Nitrogen in Farmyard Manure Applied to Wheat at Rothamsted

Plot Manuring	*N in soil 9" deep in 1893. per cent.*	*per acre (lbs.)*	*N supplied in manure in 50 years (lb.)*	*Removal of N in crops in 50 years (1844-1893) (lbs.)*	*Surplus of N over plot 3 unaccounted for in crop or soil (lb.)*
3 Unmanured.	0,0992	2570	...	850	...
2 Farmyard manure.	0.2207	5150	10000	2600	5670

The foregoing results obtained with 14 tons of farmyard manure per acre applied every year at Rothamsted and growing wheat on the same land, show that only 26% of nitrogen was recovered in the crop and approximately 57% of the nitrogen added in the 50 years has been lost since it is not accounted for in crop or soil.

Lipman and Blair observed a marked loss of nitrogen in their experiments at new Jersey and California Experimental Stations. In both the instances there was an unaccounted far greater loss of total nitrogen from the soil than that taken up by the crops.

Shutt in Canada observed a marked loss of nitrogen when virgin-prairie soils were broken for cultivation. Though this process leads to the production of more nitrate and available phosphates, it also causes much loss of nitrogen even when there was practically no loss of nitrates by leaching in these experiments, and Shutt's results are noted below;

Prairie Soils, virgin or cropped

Locality	*Character*	*History*	*Organic volatile matter %*	*Nitrogen %*
Portagela prairie, Man.	Black, friable, loam, sandy	Virgin, Uncropped. Unmanured.	19·43	0·651
...	...	Cultivated, grain for 25 years, fallowed but not manured.	14·79	0·506
Indian Head, Sask.	Black, heavy clay loam	Virgin, uncropped, unmanured.	12·83	0·371
		Cultivated, grain for 22 years; fallowed but not manured.	10·70	0·254

The balance sheet of nitrogen in Indian Head, Saskatchewan is as follows:

		Pounds per acre
Nitrogen originally present in prairie	0·374%	6940
Nitrogen present after 22 years cultivation	0·254	4750
Loss from Soil		2190
Recovered in crop		700

It appears that in humus-rich soils in Canadian prairie lands, the recovery of nitrogen is higher than in similar experiments at Rothamsted, where the soil humus is less than in Canada.

Moreover Rothamsted workers have reported that plants produced in humus-rich soil resist infection very well. Further research is needed in this line.

Direct ploughing of organic matter and Phosphates produces better yields than Composts obtained from them

Dhar, in his Presidential Address on 15/1/1937 to the National Academy of Sciences, first emphasised that direct ploughing in of organic matter is certainly better than the addition of the compost obtained from organic matter because in the direct ploughing in of the organic matter, there is much more nitrogen fixation than in composting, where even marked losses of nitrogen have been reported by soil scientists. In recent years, a very large number of comparative experiments have been carried on in the Sheila Dhar Institute.

Yield of Paddy Grain (Kgs.)

	Treatment	*Organic materials added directly Mean of 4 replications*	*Organic materials added after composing Mean of 4 replications*
1.	Soil alone	46·3	46·1
2.	Soil Wheat straw	74·3	66·3
3.	Soil Wheat straw Tata Thomas slag	96·6	88·7
4.	Soil Paddy straw	69·6	61·3
5.	Soil Paddy straw Tata Thomas slag	89·3	81·8
6.	Soil KANS (Sacchrum spontaneum)	65·3	57·6
7.	Soil KANS Tata Thomas slag	84·6	76·8
8.	Soil Mixed leaves	62·1	54·3
9.	Soil Mixed leaves Tata Thomas slag	81·5	73·5
10.	Soil Jack fruit leaves	60·2	52·4
11.	Soil Jack fruit leaves Tata Thomas slag	79·6	71·5
12.	Soil Sunnhemp (Crotalaria juncea)	58·6	51·0
13.	Soil Sunnhemp Tata Thomas slag	77·3	69·4
14.	Soil Cactus	56·7	49·2
15.	Soil Cactus Tata Thomas slag	75·8	67·6

From the foregoing results it is clear that direct ploughing in of the organic matter produces greater yield than from the compost formed from the organic matter.

Reclamation of Alkali Lands

Reclamation of Alkali soils poses a big problem for bringing back millions of acres of such unproductive lands under the plough. Various methods of reclamation by the application of chemical amendments like gypsum, sulphur, sulphuric acid, alum, etc. have been tried, specially in Egypt, Hungary, Russia, Holland and the U.S.A. with a fair amount of success. Reclamation of alkali land by merely leaching out the salts by flooding with has been practised in the U.S.A. But these methods, in addition to their being uneconomic, do not appear to bring about a permanent reclamation.

For over 44 years, we have carried out experiments in the Laboratory as well as in the fields on the reclamation of alkali soils by a mixture of organic matter and phosphates like different rock phosphates or basic (Thomas) slags. Amongst organic amendments we have tried molasses, pressmud, paddy straw, wheat straw, leaves, KANS (Sacchrum spontaneum), water hyacinth, coal etc. and in all these cases we have obtained beneficial results. Increase in the yield of paddy grains and barley grains, after incorporating organic matter and phosphate into the saline and alkaline soils of Rajasthan (India), is recorded below:

Organic matter (straw or pressmud) 10 tons/acre and P_2O_5

	10 lbs/acre Yield (Kg/acre)	
	Paddy grains	*Barley grains*
Control	45·93	93·75
Organic matter (straw)	126·12	175·60
Organic matter (straw)+P_2O_5 as bonemeal	203·91	241·90
Pressmud	370·18	266·25
Pressmud+P_2O_5 as bonemeal	501·62	382·50

The crops produced by organic matter+phosphate are richer in proteins, vitamins A, B and C and minerals than those from the control field.

Similar experiments on the reclamation of alkali soils were conducted in Phulpur (Allahabad, India) by N.R. Dhar and A.K. Rishi; three successive crops of gram, paddy and wheat were grown after incorporating straw, KANS, coal, water hyacinth and cactus (Phylo-clades) along with Thomas slag and rock phosphate. The results indicated a significant increase in available P_2O_5, exchangeable calcium, water holding capacity and permeability and a marked fixation of nitrogen along with bumper crops in the plots treated with organic materials and phosphates. The yields of the grains of gram, paddy and wheat are recorded as under:

Yield of 3 successive crops grown on the alkali soil amended with 5 tons/acre of Organic matter and 50 lbs/P_2O_5/acre as German basic slag.

	Gram grain (Kgs/acre)	*Paddy grain (Kgs/acre)*	*Wheat grain (Kgs/acre)*
Control	45	90	82·5
Wheat Straw	270	474	465
Wheat straw+German basic slag	381	625·5	607·5
KANS	241·5	453	435
KANS+German basic slag	354	585	577·5
Coal	202·5	450	427·5
Coal+German basic slag	295·5	570	555

It seems that during the slow oxidation of organic matter in the soil, carbonic acid and organic acids like acetic, citric, lactic, malic, propionic acid etc. are produced which neutralise the alkalinity of the alkali soils. Carbonic and organic acids thus produced can also readily convert tricalcium phosphate into dicalcium phosphate and small amounts of monocalcium phosphate which, being appreciably soluble, can readily supply calcium ions to the alkali soil solutions. Calcium ions brought into solution readily replace sodium ions on the exchange complex of the soil, thus increasing the exchangeable calcium status of the soil.

Value of a Mixture of Organic Matter+Phosphate in Crop Production in acidic, neutral and alkali land the possibility of their irrigation by Brackish or Sea Water

It is well known that in cold and temperate countries, due to the washing away of Ca-ions absorbed on the soil complex, the soils have a tendency of being acidic due to the replacement of Ca-ions by H-ions. Hence practical agriculturists empirically observed that liming produces larger crops. Consequently, farmyard manure+chalk or lime was largely used in crop production in Europe. The washing away of lime by precipitation containing carbonic acid is due mainly to the formation of the readily soluble calcium bicarbonate. Our experimental observation show clearly that addition of basic slag or bone-meal or rock phosphate decreases markedly the washing away of lime, chiefly because by the application of tri—calcium phosphate, to the soils containing carbonic acid, dicalcium phosphate, which is much less soluble than calcium bicarbonate, is mainly produced along with monocalcium phosphate which is the main ingredient of commercial superphosphate. Monocalcium phosphate is readily soluble and is produced in much small amounts than di-calcium phosphates by the action of carbonic acid on tri-calcium phosphate. Thus, the application of different calcium phosphates markedly decreases the washing away of lime in soils.

Similarly, the addition of lime or calcium carbonate to a soil leads to a decrease in the phosphate washing from soil by rain and snow. Calcium phosphate is hydrolysed by water mainly according to the equation:

$$Ca_3(PO_4)_2 + 3H_2O \rightleftharpoons 3Ca(OH)_2 + 2H_3PO_4.$$

This reversible chemical change is markedly checked by the presence of lime or calcium carbonate. Hence washing away of phosphate, which is a valuable plant food, is checked by lime or chalk.

In Aslander's standard fertilization method, heavy doses of farmyard manure along with N.P.K. are applied in crop production without liming. It is well known that farmyard manure contains 133 lbs. CaO per 10 tons. This lime checks the washing away of phosphate from superphosphate.

On the other hand, in arid or tropical soils due to the presence of sodium chloride and sulphate, the calcium ions absorbed on the soil complex are replaced by Nations forming sodium soils from the fertile calcium soils. It is well-known that the sodium soil, by its reaction on carbonic acid, forms sodium bicarbonate and small amounts of sodium carbonate causing the formation of unproductive alkali soils all over the world. It has already been stated that such soils can be permanently reclaimed by the application of a mixture of organic substances + rock phosphate or basic slag or bonemeal. This mixture supplies all plant nutrients and converts the sodium soils into calcium soils. A mixture of $CaCO_3$ + carbonic acid can also convert an alkali soil into a calcium soil, but, the mixture of $CaCO_3$ and carbonic acid is unable to supply all the plant nutrients. Hence, for the reclamation of alkali soils, a mixture of organic matter + phosphate is highly effective.

Similarly, the same mixture applied to acid, alkaline or neutral lands can be highly productive. Also, this mixture when applied to soils can produce crops without the formation of alkali lands even when irrigated by sea or saline or brackish water mainly because the calcium diphosphate and small amount of mono-calcium phosphate readily react with the bicarbonate or carbonate ions formed in the soil due to the addition of sodium chloride present in the sea water. Hence, irrigation by sea water in small amounts is a practical proposition in crop production all over the world provided the land is fertilized by a big dose of organic matter including coal+calcium phosphate. The phosphate mixture with organic matter is certainly much more effective than a carbonate mixture and organic matter.

Indian Basic Slag as good as American basic Slag and profitable for Crop Production in conjuuction with Organic Matter

India possesses large amounts of basic slags produced from the expanding steel industry and these slags remain unutilised. From a large number of analyses it has been found that the Tata basic slag contains 7-8% P_2O_5 which compares favourably with the phosphate content of basic slags in the American markets. The Tata basic slag and other phosphates, when used with organic matter, not only fix atmospheric nitrogen, supply available phosphate, increase the crop production and improve the fertility of normal soils, but, they also reclaim USAR and alkali lands and alkali soils and the acid soils permanently.

Phosphate-rich Soils can be Rich in Nitrogen

The potash content of soils is definitely more abundant all over the world than phosphate or nitrogen content. On the other hand, the nitrogen content in temperate climates is definitely higher than the phosphate content. It is stated that the phosphate contents of soil can vary from 0.3 to 0.0% whilst the nitrogen content from 3 to 0.04%. It has been reported that the nitrogen content of the FEN soils can be as high as 3%. Also the potash content of many soils can be as high as 3%. Hence, Sir John Russell seems to be quite right when he states that the phosphate applied to the soils may determine the course of history even in the near future, specially in cold and wet countries.

In tropical country soils, with a moderate amount of rainfall, the P_2O_5 content is usually double or slightly more than the nitrogen content, which in alluvial soils is approximately 1100 lbs./acre, that is, approx. 0.04 to 0.05% whilst the P_2O_5 content is 0.1%, that is

2000 lbs./acre. This seems to be a fundamental difference between the soils of temprate and tropical countries, the nitrogen content of temperate country soils being higher than the P_2O_5 content.

From a survey of soils of different countries it appears that the nitrogen status of a soil is intimately connected with the phosphorus status all over the world. When the P_2O_5 is 1000 lbs/acre, the nitrogen content cannot be greater than 0.1% but when the P_2O_5 content becomes 2000 lbs/acre or more, the nitrogen content can go up to 0.2% or more. In other words, as the P_2O_5 content of soil increases, there is a marked increase of the nitrogen content. As a matter of fact the increase in the nitrogen content appears to be more steep with increasing amounts of P_2O_5 content in the soil.

Why grassland is richer in Nitrogen than Forest or Timber Land

In my paper on Importance of Organic Manures and Inorganic Fertilizers (Proc. Nat. Acad. Sci., 1951, 20, pp. 151-192) it has been stated that "prairie soils or those covered with grass are richer in their humus and nitrogen contents than timber soils. This may be due to the fact that more sunlight falls on grasslands and helps in the improvemect of nitrogen status by fixation of atmospheric nitrogen from the oxidation of carbonaceous compounds than forest or timber soils". There is another important reason of this phenomenon. It has already been stated that the ratio of Ca : P in leaves of trees is 14 : 1 whilst the Ca : P of wheat straw is 2 : 1. This is a very interesting fact that the phosphate content of tree leaves in comparison to calcium is much smaller than in wheat or coat straw. It appears therefore that the calcium phosphate status of forest or timber soils is lower than that of grass soils. The various Bulletins of the University of Alberta, Canada, on soil survey bring out this point very clearly showing that the calcium phophate contents of the profiles of the wooded soils are appreciably smaller than those of open grasslands. Odynsky and Newton in Bulletien No. 53 (1953) (Report No. 15, Alberta Soil Survey) have stated on page 7 : "The phosphorus content of the surface food varies from an average of 0.08% in the black soils to an average of 0.035% present in the gray wooded soils." Calcium phosphate has been found to be able to help nitrogen fixation in soils very considerably. Hence the nitrogen and humus of forest soils is inferior to that of grass or prairie soils.

Sunlight increases Soil Nitrogen content

Moreover, in our publications since 1951, the greater nitrogen contents of grasslands than in forest or timber lands, have been explained from the viewpoint that in grasslands there is more calcium phosphate and they receive more sunshine than the forest lands. Recently, we have compared the nitrogen status of grasslands and that of neighbouring lands under bushes and shrubs and we have always observed greater amounts of nitrogen in the grasslands than in lands receving lesser sunshine.

Hans Jenny and S.P. Raychaudhuri have reported that comparison of Indian with American soils, particularly those of California, Texas, Atlantic Coast, showed an unquestionable superiority of the former over the latter when sites having equal mean temperatures were compared. But the Indian soils had much lower nitrogen and carbon contents than the tropical soils of the Central and South America.

Moreover, the average nitrogen content of soils in Ootacamund and Kodaikanal, which are hill stations in the south of India near the equator, is 0.335% and 0.332% respectively while the North Indian hill station of Simla has 0.241% nitrogen and Mussoorie has 0.266% nitrogen. Similarly, Ambala and Aligarh, lying in the Northern Indian plains, show a nitrogen status of 0.036% nitrogen and 0.044% nitrogen, whilst Madras and Madurai in the South near the equator have 0.054% and 0.062% nitrogen respectively. The rainfall and temperature in all these stations are about the same.

The observations showing greater nitrogen status of lands near the equator support the photochemical viewpoint of nitrogen fixation. Undoubtedly, world soil nitrogen is created by the fixation of atmospheric nitrogen in the slow oxidation of organic matter aided by sunlight absorption and phosphate.

Phosphates helpful in the Formation of Nitre Beds

In a number of publications, Dhar has advanced a theory explaining the formation of natural nitre beds in Chile and other parts of the world based on the phenomenon of nitrogen fixation aided by sunlight. It has been reported that phosphates exist in the overlying rocks near the deposits of the Chile salt petre. From our experiments we have observed that when calcium and other phosphates are mixed with all types of organic matter undergoing slow oxidation, there is marked fixation of atmospheric nitrogen and formation of proteins, aminoacids and salt of ammonia. This fixations of nitrogen by the slow oxidaton of organic matter is much greater in presence of light than in its absence and, actually, light is utilised in producing more nitrogenous compounds. Moreover, in presence of calcium and other phosphates, the fixation of nitrogen is much accentuated.

Hence all types of organic substance, like seaweeds, planktons when mixed with guano or bird deposits or bones of fishes or animals rich in calcium phosphate, fix atmospheric nitrogen copiously, specially in presence of sunlight in areas like Chile, Peru etc. These nitrogenous compounds in course of time can undergo nitrification more in light than in the dark and can be converted into nitrate of sodium, potassium, calcium, magnesium etc.

We have observed that when potassium salts, sodium salts or soluble calcium or magnesium salts are mixed with nitrogenous substances undergoing nitrification, the formation and decomposition of the unstable and explosive substance, ammonium nitrite, which is always produced in the nitrification of nitrogenous compounds, is decreased due to the formation of nitrites of the alkali and the alkine earth metals. Consequently, the formation of nitre beds may be due to the photochemical, catalytic and bacterial nitrification of the nitrogenous compounds obtained from weeds, planktons, animal bodies and those fixed in the slow oxidation of organic substances with C/N ratios greater than 10 aided by calcium phosphates derived from sea animals, fishes and dung of the birds.

It is quite possible that under certain conditions, the soluble nitrates thus produced may be separated from the calcium phosphate by washing down the highlands and accumulated by the evaporation of water in the valleys. That sea water and sea weeds and materials present in the sea bed play an important part in nitre bed formation is clear from the following composition of an average sample of caliche, which contains many chemicals present in the sea water and beds: sodium nitrate 8-25%, potassium nitrate 2-3%, sodium chloride 8-25%, sodium sulphate 2-12%, calcium sulphate 2-6%, magnesium sulphate 0-3%, sodium biborate 1-3%, sodium iodate 0.05-0.1%, sodium per-chlorate 0.1-0.5% and insoluble matter 23-70%.

Organic Matter produces Crops of Better Quality

Apart from the increase in the yield of crops by the application of organic matter and phosphates, there is another role of vital importance showing that the quatity of the crop produced by a mixture of organic matter phosphates is better than that produced in the Control Soil' or that fertilized by the application of NPK. The proteins, vitamins A,B,C and minerals are apprecibly greater in the organically produced crops than those obtained in the unfertilized or chemically fertilized land. In this respect the behaviour of water hyacinth is the best. A mixture of water hyacinth phosphates improves the quality of the crop to a greater extent than a mixture of straw phosphates.

In our comparative study of organic matter (10 tons water hyacinth and 100 lbs. p_2O_5 as rockphosphate) and fertilizer (100 lbs. N, as ammonium sulphate) for growing potato and other vegetables and cereals we have observed marked increase in protein, minerals and vitamins contents in the organically treated crops. The following table shows our results with potato:—

Types of potato	*Protein* *gm.*	*Phosphorus* *mg.*	*Calcium* *mg.*	*Potassium* *mg.*	*Vitamins* *A* *I.U.*	*B* *mg/100 gm.*	*C* *mg/100 gm.*
1. Inorganically grown	1·86	56·29	11·22	247·14	42	0·083	18·5
2. Organically grown	2·01	64·00	18·57	276·68	56	0·092	28·4

Oxidisability of Edibles & Nitrogen Fixation by their Slow Oxidation in Air

Physiologists have declared that animal proteins are oxidised in the human body more quickly than carbohydrates and fats for heat generation.

We have carried on a large number of experiments on the oxidation of pulses, meats, fishes and carbohydrate-rich edibles on TiO_2 surface and the following results (p. 58) have been shown obtained.

From the extensive experiments carried on by us with different types of food materials some very interesting conclusions are derived. With protein-rich food materials the percentage of carbon oxidised is almost inversely proportional to the C/N ratio. In other words, the greater the protein, the greater the oxidation. Similarly, with carbohydrate-rich materials like RAGI, wheat, rice, maize, banana, tapioca and potato, the percentage of carbon oxidation is also inversely proportional to the C/N ratio. But the difference in percentage oxidation in carbohydrate-rich materials is not wide and varies from 6.8 to 8.8%, although, the C/N ratio differs from 15.03 to 365.5. It seems, therefore that from the digestibility viewpoint these carbohydrate-rich food materials are practically of the same value. It is extraordinary that

Food materials	*C/N ratio*	*Percentage oxidation after 100 hours*	*Efficiency of Nitrogen fixation Mg. of N—fixed per gm. of C oxidised*
Protein rich materials			
Meats			
Chicken ...	10·5	34·56	15·4
Lamb ...	12·0	31·43	16·7
Beef ...	12·50	29·7	17·0
Pork ...	12·82	28·8	17·4
Pulses			
Black gram (URAD) ...	7 0	48·8	7·4
Green gram (MOONG)...	7·3	43·38	8·3
Fishes			
Sea fish ...	15·4	26·0	24·0
River fish :			
Royal ...	14·5	27·2	21·2
Beacha ...	14·2	27·7	19·8
Carbohydrate-rich materials			
Cereals			
Wheat ...	21·02	8·4	91·0
Brown rice ...	51·14	7·56	86·5
Maize ...	23·10	8·2	89·5
RAGI ...	15·03	8·8	95·2
Tubers			
Tapioca ...	365·5	6·8	74·0
Potato ...	101·5	7·1	82·3
Fruit			
Banana ...	61·35	7·4	85·0

all the food materials so far investigated show nitrogen fixation varying from 7.4 mg. to 95.2 mg. per gm. of carbon oxidised. The interesting phenomenon observed is that efficiency of nitrogen fixation of carbohydrate-rich materials varies from 74 to 95.2 mgs. per gm. of carbon oxidised on a titania surface in presence of light ; although the C/N ratio varies from 15·03 to 365·5. It is reasonable to conclude, therefore, that the common carbohydrate-rich food materials are of the same value in the animal body from the viewpoint of digestibility and creation of nitrogen compounds in the body. Hence, man can eat the cheapest material from amongst the following food materials ; RAGI, wheat, maize, rice, banana, potato and tapioca. The Ca contents of these food materials very from 0.286% of RAGI to 0.015% in potato. The P_2O_5 content of RAGI is 0.687% as against 0.103% with tapioca, From the mineral point of view both RAGI and wheat are better.

It is quite interesting to note that when it is air dried, the fish carbon varies from 48.8 to 55.6%. The nitrogen content is 3.15 to

3·83%. In the case of meat the carbon varies from 41.2 to 47.43% and the nitrogen from 3.57 to 3.94%. Hence the food value of fish and meat does not differ much. Fish is certainly richer in minerals (CaO and P_2O_5) than meat and thus in comparison with fish meat is more acid producing except chicken. The carbon of chicken is 41.37% and nitrogen 3.94% and the C/N ratio is 10.5. From the mineral poins of view ($Ca_3(PO_4)_2$), chicken is the best. Europeans pay more price for beef than other varieties of meat as they declare that beef is very juicy. But from the chemical analysis, chicken is richer in protein and minerals than beef. Pork is the cheapest meat in Europe, but, from analytical viewpoint, pork is better than mutton. Amongst the two pulses—URAD & MOONG—the nitrogen content is of the same order as in fish and meat, but, the mineral ($Ca_3(PO_4)_2$), content of URAD is also of the same order as in MOONG. The P_2O_5 content of MOONG is 0.115% and of URAD 0.127% and CaO content of MOONG is 0.798% and that of URAD 0.822%. But the oxidisability of the pulses is appreciably greater than that of fish or meat. The order of oxidisability determines the quickness with which the food can supply heat to the body. In this respect the pulses seem to be best; next to pulses is meat and then comes fish. But the carbohydrate-rich materials are oxidised at a low speed when compared with protein-rich materials.

When a food or energy material is allowed to undergo oxidation in air, the carbonaceous compounds are partially oxidised into carbon dioxide and weak organic acids which, in course of time, may undergo further oxidation to carbonic acid.

In diabetes, the glucose produced in the body from the food materials does not undergo oxidation and aceto-acetic acid, β-hydroxy butyric acid, acetone etc. are produced along with carbonic acid. On adding sodium or potassium salts of earbonic or citric or tartaric acid, a part of the acidity is neutralised.

When a human being takes a mixed diet consisting of carbohydrates, fats and proteins, there is the formation of ammonia which is converted into urea and some weak organic acids. If the food is rich in vegetables containing minerals like calcium and magnesium phosphates etc. which can act as buffers in neutralising H-ions from the acids produced, the body tissues are not affected by the acids produced from the metabolism and there is no problem of gastric troubles.

It is interesting to record that in RAGI the CaO content is 0.286% and MgO is 0.188% and K_2O 0.482% making a total of 0·956%, whlist the P_2O_5 content is 0·687%. Thus, in the metabolism of RAGI in the animal body more alkaline materials are available than P_2O_5 but the K_2O forming soluble phosphates with P_2O_5, will be washed away readily. In the case of rice there is no MgO; the CaO and K_2O form 0·277% whilst P_2O_5 is 0.2602%. Hence from the mineral point of view RAGI is better than rice. In the case of wheat the CaO and MgO is 0.345% and K_2O is 0.347% whilst P_2O_5 is 0.364%. Hence from the mineral retention viewpoint wheat is better than rice but inferior to RAGI. Maize is definitely an acid producing food because the CaO and MgO form 0.185% and K_2O 0.475%; but the P_2O_5 is high, being 0.558%. From the acidity point of view, maize containing 0.553% P_2O_5 and only 0.185% CaO and MgO is certainly more acidic than rice containg 0.2602% P_2O_5 and 0.156% CaO and wheat containing 0.365% P_2O_5 and 0.345% CaO and MgO. In other words wheat, which is moderately rich in minerals and vitamins and is more oxidisable than rice, is a better food than rice which is certainly easy to consume in the cooked condition as it is nice and soft. Moreover, the nitrogen fixation in wheat is greater than it is in rice.

Tapioca like potato is a tuber; the CaO and MgO in tapioca is only 0.0802% but the K_2O is high, it is almost 10 times greater than CaO and MgO and is 0.87%; the P_2O_5 is low and is 0.103%, hence, it cannot be considered as an acid food material. All over the world potato is largely eaten; its CaO and MgO content is low, being 0.0479% but the K_2O is high, being 1.06% and the P_2O_5 is 0.276%. Hence, for all practical purposes this is poor in minerals but almost a neutral food material.

Banana is eaten in ripe as well as in green condition in tropical countries. Green banana has 0.217% CaO and MgO and 1.54% K_2O, 0.587% P_2O_5. Thus, it is much richer in minerals than potato.

In the case of the 2 pulses URAD and MOONG the protein content is high and is: URAD 20.6% and MOONG 20.0% and is likely to be acid forming in the body, but the CaO and MgO form 0.945% and K_2O 0.835% whilst the P_2O_5 is only 0·127%. Hence the acidity produced from this protein-rich material is likely to be neutralised by high amounts of CaO, MgO and K_2O forming 1.775%. The behaviour of the other pulse, MOONG, is about the same possessing 1.589% mineral mixture ($CaO+MgO+K_2O$) and only 0.115% P_2O_5.

Beef contains 0.65% P_2O_5 and only 0.14% CaO whilst pork contains 0.17% CaO and 0.44% P_2O_5 and mutton has 0.12% CaO and 0·56% P_2O_5. These 3 meats have to be considered as acidic foods. Chicken is much richer in lime, *i.e.* 0.42% CaO but the P_2O_5 content is high, being 0.78%. Hence chicken and the fishes are certainly mineral rich and are less acid producing than beef or mutton or pork.

In every case the P_2O_5 content varies from 3 to 5 times greater than CaO whilst with fish and chicken the P_2O_5 is double or less than that of CaO.

It is well known that tricalcium phosphate formed from 3 CaO and P_2O_5 is feebly alkaline and acts as an excellent buffer for the removal of H-ions forming $CaHPO_4$ which is almost neutral. But calcium diphosphate, which is largely used mixed with animal fodder, is formed by the reaction of 2 CaO and 2 P_2O_5. In other words, for the formation of tricalcium phosphate in the animal body 168 grams of CaO have to react with 142 grams of P_2O_5, that is, the amount of lime required is about 20% greater than that of P_2O_5, whilst for the formation of $CaHPO_4$, 112 grams of CaO are needed to react with 142 grams of P_2O_5. In this case the amount of lime requirement is 25% less than that of P_2O_5.

Starch and Calcium phosphate rich Foods save Proteins and fix Atmospheric Nitrogen

Rübner has reported that if a well nourished man having 2100 grams of nitrogen as protein in his body is fed with a diet adequate in calories but very low in protein, he loses only 1 gram of nitrogen per day.. His nitrogen equilibrium is established after 3 years. He loses on an average of 0.5 gm. of nitrogen per day, forming the total loss of about 500 grams of body nitrogen in 3 years. In other words, only 1/4th. of his cell nitrogen is oxidised within 3 years.

Rubner also showed that on a pure carbohydrate diet at the beginning, the loss of nitrogen is 4 grams and in the end 1.8 gm. per day and then death from his protein-free diet will take more than a year and danger from protein starvation is less marked than from an inadequate supply of calories.

Luthje has observed that P_2O_5 retention in the animal body is associated with protein retention for the formation of new tissues including bones. In ordinary dietary a greater intake of material, rich in calcium phosphate, leads to the construction of new flesh.

The research work carried on in this Institute has quantitatively proved that phosphorylation of aminoacids and proteins leads to their stability and marked decrease in their oxidation. For a number of years we haue shown that proteins or aminoacids present or added either in the soils or in the animal body undergo oxidation readily by air. The following changes take place in the animal body: Proteins $\longrightarrow$ aminoacids $+ O_2 \longrightarrow$ ammonia and ammonium salts. The ammonia produced combines with CO_2 aided by the energy of respiration and forms mainly urea and small amounts of uric acid, creatine etc. Physiologists have always asserted that urea nitrogen is the measure of protein loss from the system. In the soil or a chemical surface, ammonia and ammonium salts are further oxidised to nitrite and nitrate. In these processes the unstable and explosive substance—ammonium nitrite—breaks up into nitrogen gas with evolution of heat as in the equation : $NH_4NO_2 = N_2 + 2H_2O + 718$ K. cal. This leads to a marked loss of nitrogen when nitrogenous fertilizers and manures are applied in crop production. It is well known that the recovery of nitrogen applied in crop production is of the order of 30%, showing that the majority of applied nitrogen is lost. On the other hand, proteins, aminoacids etc., ingested as food materials and the protoplasmic cells containing proteins, undergo oxidation in the body forming ammonia, which is converted into urea and small ammounts of other nitrogenous products. These are eliminated mainly as urea in the urine and faeces. This oxidation is greatly retarded by phosphorylation and addition of carbohydrates. The protein sparing property of a mixture of carbohydrates and phosphate and their ability to fix atmospheric nitrogen may lead to an addition of nitrogenous compounds in the animal body. Hence the shortage of proteins can be certainly met by the intake of cheap carbohydrate food and vegetables rich in calcium phosphate and vitamins fortified by small amounts of milk. It can be concluded that if very careful experiments are carried on quantitatively on animals including humun beings, the results are likely to show appreciable nitrogen fixation even in the animal body kept on a diet rich in carbohydrate, aided by calcium phosphate. From our experimental observations on nitrogen fixation in the slow oxidation of the food materials and the survey of the vast literature on animal metabolism, it can be concluded that even in the body tissues carbohydrates enriched by calcium phosphates can add appreciable amounts of animal cell by fixation of atmospheric nitrogen and saving the protoplasmic nitrogen as is readily happening all over the world in soils and on chemical surfaces.

The reported deaths after long protein starvation may be caused by mainly acidosis of the system and this can be stopped by the calcium phosphates, which can always act as excellent buffers.