

A CENTURY OF LIEBIG'S THEORY OF MINERAL NUTRITION OF PLANTS AND OF SOIL FERTILITY

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IT is now a century since Liebig, the German Chemist, announced in the year 1840, his theory of the mineral nutrition of plants and soil fertility. The announcement is not only an important landmark in the progress of knowledge of the chemistry of plants and the science of plant nutrition and crop production, but is the foundation of Agricultural Chemistry as we know it to-day.

The history of science abounds with instances in which thought and research changed from time to time following discoveries of fundamental importance. Such discoveries, eventually directed experiment and thought into new fields, leading to new knowledge and expansion in scientific outlook, without at the same time invalidating previous knowledge and experience. Liebig's theory is an example in point. It will be interesting and instructive to briefly recapitulate the major developments leading to Liebig's theory and to review the experience and the trend of research and thought on soil fertility and plant nutrition during the century that has elapsed.

Till Liebig expounded his views in the year 1840, the "humus theory" of plant nutrition held the field and it was believed that plants should be nourished by a substance of a similar nature. Chemistry and Agricultural Chemistry as they are known to-day had their beginnings in the mists of alchemy. In those days the knowledge of the constitution of matter was only in terms of the four elements or primordial materials of the Aristotelian philosophy, *viz.*, fire, air, earth and water. Towards the end of the sixteenth and the beginning of the seventeenth centuries Paracelsus taught that life was a chemical process and that the bodies of animals and plants were chemical laboratories. The belief was held that compounds manufactured by life processes in the bodies of animals and plants could not be made in the laboratory.

The discovery of several chemical elements in rapid succession between the years 1750 and 1800 and the development of quanti-

tative methods of experimentation by Lavoisier and de Saussure marked the beginnings of Agricultural Chemistry and the study of the chemical composition of plants received a powerful impetus. The synthesis of urea in the laboratory by Wöhler in 1828 was another step in advance. It finally disposed off the distinction between substances made by life-process in the bodies of animals and plants and those made in the laboratory. These developments opened up fresh fields of enquiry and led Liebig to turn his attention to plant chemistry. He made chemical analyses of the ashes of plants and manures, carried out experiments on a piece of uncultivated land at Gissen and discovered that by applying to the soil nothing but mineral salts he could turn the land into as fertile a spot as could be found in all Germany. He discovered that plants could absorb minerals and assimilate them and could manufacture their organic materials from air and water. He attributed the effectiveness of farm-yard manure to the mineral salts of phosphorus, potassium, sodium, calcium, magnesium and others contained in the manure and also found in plant ashes, dismissed the humus theory and announced his mineral theory of plant nutrition and soil fertility.

Although this announcement raised a bitter controversy in the beginning, its value was eventually recognised. Liebig, by analysis and synthesis of the then existing data, clarified the ideas on plant nutrition, placed them on a scientific footing and simplified manuring of crops. A chemical analysis of the soil would indicate what was lacking or inadequate in it and the restoration of the lacking or inadequate element to the soil would restore its fertility. It was all so simple and easy, and therefore these ideas of chemical treatment of the soil rapidly gained favour. The use of artificial or chemical fertilisers became popular and a huge artificial fertiliser industry had arisen.

The earlier experiences in the practical application of the theory to the humus rich

soils of the temperate climates of Europe gave such unqualified support to the theory that it was believed that artificial or chemical fertilisers could for ever effectively substitute farm-yard manure and other organic manures. The belief developed that farming might be only chemistry and a matter of supply of mineral salts to the soil. Plant nutrition came to be regarded as entirely a matter of direct mineral absorption and plant nutritional and agrobiological concepts have been developed and interpreted in terms of fertiliser elements.

Subsequent developments provided evidence that soil fertility was not quite such a simple matter as that. Towards the end of the nineteenth century discoveries, led by Pasteur, of bacteria and his studies on fermentation processes assumed a definite stage and shape, and threw light on the biological processes in the soil, and brought the realisation that in soil fertility there was something more than continuous supply of mineral fertilisers. About the year 1850 Pasteur pointed out that important changes especially oxidations are brought about by Micro-organisms. In 1877 Schloesing and Muntz and a little later Schloesing established the oxidation of soil organic matter to nitrates by bacteria. In 1888 Hellriegel and Wilfarth investigating the problem of nitrate supply and plant-growth observed that while graminaceous plants failed to grow without nitrate supply leguminous plants could do so. This was ultimately traced to symbiotic nitrogen fixation. Towards the close of the century Knox, Winogradsky and others showed that atmospheric nitrogen was fixed in the soil by azotobacter.

The birth of the twentieth century saw the extension of the zone of soil and plant research to countries outside Europe and America and included the hot, humid, and dry tropics. The increase in the number of research workers working under different conditions of soil, climate and crops soon widened the scope of enquiry. Gradually knowledge accumulated. The importance of organic matter and micro-organisms in the soil became apparent. Soil processes and the nitrogen and carbon cycles became clearer. Farmers and experimenters were puzzled by the fact that manures like farm-yard manure, relatively poor in mineral plant foods and in their availability, produced equally good and even better results than

mineral fertilisers. The long period experiments at Rothamsted in England and at Pusa and Coimbatore in India showed that although in the earlier years mineral or chemical fertilisers could produce better results than farm-yard manure, their continued application tended to decrease crop yields compared to farm-yard manure and green manures. Mineral or chemical fertilisers began to find their place as immensely important but not all-important. The sustained and better action of the organic manures was, however, attributed to the better moisture-holding powers of the soil.

Then came studies on human and animal diets and the discovery of vitamins. Once again vistas were opened up. Workers in animal and plant chemistry began to find common ground. Such important characteristics as sexual differences and sexual reproduction and such vital functions as respiration in plants are recognised to be similar to those in animals in their fundamental principles. But, no such similarities were yet thought of in regard to the fundamental nutritional requirements of plants and animals. The role of organic matter on crop-growth was considered to be only indirect and the existence of accessory factors in plant nutrition similar to vitamins in animal nutrition were either not considered or disregarded.

Bottomley¹ and later Mockeridge² announced for the first time that extracts of fermented organic manures gave to plants certain growth-promoting substances which they called "*auximones*" and which they considered essential to plants. The hold of Liebig's mineral theory was still strong and Maze³ just then showed by water-cultures the importance of trace elements for plant-growth. The views of Bottomley and Mockeridge were vigorously opposed and their results were explained in the light of Maze's results. Bottomley died and Mockeridge in a later communication⁴ even abandoned her former views on the direct effect of organic matter on plant-growth.

Nevertheless, the experiences in the field and in the laboratory compelled investigators to revert to this question on the effect of organic matter and manures on soil fertility and the work of the last two decades in India and outside has recorded notable advances and opened up new lines of thought and research.

The work in India of Viswa Nath,⁵ McCarrison and Viswa Nath,⁶ and Viswa Nath and Suryanarayana⁷ has provided a complete picture and has thrown new light on the role of organic matter and micro-organisms in plant nutrition and on the interrelationship between, and the inter-dependence of the three components of the system soil-plant-animal. These workers have shown that organic manures play a part hitherto unsuspected and that they provide certain substances analogous to vitamins which are absorbed and assimilated by plants leading to improvements into the quality of the end products of plant metabolism either as food or seed material. They have stated on the basis of their experimental evidence that:

1. Plants also have accessory food factors, akin to vitamins, for proper development and reproduction.
2. Organic manures have as one of their functions the supply of these accessory food factors.
3. There exists a cycle or chain of accessory factors beginning with soil micro-organisms and ending with returning to the soil through plant and animal bodies.
4. Nutritional factors for animals are associated with nutritional factors for plants.

These views which were published in 1926 not only did not receive acceptance, but even roused opposition due to partly to their newness and the knowledge being incomplete and partly to the difficulties experienced in getting clear of the narrow view-points resulting from a too limited experience. In the few years that have elapsed more data have been obtained in different parts of the world in support of the views mentioned above.

At a discussion held by the Royal Society of London in the summer of 1937⁸ the available information scattered in several publications was reviewed and it was recognised that the case established in the nutrition of animals was equally established in the nutrition of the most diverse varieties of cells and that all cells from the lowliest bacterium to the cells of the highest animals carry out the series of reactions leading to the production of energy and growth by the help of substances mostly of the nature of vitamins in animal nutrition.

The isolation of *auxins*, substances con-

cerned in the growth of plants, by Kögl in a crystalline form from urine, malt, yeast, liquid manure and farm-yard manure, and Kögl's observations on the existence of a cycle of growth factors in nature⁹ provided further support to Indian work. The work of Thimman,¹⁰ of Link¹¹ on the role of micro-organisms as factors in the regulation of plant processes; and the work of Link¹² and of others have provided evidence in support of the statement on the effects of organic manures and substances produced by microbial fermentation.

McCarrison and Viswa Nath¹³ have drawn attention to another aspect of the subject. They have shown that manurial and fertilizer applications are capable of reacting on plants not only by increasing yields, but also by influencing the quality of the seed and by bringing about changes in the composition and nutritive value of the produce, and that in this respect the produce raised with mineral fertilisers on soils poor in organic matter is inferior to that raised with farm-yard manure. These observations find support in the results of work by Rowland and Wilkinson,¹⁴ Thomas and Thompson,¹⁵ Booth,¹⁶ and of Howard¹⁷ in England; Ysabel Daldy¹⁸ in New Zealand, Tallarico¹⁹ in Italy; Hunt,²⁰ Breazeale,²¹ Thompson²² in America; Kruger,²³ Kottmier,²⁴ Wachholder and Nehring,²⁵ Smallfuss,²⁶ and of Rudolph Berk²⁷ in Germany. On the other hand the results of Harris²⁸ in England, Schunert and his associates in Germany²⁹ do not support the view that fertilisers and manures influence the nutritive value of crops. In 1936-37 experiments were made in Germany under the joint auspices of the Association for Scientific Research, the National Board of Health and the Society for Nutrition Research. The nutritive value of vegetables grown with animal manure plus fertilisers were tested. On adults the results showed no definite effect. On children the results showed that vegetables grown with animal manure and artificial manure together were superior to those grown with animal manure only. In similar experiments in New Zealand by Chapman³⁰ vegetables grown on humus-treated soil when fed to school children were found superior to vegetables raised with mineral fertilisers. There are thus two schools holding opposing views and the existence of these differences is the greatest stimulus for further investigation and elucidation.

Although our ideas have undergone changes and notable advances have been made since Liebig's days, the original theory is still valid. But the humus theory which prevailed a century ago is again coming into its own but in a qualified manner. The developments of the past century direct pointed attention to one important aspect, namely, the differentiation between soil fertility and soil fruitfulness. Organic manures and organic fertilisers build up and maintain soil fertility for artificial fertilisers to be fruitful. It is in the recognition of this truth lies the reconciliation of the opposing views. There is also the growing recognition that we are at the beginning of new knowledge and that workers in plant and animal nutrition may increasingly find common interests in the studies on cell metabolism. We are indebted for our present knowledge to the pioneers of the past and look forward to future developments which may give us more knowledge and control over soil fertility.

¹ *Proc. Roy. Soc., (B)*, 1914, **88**, 237.

² *Ibid.*, 1917, **89**, 508.

³ *Ann. Inst. Past.*, 1914, **28**, 21.

⁴ *Ann. Bot.*, 1924, **38**, 723.

⁵ *Jour. Madras Agric. Student's Union*, 1926, **14**, 19.

⁶ *Ind. Jour. Med. Res.*, 1926, **14**, 351.

⁷ *Mem. Dept. Agric. Ind. Chem. Series*, 1927, **9**, 85.

⁸ *Proc. Roy. Soc. (B)*, 1937, **124**, 1; *Nature*, 1937, 161.

⁹ *Chem. Ind.*, 1937, **57**, 49.

¹⁰ *Jour. Gen. Physiol.* 1934, **18**, 23.

¹¹ *Bot. Gaz.*, 1937, **98**, 816.

¹² *Nature*, 1937, **140**, 507.

¹³ *Loc. cit.*

¹⁴ *Biochem. J.*, 1930, **24**, 199.

¹⁵ *J. S. C. I.*, 1938, **57**, 210.

¹⁶ *Ibid.*, 1940, **59**, 181.

¹⁷ *Chem. and Ind.*, 1938.

¹⁸ *Nature*, 1940, **145**, 905.

¹⁹ *Mem. Acad. Ital. Biol.*, 1932, **3**(1), 5.

²⁰ *Ohio Exp. Stn. Ann. Rep.*, 1928.

²¹ *Univ. Arizona Tech. Bull.*, 1927, **16**.

²² *Proc. Amer. Soc. Hort. Sci.*, 1937, **34**, 599.

²³ *Landw. Jahrb.*, 1927, **66**, 781.

²⁴ *Kuhn. Arch.*, 1927, **15**.

²⁵ *Bodenk. Pflanz.*, 1938, **9/10**, 708.

²⁶ *Phytopath. Z.*, 1937, **5**, 207.

²⁷ *Boden. U. Pflanz.*, 1939, **12**, 129.

²⁸ *Biochem. Jour.*, 1934.

²⁹ *Biochem. Z.*, 1934-39.

³⁰ *Nature*, 1940, **145**, 905.

OBITUARY

Mr. NOSHIR S. DOCTOR, M.Sc., A.I.I.Sc.

A PROMISING scientific career was tragically cut short by the death on May 26th last of Mr. Noshir Shapoorji Doctor, as a result of injuries sustained in a motor-cycle accident at Bangalore. Mr. Doctor was working for the PH.D. at the Indian Institute of Science.

Born on March 4th, 1914, at Broach, near Bombay, Noshir Doctor was educated at the Government High School, Broach, and matriculated in 1931. He joined St. Xavier's College, Bombay, in that year and except for a short break in 1933 at Karachi, was there till 1936, when he graduated with a First Class and Distinction in Chemistry, securing the College Gold Medal. He then joined the Indian Institute of Science, Bangalore, and three years later, secured

the M.Sc. degree of the Bombay University and the Associateship of the Indian Institute of Science.

Possessed of sterling qualities of head and heart, Noshir Doctor had won the regard of both his Professors and colleagues. He was a good sportsman and, both at school and college, distinguished himself on the field. He won a number of prizes in sports at the Centenary Celebrations in connection with the anniversary of the late J. N. Tata.

Such a premature death at the age of 26 and at the very threshold of a career that held every promise of being very successful, the news of his tragic death came as a great shock to his many friends at Bombay and Bangalore. To his bereaved parents and relatives we offer our sincere condolences.

J. P. DE SOUZA.