Indian Journal of History of Science, 45.2 (2010) 199-239

SCIENTIFIC ENQUIRY IN AGRICULTURE IN COLONIAL INDIA: A HISTORICAL PERSPECTIVE

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(Received 12 June, 2009; revised 29 April, 2010)

India had a long history of agricultural practices before the beginning of the British colonial rule. Indian farmers were not conscious enough with the scientific parameters of requirements of plants and soils that ruled the production and improvement of crops. Only in 1905, an Imperial Agricultural Research Institute was established at Pusa in Bihar as an outcome of the Bengal and Orissa Famine Commission's policy of having a special department to watch over the interest of agriculture. This institute was able to produce some very good and improved quality wheat due to the efforts of Economic Botanist, Sir Albert Howard and his coworkers which included selection of the existing good agricultural types in the mass and then cross-fertilization. In 1911 Hector at Dacca (now in Bangladesh) initiated research on rice. Later a number of experimental researches were done by Indian scientists at different Research Stations that were established by the colonial rulers for the progress of agriculture in India. The research programmes in India for crop improvement were motivated by the researches done in Europe on plants and soils. They inspired the Indian scientists to work on crop improvement and production and laid the foundation for scientific agricultural practices in India. This article presents an overview of the scientific agricultural research taken up by the colonial scientists in India for commercial purposes.

Key words: Albert Howard, Crop improvement, Cross-fertilization, Rice, Scientific agriculture, Sugarcane, Wheat

INTRODUCTION

The application of science to agriculture began in Europe during 1834s when Jean Baptiste Boussingault[1] laid the foundation of agricultural chemistry. Later in 1840, Justus von Liebig[2] did experiments with artificial soil fertilizers and

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held that the transformation of inorganic into organic substances takes place exclusively in plants. In his classical monograph on agricultural chemistry he at once attracted the attention of the agriculturists in Europe to the supreme importance of soil and the soil solution in the raising of crops. The landowners in Britain realized the responsibilities of improving their land and improved the agricultural knowledge of their tenants. As a result, Britain soon took the premier place as the most successful farming country in the world. When the East India Company (EIC) established their rule in some parts of India they took interest in the agricultural produces and practice of Indian cultivators. They noticed that "India, rich in natural products, and easily cultivated, having water near the surface, and its plains intersected by magnificent rivers, with a climate in which wheat and barley…………could be cultivated in one season and at another rice and *joar*"[3]. As a trader, the British were primarily interested in commerce with the agricultural produces of India. They had already observed that the Indian farmers were acquainted with the variations of temperature, dryness and moisture in the climate that allowed cultivation of rice, wheat and barley at different time of the year. These were the main cereals required for the human consumptions. The Indian farmers also knew the rotation of crops. Though different ancient Indian texts on plants and agriculture reveal that the Indian farmers were quite conscious of the nature of soil and its relation to the production of specific crops of economic importance, however, the exact chemical composition of different kinds of soils was not known to them or to the authors who had written these texts during the Vedic and post-Vedic periods. Indian farmers acquired knowledge by experience and passed those knowledge from generation to generation in the form of maxims, proverbs, etc. and that aided the peasants for centuries. Extensive method[4] of cultivation was the usual practice in India (those suitable for large areas) at that time, which had utilized neither the full energies of man or beast nor the potential fertility of the soil. It would be observed that in this peasant agriculture the great pressure of population on the soil resulted in poverty, most marked where extensive methods were used on smallholdings, which really needed intensive farming.[5] The British in India, realized that the indigenous cultivators could be taught the experiences of other nations, as well as of other places. Since, agriculture was then a gamble in India, depending on the pleasure of monsoon and the failure of it meant a sure famine, a modification in the indigenous practice was therefore found to be essentially necessary. Subsequently, to give an impulse to commerce and to obtain materials for manufactures, it became necessary to investigate both the natural productions of India and the fruitfulness of its soil, not only as fitted for variety of products but also with reference to its ability to produce more than what would be sufficient for the sustenance of its inhabitants.

The cereal grasses yielded the greater proportion of the food of man, so the British took more interest in improving the cultivation of rice, wheat, etc. By far the most important crop in India before independence was rice and it was grown whenever possible. The production of rice exceeded that of any two-food crops put together. Whenever the soil and water supply permitted, rice was invariably grown. A study of this crop is illuminating. At first sight rice appeared to contradict one of the great principles of the agricultural science of the Occident, namely, the dependence of cereals on nitrogenous manures. Large crops of rice were produced in many parts of India on the same land year after year without the addition of any manure whatever. The rice fields of the country exported paddy in large quantities to the centers of population or abroad, but there was no corresponding import of combined nitrogen. It was amazing that in spite of this unfavourable factor soil fertility had been preserved for centuries: this was because no artificial manures had been used. The crops were able to withstand the inroads of insects and fungi without a thin film of protective poison. The value of Indian wheat crop too was very great as most of the wheat grown was consumed in the country itself and in certain tracts formed an important source of food for the people. The remainder was exported to Europe. Both the Indian population and European market required wheat with high nitrogen, with good flour strength and with good milling characters. Though Indian wheat had a poor reputation in the English market as regards strength, their great dryness was a quality of considerable value to the English miller. Therefore, any improvement in the strength of Indian wheat meant improved prices and an increase in value of the export trade. As a result researches on the improvement of wheat in India started from the end of the nineteenth century. However, the earliest results of success in scientific agriculture included the crossing of thin native sugarcanes with the thick or "noble" sugarcanes first introduced from Mauritius (called "Mauritius red") in 1827. This work was done at Coimbatore for its warm climate that was vital for the thick sugarcanes to set seed. Later research on improved sugarcane crop was initiated in 1912 at United Province[6]. Science historians have written a number of articles in different books on agriculture in colonial India in recent times. However, none has explored the scientific enquiry on agriculture during this period. In this paper, the author intends to present the history behind the establishment of botanical gardens, the agricultural research institute and the impact of science on the improvement of crops, like wheat, rice and sugarcane, in colonial India.

Establishment of Botanical Gardens

The British established botanical gardens at Calcutta (1786), Saharanpur (1817) and Dapooree (1828) and these were among the first botanical gardens. These gardens provided the avenues for successfully cultivating the valued productions of many different parts of the world that were thought would improve not only Indian Commerce but of the world in general.

In 1786, the Botanic Garden at Shibpur near Calcutta was established. However, Colonel Robert Kyd had already cultivated part of it. His love for science particularly botany induced him to begin the Botanical Garden and Public Nursery at Calcutta with the support from the Honourable the English East India Company. Useful plants such as grains and timbers were first introduced and then spread into the culture of the country. The Botanic Garden of Calcutta had been useful in introducing many important plants in India. At the beginning of 1796, Dr. William Roxburgh applied to the Government to write to the supercargoes at Canton, China for various kinds of sugarcane and seeds of all vegetables that yielded flax and hemp. Among the plants received from China towards the close of 1796, a new species of sugarcane called *Saccharum sinense* or Chinese sugarcane had been introduced at this garden by Captain Sleeman of the East India Company's service. At the close of 1799 many hundred thousands of plants had then been distributed over the country amongst the sugarcane cultivators. The new plant had the advantage of being hard and solid so that it could resist "the forceps of white ants and the teeth of the jackal, two great enemies of the East-Indies sugar plantations"[7].

Compared to the moist climate of Bengal the northern plains of India were dry and open and hotter in the summer and colder in the winter. It was thought that the agricultural products of temperate regions could be grown in the northern plains with great ease during the cold season. Therefore, it was evident that the agricultural and horticultural experiences of the garden situated near Calcutta would be inapplicable to the plains of Northern India. A different field, therefore, was required to ascertain the physical agents on vegetation in the North and to introduce suitable plants from other countries for subsequent distribution, so as to produce the same effects for the northern, as had been proved to have been the case in the eastern and southern provinces. Fortunately, there was a public garden nearly at the most northern limit of the British Indian territories. The Native Government that preceded the British established this in 1779. When the Marquis of Hastings visited the place in 1816, he was delighted to find a garden established by an ‘Asian Prince’. The garden at that time had degenerated pretty nearly into a grove of self-sown mango trees and a few clear patches where kitchen vegetables were grown. As he was distinguished for his enlightened views on the advancement of science, he recommended the institution to be formed into a Botanic Garden. As a result, the Botanic Garden at Saharanpore was established in 1817 and Dr. Govan was appointed the first superintendent. He put much effort to renovate the exhausted soil. Many useful and ornamental plants and trees were introduced from the Calcutta Botanic Garden and also from the Himālayan Mountains. After his return to England due to ill health, Dr.Govan presented a Memoir to the Royal Society on Natural History and Physical Geography of the Himālayas between the Sutlej and the Jamuna. It was published in the second volume of *Brewster's Journal of Science*. The latitude, elevation and vicinity to the hills, the nearness of water to the surface, and above all the facility of irrigation from Doab Canal, made Saharanpore Botanic Garden particularly favourable for the introduction of plants of more temperate countries in India. The Honourable the Court of Directors in a letter dated 28th June 1820 remarked, “We have pursued with great pleasure the very interesting Memoir by Dr.Govan, upon the advantages derivable from the Botanic Garden at Saharanpore, connected with the object of exploring the Natural History of the Himālayan Mountains near the base of which the garden is said to be situated”[8]. In the Bombay Presidency, besides experiments on silk, wool and cotton farms that had been at different times established, there was also a Botanic Garden where experiments were done on the introduction of useful plants into that side of India. Sir J. Malcolm purchased the house, garden and grounds of Dapooree near Poona, in 1828 for the use of Government. Sir Malcolm, in proposing its establishment said, “ I am anxious for the promotion of liberal science, and I am much alive to the expediency and policy of every measure that can, without unjustifiable expenditure, benefit the country, and add to the peaceable occupation and enjoyment of its inhabitants, of whose habits and characters, I have sufficient knowledge to be convinced that not example, but every stimulus we can apply, is necessary to rouse them to exertion in the pursuit of objects which are obviously for their own advantage; and I believe the establishment that I have proposed, to be quite essential to accelerate their advance in that branch of useful improvement to which it belongs". He relates that one Marhatta chief, speaking of his success in rearing potatoes, said with truth, "a new vegetable is a trifle to you Europeans compared to what it is to us Brāhmins." Mr. Williamson was appointed the first superintendent of the garden but died shortly afterwards. Dr. Lush succeeded him[9].

Gardening and agriculture were, no doubt practiced in eastern countries long before they were known to Europe. Once introduced, they had, like many others of the arts, attained a degree of perfection unknown in the countries of their origin. Therefore, the British thought that a steady application of principles to practice, would ensure the utmost success in the culture of as great a variety of useful and valuable products, within the wide-spread dominions of the Indian Empire, as would be practicable within the limits even of several different countries. That eventually would allow them to extend their commerce and increase the revenues of the states. William Carey opined that agricultural societies would more effectually accomplish the object of improving the culture of grains[10] "and that premiums bestowed by them upon successful candidates in the various branches of husbandry, would operate with greater success, where these operations must necessarily be carried forward on a large scale, and a comparative view made of the advantage attending different modes of culture and of the produce of different kinds of soil. The best substitute for such a society seems to be the attaching of an experimental farm to a botanical garden which will be well repaid by the experiments made there on the cultivation and produce of different kinds of grain on the strength and durability of the fibers of the bark of various plants, and upon various other subjects highly important to the agricultural interest of the country". The Agricultural Society of India was thus created in 1820, and by 1830 it imported new varieties of maize, cotton and sugarcane for growing in India. However, it was not until 1863 that the first agricultural experiment station was set up at Saidpet near Madras (now Chennai). In 1876 it became an agricultural college. Some machinery, such as plough and cultivators (steam-driven) and other implements such as seed drills, threshers and chaff-cutters were imported. But there was no attempt to observe the local agriculture and to learn what the farmers in and around Madras knew or required to make their work profitable. The imported machines eventually all rusted away due to non-use. The Saidpet station was later abandoned, with the 'erroneous conclusion by the colonialists that the Indian farmers were conservative and unmotivated to accept changes'[6].

Establishment of Agricultural Research Institute

The series of devastating famines caused a heavy and severe damage to agricultural progress in India during 19th century. In 1866, on the conclusion of the Bengal and Orissa Famine Commission, the policy of having a special department to watch over the interest of agriculture was first mooted. However, Lord Lawrence thought the step premature and no positive action was taken[11]. In 1868 Lord Mayo, himself a farmer was appointed Viceroy of India. On arriving in India he wrote, "the time has come when we ought to start something like an agricultural department in the Government of India. Agriculture, on which everyone here depends, is almost entirely neglected by the government. We believe it to be susceptible of almost indefinite improvement"[12]. In 1870, Lord Mayo again took up the matter chiefly to improve the supply of cotton from India because during the civil war in America in 1863-64, the export of cotton to the textile mills in Manchester was affected. He planted the seed for the Department of Agriculture in the Government of India and put necessity of establishing Agricultural Department under a Director in each province. Allen Octavian Hume, the collector of Etawah was in charge of the new department. Hume started to learn from the local farmers about the soil, climate, ploughing methodology, crop rotation and weeding. In 1871, under Lord Mayo's administration a Department of Revenue, Agriculture and Commerce was created. But 'burdened with multiform duties the new Department had neither the leisure nor the power to take up either directly or efficiently the many problems that affect the agriculture and rural economy of the empire'[13]. After the assassination of Lord Mayo in Andaman Islands Hume was abruptly dismissed from his post, presumably commenting about the lack of Government support for the Department of Agriculture in a critical pamphlet called "Agricultural Reform in India"[12]. However, in 1880 the Famine Commission in their Report very strongly recommended the necessity of establishing Agricultural Department under a Director in each province. The Secretary of State added pressure to the Government of India to forward the Famine Commission recommendations and as the outcome; an Imperial Department of Agriculture was formed in 1881 by separating the Revenue and Agricultural Department from the Home Department. The Secretary of State advocated to "instituting measures for agricultural research in India and the promotion of agricultural knowledge in the Civil Service"[11]. The necessity of having a scientific ground-work as the basis of all attempts at agricultural improvement, and chemistry being the science that bore, perhaps, most directly on agriculture, the Secretary of State was asked to sanction the appointment of an Agricultural Chemist to act with the department. The selection of an expert was entrusted to Sir James Caird who himself was one of the Famine Commissioners. On his advice, John Augustus Voelcker , an agricultural chemist of the Royal Agricultural Society of England came to India in 1890 to join as an expert to report on Indian Agriculture. The purpose of his mission was (i) the improvement of Indian agriculture by scientific means and (ii) the improvement of Indian agriculture in general. Voelcker met Hume who in the meanwhile had retired to Simla, and although Hume is not mentioned in the Voelcker Report, it is clear that Hume's views must have found a sympathetic ear. In 1892, Dr.J.W.Leather, an agricultural chemist was appointed and a cadre began to evolve. It was not a permanent post and Dr. Leather was engaged for a period of five years[14]. His appointment marked the beginning of research in agricultural chemistry and soil science in India. The credit goes to Dr.Leather for initiating permanent manure experiments for critically evaluating soil productivity on a long-term basis[15].

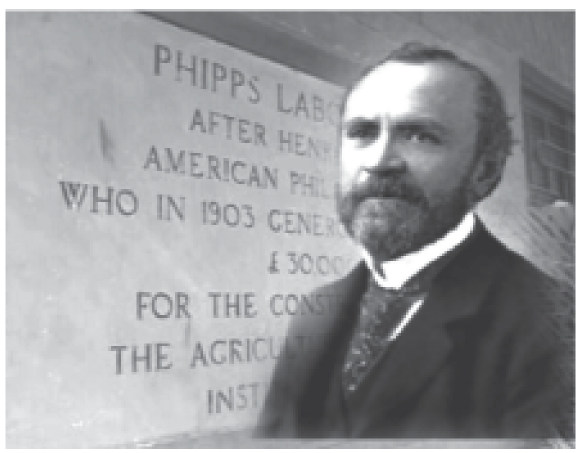

Fig.1. Henry Phipps, American Philanthropist

The things, however, did not move till the appointment of George Nathaniel Curzon (1859-1925) as the next Viceroy. Lord Curzon read Voelcker Report and set the wheel in motion by elevating the Bombay Director of Agriculture to the newly created position of Inspector-General of Agriculture in 1901. Several other positions were created such as the Imperial Mycologist, the Imperial Entomologist, the Imperial Agronomist, and an Imperial Economic Botanist. The famines of 1890s made the Government to consider the importance of agriculture and establish a research institute. In 1892, the Imperial scientists met at an open site in Pusa, a sleepy village in Bihar about 50 miles north of Patna. This site had been with the Government for a long time having been acquired cheaply due to a privately owned but failed indigo and tobacco plantation, and now Lord Curzon had big plans for its use. An American philanthropist and a friend of Curzon's wife, Henry Phipps (Fig. 1) had visited the couple from Pennsylvania, USA for attending the ceremony in India associated with the coronation of King Edward. Phipps gave Lord Curzon an unrestricted grant of US$30,000 and with it Curzon decided to build a Research Institute at Pusa. In 1905, the Imperial (now Indian) Agricultural Research Institute (IARI) was established at Pusa (Bihar) (Fig.2)

Fig. 2. Imperial Agricultural Research Institute at Pusa (Bihar)

While inaugurating IARI Lord Curzon referred to farming as India's greatest living industry. He also emphasized that agricultural education, particularly in villages, should begin in school. Over the next 30 years much basic research was carried out at Pusa. There was emphasis on recording diversity in wheat, barley, gram (chick-pea), *arhar* (pigeon-pea), linseed and maize, and on water use and nutrient use efficiency and plant pathology at this Institute. However, to meet the needs of agriculture at the national level, the Indian Council of Agricultural Research (ICAR) was established in 1929 on the basis of a recommendation of the Royal Commission on Agriculture headed by Lord Linlithgow. The Royal Commission emphasized the critical role of research in fostering sustainable advances in agricultural production in the following words: "However efficient the organization, which is built up for demonstration and propaganda be, unless that organization is based on the sold foundation provided by research, it is merely a house built on sand"[16]. However, it was towards the end of 19th Century and beginning of 20th Century that the foundation for Agricultural Education was laid in India with the establishment of six Agricultural stations and Colleges at Lahore (Lyallpur), Kanpur (1893), Nagpur (1906), Poona and Coimbatore (1907) and Sabore (1908). At Poona, the Department of Agriculture was established in 1877 followed by setting of similar departments by the provinces. It was soon realized that research and education were the very foundations for the development of agriculture.

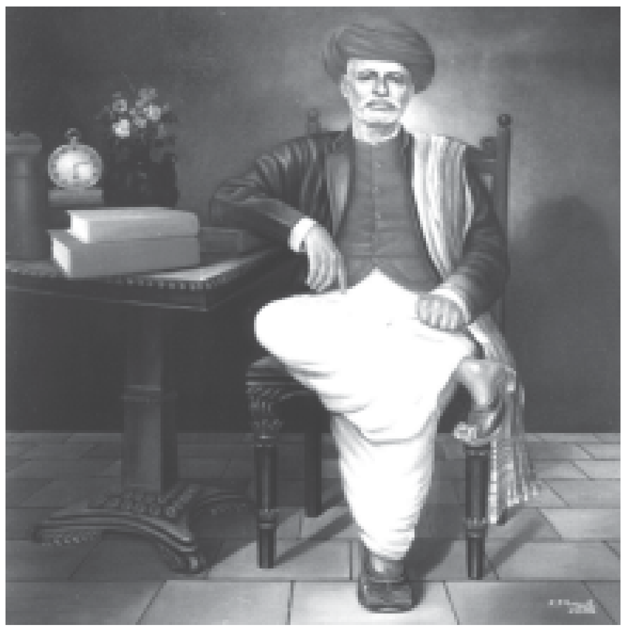

Fig. 3. Mahatma Jyotiba Phule

Mahatma Jyotiba Phule (Fig. 3), the noted thinker, social reformer and agriculturist of Poona appealed to the British Government to set institutions for agricultural education and research in India. This led to the opening of a branch for teaching agriculture in the College of Science at Poona in 1879 that was subsequently developed into a separate College of Agriculture in 1907. Initially three-year diploma of the Bombay University was offered at this college. In 1899 a degree course leading to Licentiate in Agriculture (L.Ag.) was started. The Bombay University in the year 1909, further extended the scope of these studies, raised the standards and instituted the degree of Bachelor of Agriculture (B.Ag.). Its nomenclature was changed to Bachelor of Science in Agriculture B.Sc. (Ag).

The Institute at Pusa was located at a relatively remote place with one small railway station. Since only a few trains stopped at the station, the institute could not attract the best talents of the land. After a severe earthquake in 1934, the main building was damaged (Fig. 4) and the Institute was then shifted to the western edge of New Delhi in 1936, much to the delight of everyone who worked there.

Fig. 4. The Institute after a severe earthquake

Agricultural Research in Colonial India

Sugar cane

Sugarcane is one of the ancient agricultural produces of India. However, the Greeks knew sugar four or five hundred years before the Christian era. Sugar was first known as 'honey of cane'. European 'sugar candy' (or '*Śakkar kuṇḍ*') points to its Indian origin. Sugarcane used to occupy a humble place in the agricultural economy of colonial India, as the product of the cane could not compete with other countries to which it had freely given this natural wealth. However, in 1790 a quantity of Benaras sugar with samples of other sugar was sent to England for trial. In February 1791, Lt. J. Paterson of the Bengal establishment addressed to the Court of Directors, stating that sugar could be cultivated in Bengal with many superior advantages, and at less expense than in the West Indies. However, after his return to India he did not get the facilities he had expected. Later in 1792, it was suggested that various particulars relative to the existing state of sugarcane cultivation would be ascertained by the collectors of revenues and would include the amount of increase or decrease in the production and also whether it laboured under any peculiar disadvantage[17].

Great care was then taken in the cultivation of sugar cane and comparatively heavy doses of nitrogenous manures were given in the form of oil cake. The results were excellent. But, though the quality was good, the crop was relatively unimportant as paddy used to occupy a more lucrative place to the farmers. The sugarcane thus became a luxury crop and was grown on a very small scale in any one holding. There had been considerable decrease in the area under the crop in certain provinces, notably in Bengal, Bombay and the Central Provinces. However, there had been increase in Madras, the United Provinces and Assam. It was then observed that except in some of the submontane tracts of the United Provinces and the Punjab where thick canes and heavy yields succeeded, the canes were thin and short in other tracts. They displayed no tropical luxuriance, though they were hardy against drought and water logging and consequently often grown on unsuitable land. The systematic study of sugarcane in India may be said to date from 1901-02 when in consequence of the destruction of the crop in Madras by 'red rot', Dr. Charles Barber started the well-known Samalkota (in Andhra Pradesh) farm where efforts were made to discover 'red rot' resistant varieties. Before coming to Madras, Barber had worked on sugarcane in the West Indies. He was a specialist thoroughly conversant with the subject. The main lines on which Barber was working at Madras had been suggested by the experience of sugarcane growers of Java. Between 1882 and 1892, the sugarcane crop of Java was devastated by disease and although scientific investigations were carried out no remedy was found. It was then decided to import canes from other countries. A number of these imported varieties proved to be less susceptible to the disease than the local canes. Thus, the industry struggled on, but none of the imported canes were altogether satisfactory. The important discovery, however, was that the canes produced seed and this opened up a new possibility of using the resistant parent for crossbreeding. That helped the industry in Java to re-establish completely. A similar calamity visited India. The Samalkota station was started but the work was confined to the introduction of canes from other countries in the hope that by this haphazard method some might be found to replace the dying canes of Madras. The results, Barber noted were "unexpectedly and perhaps undeservedly successful" and Madras claimed to have a fine set of canes. However, the method was tedious and costly and many disappointments were met with. It was found that none of the imported canes were immune and there was always the risk that they would ultimately succumb when faced with adverse conditions of local agriculture. Moreover, hardly any of these varieties were suitable for introduction to the large areas under cane in Northern India. It was noticed that in these tracts the better class canes, which were heavily diseased, had given place to inferior but hardier varieties. According to Barber these were amongst the poorest quality of cane in the world. The problem, therefore, was the introduction into the main sugarcane tracts of Northern India of richer canes giving higher yields with greater resistance to disease and yet adaptable to the methods of cultivation employed by the local cultivators. Barber devoted himself to the work of improvement of Indian cane sugar. Coimbatore was selected for the work as it was noticed that there canes produced flower every year and also produced pollen. Earlier in 1827 Barber successfully crossed the thin, native sugar cane with the thick or ‘nobel’ sugar canes first introduced from Mauritius (called ‘Mauritius red’) at the Coimbatore agricultural farm. He worked for producing superior hybrid seedlings between the local northern canes and the best southern canes. It was also noticed that cane under cultivation had only certain length of useful life, after that they had to be discarded. A batch of good new cane would only survive for a certain time, after which they would die out on account of deterioration and disease. Improved canes introduced through the Samalkota farm disappeared in eight year. Therefore, it was understood that cane breeding could never be slacken. At the Coimbatore farm, Barber advised the provincial officer in the Survey on the selection of the best indigenous varieties and on the method of propagating hybrid seedlings. Since his appointments in India great advances in the sugarcane research had been done in the provinces. In the United Provinces, farms were opened at Nawabganj, near Bareily for the collection and growth of canes and their comparison with the imported ones. Under Mr. George Clarke chemical investigations were carried out at Shahjahanpore. Messrs. Taylor and Woodhouse at Sabour, Bihar, had done much good work on sugar cane cross breeding. A large area was taken up in the Kamrup district of Assam, where the thick canes had already successfully grown and was developed on a commercial scale later. In the Punjab, Messrs. Barnes, did much excellent work on sugarcane[17].

A successful research was carried out on the sugar cane crop in India during a period of nearly twenty-seven years: 1908-1935[18]. In 1910, the investigations on sugar cane were mainly concentrated in the United Provinces in

Northern India, where a considerable local industry was already in existence. At the beginning of the hot season in March, narrow-leaved, thin canes were planted under irrigation; the crop was crushed by bullock power during cold weather; the juice was converted into crude sugar in open pans. The yield was low, a little over one ton per acre on the average. The indigenous varieties that had been cultivated for at least twenty centuries were thin, short and very fibrous with juice rich in sugar in good season. They reminded one more of the wild species of the genus *Saccharum* than of the thick sugar cane found in tropical countries. Five or six varieties were grown together, each with a name, usually of Sanskrit origin, denoting their qualities so that people could readily recognize each variety. The yield of cane was raised from 13 to 16 tons when an attempt was made to intensify the cultivation of the best type by the cultivators in the Rohilkhand Division. However, this method could not increase the yield of cane beyond 27 tons per acre and the thin, watery juice contained so little sugar that it was not worth extracting. To raise the out-turn of sugar in United Provinces, a combination of intensive methods of cultivation with more efficient varieties adapted to the very special climatic conditions was then found to be necessary. Attention was then paid to the two chief factors underlying the problem: (1) the discovery of a suitable variety of cane, and (2) the study of intensive cane growing with the object of finding out the maximum yield that could be obtained.

In 1912, a special sugar cane farm was established when the Director of Agriculture gave their agricultural chemist, George Clarke the best farm near Shahjahanpur on the bank of Kanout River. When the work was started, 95 percent of the sugar cane area of United Provinces could yield only 13 tons per acre, producing just over one ton of crude sugar (*gur*). The Agricultural Chemist was given the charge to develop this primitive industry, at first purely on chemical basis. Clarke combined a first class knowledge of chemistry and general science with considerable experience of research methods obtained at the Nottingham University College and the School of technology, Manchester. Moreover, he was the son of a farmer and thus was familiar with good agricultural practice. He also possessed the gift of correct diagnosis and the persistence to solve the problems to be investigated. He took the results of the investigations to the people and firmly welded that into the practice of the countryside. Two Indian officers – S.C.Banerjee (afterwards Rai Bahadur) and Sheikh Mohamed Naib Husain (afterwards Khan Bahadur) were associated with Clarke throughout his research work. Banerjee was in charge of the laboratories and Naib Husain was full of energy and drives to break new ground in crop production. Both these men gave their lives to their work at the Shahjahanpur farm. The collection of cane varieties at Shahjahanpur included a Java seedling – POJ 213, which was exactly suited to the local soil and climate and which responded to intensive cultivation. This Java cane was a hybrid. Its pollen parent was the Rohilkhand variety "*Chunni*" which had been given to the Dutch experts, who visited India 20 years earlier, by the Rosa Sugar Factory. *Chunni* was immune to 'sereh' a serious disease threatening the sugar industries in Java. When Chunni was crossed with rich tropical canes, good quality seedlings immune or very resistant to 'sereh' had been produced. This was widely known throughout the world as POJ (Passoerean Ost-Java) seedlings. POJ-213 proved valuable during the early stages of the Shahjahanpur work. The cultivators among whom it was known as 'Java' readily accepted it. A large area was soon grown in Rohilkhand and it saved the local sugar industry which was on the verge of extinction[18].

Wheat

Wheat, a grass of the *Gramineae* family, of the tribe *Hordeae*, and of the genus *triticum*, is the most widely grown of all the cereal grains. It is adapted to a wide variety of soils and climatic conditions, and can be grown extensively throughout the world. Its great popularity as human food is due to its mild, acceptable flavor and the unique ability of its principal proteins to form gluten when mixed with water to make dough. The gluten gives a soft, springy quality to bread dough, and enables them to retain the carbon-di-oxide which is produced by yeast fermentation; this permits the production of light, finely textured loaves of bread. Flour from other cereals such as barley, corn, rice and rye, which do not have gluten-forming properties, yield rather heavy loaves. The wheat growing area of the Indian Empire embraced the whole of northern India down to the Gangetic delta and the greater part of the Central Plateau above the Ghats. The crop was not cultivated at all in the Bombay Konkan or in the coastal districts on both sides of the Bay of Bengal, while in Assam and in Burma (now Myanmar) wheat was of very little importance. Although the distribution of wheat in India was very wide, it was observed that the Northwest was the great wheat growing tract and nearly 75% of the crop used to be produced in the Punjab and United Provinces. About 10 percent of the total cultivated area in India was under wheat and about 15 percent of the total area under cultivation was in the native states. About 80 to 90 percent of the total amount of the wheat crop used to be retained in the country for consumption.

As early as 1817 the Secretary of State for India called for a complete report on Indian wheat. Samples of all the wheat grown in India were sent to England where Forbes Watson examined them. The results of milling and baking tests performed by Watson confirmed that 'India is capable of growing wheat of highest quality'. It was also found that a considerable number of samples were far superior to any of the Indian wheat usually available in the then London market. In the last quarter of the 19th century, however, attempts were made to produce 'pedigree seed' of a number of selected wheat varieties, such as Muzaffarnagar white, Buxar white and the selected 'pissi' wheat, which had given better yield performance than the local mixtures. Large quantities of such 'pedigree seeds' were distributed for cultivation. The selection work was carried out in the farms at Kanpur in 1880-81. During the season of 1886-87 trials of English 'Pedigree' wheat supplied by Messrs. Oakshott and Co. of Reading were made in Madras, the Punjab, Bombay, United provinces and also in the Central Provinces. In most cases the samples did not germinate. The experiment was a total failure and showed that ordinary English wheat would not mature sufficiently rapidly under Indian conditions. In the records of the Kanpur and Nagpur farms there were several references to the trials of English wheat using the selection methods adopted in England in 1857. However, the attempts were total failures. Later the work of selecting large and small ears and large and small seeds from the same ear was carried out at Poona from 1903-05. However, none of these methods yielded any permanent improvement[19]. In the early records dealing with the wheat improvement work in India reference to trials of exotic varieties were frequent. Various Canadian, American, English, Egyptian and Australian varieties as well as isolated samples from Palestine, Mexico and Russia were grown during the late 19th century. However, the introduction of exotic wheat was largely unsuccessful because of the 'extreme lateness of the exotics under Indian conditions and also due to their grain characters that were not acceptable to the farmers and the trade'[20]. From 1896 to 1901 Government of India (GOI) received several consignments of rust-resistant crossbred Australian wheat raised by William James Farrer (1845-1906) in Australia and the importance of the work was noticed. Farrer was a wheat breeder who did many experiments in New South Wales, Queensland on the improvement of Australian wheat. The Australian wheat was distributed to the Kanpur and Nagpur farms and also to the Lahore Botanical Garden. However, it was found that the varieties, which resisted rust successfully in Australia, were attacked to a greater extent in India than the indigenous kinds and also ripened too late for Indian conditions. Another disadvantage was that most of the hybrids continued to split and give rise to various forms. The reports from the Kanpur and Nagpur farms were unfavourable and none of the Australian wheat was found suitable for introduction into general cultivation. In the Kanpur farm report it was stated, "for rust-resisting quality, for hardiness and prolificness Muzaffarnagar wheat has been equaled by a few and surpassed by none"[21]. A small amount of success was obtained in the Punjab. From 1898-99 onwards the New South Wales cross-bred were tried at Lahore and a certain number proved to be fixed and free from rust. These were selected for further experiments at the Lyallpur farm. On the whole the experiments proved conclusively that the hope of introducing rust-resistant wheat from abroad had to be given up and the Australian methods for wheat improvement had to be implemented. Accordingly, the Director of Land Records and Agriculture of the North-West Provinces and Oudh, W.H.Moreland was selected for this important mission. In 1900 he was sent by the Indian Government to Australia to study Farrer's methods on the spot and to report on their suitability for Indian conditions. The result of this mission was summed up in an admirably written article published in the Agricultural Ledger in 1901. It was recommended that "cross-breeding should be taken up at a Central Station and the first work should be an attempt to produce wheat which will stand drought and resist or escape rust"[22]. The wheat breeding on the lines of the Australian work had been started at the wheat breeding station at Kanpur in 1902 with the help of a grant from the Revenue and Agricultural Department of the GOI. The object of the Kanpur station was principally to produce wheat resistant to drought and rust for use in the black soils of the Bundelkhand Districts. It was found that the length of the growth period and the moisture conditions were the chief factors in the production of wheat in India and these materially influenced the varieties grown and the practices of the various agricultural tracts. A considerable amount of attention was paid to the manorial requirements of the wheat crop and numerous field experiments on the subject were carried out principally at the Kanpur and Nagpur experimental farms. It was concluded that given suitable soil moisture for germination and the subsequent growth of the crop, the limiting factor in the production of wheat was the supply of nitrogen in an available condition. This was best applied in the form of farmyard manure or cow dung, which gave better results than saltpeter in the long run on account of good influence of dung on the tilth and moisture-retaining power of the soil. It had been found that the protein content of wheat was influenced chiefly by the soil and climatic conditions under which it was grown. The moisture retaining properties of the soil had more influence on the level of fertility; nitrogenous fertilizers frequently enhanced the yield quite markedly without greatly affecting the protein content. In general, however, increasing the available nitrogen in the soil the protein content of wheat was raised. Thus, wheat grown on summer fallow or after legumes was found usually of higher protein content than when grown after cereal grains or grasses. Although the soil and climatic conditions had the greatest influence on protein content, genetic factors were also involved, since some varieties produced wheat of higher protein content than others, when grown in the same environment. However, greater success was achieved in the introduction of Indian varieties into new localities. Buxar wheat was distributed widely in Bengal and Muzaffarnagar wheat in Bombay, Sind and Bengal. In the United Provinces depots were established for the distribution of Muzaffarnagar wheat, which proved to be much superior to the local variety and with a view to encourage an export trade. Though early British workers did little to improve the variety at least they extended the area under wheat cultivation. As a result, except in the years of deficient rainfall India became practically self-supporting in wheat. On the economic side India produced enough wheat for home consumption and ranked third (after Russia and USA) as an exporter of wheat. The problem, however, was to improve the crop on lines which would suit both the local taste and the export market[23].

The wheat research started at the laboratory of IARI at Pusa-Bihar from its inception. In January 1906, the Board of Agriculture in India considered the subject of the improvement of Indian wheat. It was found that the information on the crop was somewhat scanty and was moreover widely scattered among the various farm reports and in other papers not usually accessible. Mr.F.G. Sly, I.C.S., officiating Inspector General of Agriculture in India, considered it 'desirable that all the useful information on the subject including the results of the experiment hitherto conducted on the experimental farms in the country, should be brought together and a botanical survey of wheat of India should be made'. Albert Howard, the agricultural botanist at IARI was entrusted with the work in 1906. Most of the wheat that was in cultivation during that period was markedly liable to rust attacks and the damage done every year was very great. Another respect in which many of the Indian wheat were defective was in the strength and standing qualities of the straw. Wheat with weak straw were found to be very liable to damage by lying through wind and rain during the ripening period, which resulted in a greatly diminished yield. This was notable in many of the wheat grown in the United

Provinces and in Bihar. It was found by agriculturists that the wheat grown in India could be very greatly improved in many respects, notably in rust-resistance, in the strength of the straw and in the quality of the grain. The production of more rust-resistant wheat by hybridization suitable for various tracts was thought to save a large portion of enormous annual loss of over 400 lakhs of rupees (loss due to wheat crop in 1889) whereas the defect in strength and standing qualities were found to be remedied without much difficulty by crossing weak with strong straw-types.

The rediscovery of Mendelian laws of inheritance in 1900 and their working out at Cambridge provided inspiration to scientists in biological fields. As a result, there was a very powerful up rise of scientific effort during the next twenty to thirty years. Not only agricultural botany but also other applied sciences were developing on vigorous lines.

Fig. 5. Sir Albert Howard (right) with his wife and others

Albert Howard (1876-1930) arrived in India with his wife, Gabrielle Louis Caroline (Fig.5) in 1905 and joined the IARI at Pusa-Bihar as the Agricultural/ Economic Botanist. He had closely observed Sir Rowland Henry Biffen, a well known British botanist and geneticist, at Cambridge to make crosses and selections from the progenies on Mendelian lines and successfully bred rust resistance wheat lines by crossing “Gurkha”, a disease resistant wheat from Russia with “Square Head’s Master”, one of the most widely cultivated wheat in England at that time. Howard had different types of experience and some highly successful work at his credit. He had obtained a very good insight into the growing of cocoa, sugarcane and other tropical and semi-tropical crops. He had demonstrated at the Wye College that the female hops (dried cone like flowers of a twining climbing plant used in brewing to give a bitter flavour and as a mild sterilant) could not be cultivated without the presence of a male plant alongside. Though there had been much controversy among the growers on the point, it was held by some that male hop harboured disease; Howard on the contrary proved that the presence of the fertilizing male plant was a safe guard towards the plant health. Owing to the great value of the British hop industry, it was greatly received by the growers. However, Howard followed the same method at Pusa that he had learnt at Cambridge. Before the Agricultural Board meeting in 1906, Howard stated, "The present condition of Indian agriculture is the heritage of experience handed down from time immemorial by people little affected by the many changes in the Government of the country. The present agricultural practices in India are worthy of respect, however strange and primitive they may appear to the Western ideas. The attempt to improve Indian agriculture on Western lines appears to be a fundamental mistake. What is wanted is rather the application of Western scientific methods to local conditions so as to improve Indian agriculture on its own lines"[23] .The first task, therefore, that Howards set themselves was to find out better varieties and study their characteristics.

Albert Howard initiated wheat-breeding work on a systematic basis in India. He noticed that the emphasis laid by the previous investigators on the introduction of foreign varieties was unnecessary and mistaken. He concentrated on native types, which had had a history of several thousand years and had become adapted to the conditions of the country. The methods open to the investigators were, first selection and then hybridization by cross-fertilization. Selection included both isolation of and existing good agricultural type in the mass and also the creation of a new type by breeding from a single chosen plant of promise. Owing to the very mixed character of the Indian wheat crop as were grown ordinarily, the first step in the improvement was a botanical survey of the Indian varieties already in cultivation. He then separated type specimens of almost every Indian variety. From the wheat of Punjab 25 types were isolated. However, none of the Punjab wheat indicated any 'strength' that was of great commercial importance. The English miller wanted 'strong' wheat to mix with the weak varieties grown in England. Strong wheat was necessary to produce large well-shaped or well-piled loaves. At that time most of the wheat of the world were weak and starchy, poor in gluten and when baked used to give heavy loaves. To obviate these strong flours was required to be mixed with weak varieties. It was suggested that if India could produce 'strong' wheat, the British would therefore, be able to command a special market and preferential prices. Moreover that would meet the taste of the local market because Indians appreciated good flour. Introduction of this quality of 'strength' into Indian wheat became a problem of primary importance to the Howards. Moreover, besides the want of 'strength', Howards detected other defects in these pure types. They found another disadvantage – all Indian wheat produced weak straw. They noticed that in India winter rains were often accompanied with high winds and in March, hot dry winds prevailed. As a result, the crop with weak and brittle straw used to lie by rain and wind on grounds and caused much damage to the wheat production. Therefore, it became essential to strengthen the straw so that it could carry heavier heads and cause less damage to the production. Sample of seeds from the chief wheat growing areas were sown and the results were observed in 1906 and succeeding years. Nearly forty different botanical varieties were found in the Indian wheat crop. Ten of these belonged to the macaroni wheat (*Triticum durum*), six to the group of dwarf wheat (*Triticum compactum*), there was one variety of Emmer (*Triticum dicoccum*) and nineteen varieties of bread wheat (*Triticum vulgare*). No spelt wheat was found. Subsequently, the wheat of Baluchistan were examined and classified. Interesting forms, intermediate between T.turgidum and T. vulgare were found but nothing of economic importance emerged. These preliminary studies led to isolation of large numbers of varieties and of unit species, which formed the basis for subsequent work. Some of the unit species found was distinctly superior in general vigor and yielding power to the mixtures ordinarily grown. Another important point to notice was that since Indian wheat season was short, the wheat required maturing early. There was also the danger of 'rust' about the time of flowering and possibility of drying up due to early spring hot wind. Therefore to produce varieties, which would rapidly pass through the stage between flowerings and ripening so as to minimize the risk of 'rust', was desirable to the researchers. The new Indian wheat, known as Pusa wheat was perhaps the greatest practical achievements of the Howards. Some fifty named varieties were eventually produced by brilliant and sustained work. Faced by unlimited possibilities in front of them the investigators had decided at an early date "to concentrate from the beginning on the best only" and their advice on this point was insistent[23].

In 1906, Howard commenced both at Pusa in Bihar and Lyallpur in the Punjab (now in Pakistan), a system of selection from single plants which enabled him to produce several wheat of much greater value than the mixture then in cultivation. One of the first of the wheat obtained by selection was Pusa 6. This variety possessed a small grayish grain of a much higher quality than any of the ordinary Indian types. In spite of it being rust resistance it had not been introduced into general cultivation. It had two great weaknesses – poor standing power and a tendency to drop its grain. However, Pusa 6 proved to be of greatest value in hybridization. The good qualities of its grain and its resistance to rust could readily be transmitted to the offspring. Pusa 6 performed well in countries where the wheat crop did not stand so long in the field after ripening as in India. A good deal of seed had been sent to South Africa. A large number of other promising wheat were obtained from the cultures of 1906 and Pusa 12 proved to be the most successful of all the early Pusa selections on account of its great adaptability and high yielding power. Yields as high as 337.5 maunds per acre had been obtained from United Province, Simla Hill States, Eastern Punjab, Sind and some of the Rajputana States. Perhaps the best of the Pusa wheat as far as the grain characters were concerned was Pusa 4 obtained by selection from a heterozygote shortly after Pusa 12. It possessed a strong straw and a large, translucent white grain of very fine appearance. It was a rapidly maturing variety immune to yellow rusts and was very suitable for tracts where early wheat was required. Pusa 4 had proved to be very suitable for certain tracts in India notably, Bihar, Budelkhand, the Northwest-frontier Province and Gujerat. When full grown the grain had a very fine appearance and had been awarded the first prize for hard wheat at Australia. In the Report of the judge of the Royal Agricultural show at Sydney, Australia, in 1920, this wheat was referred to as follows:

"A sample of the Indian wheat, Pusa 4, exhibited by Mr.W.H.Scholtz of Gilgandra, is worthy of mention. It yielded a percentage of excellent colour flour of 53 quarts to the sack strength, which was the highest water absorption of all the flours tested in the competition"[23].

It was an achievement for Indian wheat breeders. Pusa 4 was later well established in Australia and was regularly distributed by the Queensland Agricultural Department. This variety had also been reported to do well by the Agricultural Department of Rhodesia. In India the grain was much appreciated for consumption and was often used for ceremonial and festive occasions. At Pusa four other varieties were also isolated, namely, Pusa 20,21,22,23; of these Pusa 22 proved to be the most useful and subsequently gave rise to superior hybrids. However, all four were later discarded for various reasons. At Lyallpur sub-station, 25 agricultural types were isolated, although none of these were of a really high quality. Only Punjab 11, white bearded wheat with red chaff was adopted for distribution on account of its quality. In 1923, the area under it amounted to 750,000 acres.

The process of crossbreeding and hybridization had been completely revolutionized by the discovery of Mendel's work on hybridization. Under the old method crossing was purely accidental. One never could tell what one would get out of the resulting crosses. One could pick out what seemed to approximate most closely what was wanted and the remainder would be thrown away. There was no guarantee that the cross would breed true in the second generation. The Mendel's law made it possible to obtain positive and certain results from plant breeding in a comparatively short time. By means of this method it became possible to create new plants combining the desirable qualities of both the parents. Hybridization, like selection, is only possible after the separation of mixed plants into their ultimate constituents. Most of the Mendelian work in British India was done on wheat. In wheat breeding it is desirable to use for crossing only pure lines, i.e., the progeny of single plants. It frequently happens that when a wheat mixture has been resolved into its constituents, all the desirable qualities are not found in one wheat. Thus some wheat, characterized by high yielding capacity may be found defective either in quality, in resistance to rust or in strength of the straw. Others may possess these characters but give poor yields. It is in producing new wheat perfect in all respect, that hybridization as a method of improvement has its value. Mendelism implies a complete study of the inheritance of characters in which each character is considered to act as a unit or a group of units. For example, in wheat when rust-liable and rust-resistant wheat are crossed the plants of the first hybrid generation are all rust-liable like one of the parents. In the second generation, however, splitting takes place; some of the crosses still remain rust-liable while others (a lesser number) are rust resistant. The latter, in succeeding generations, breed true to a rust-resistant character. It is therefore possible to introduce the character of rust-resistance into wheat wanting in this quality, by crossbreeding. Similarly, such characters as high grain quality, strength of straw, etc can be introduced into a wheat defective in these characters. These were the lines on which the Pusa experiments on wheat had been carried out. High yielding wheat of poor quality had been crossed with wheat of high quality but poor yield. In their third and fourth generations of these crosses it had been possible to select and fix wheat, which possessed the high-yielding power of one parent with the high-grain quality of the other. However, Mendelian work performed slowly and required infinity of patience.

The crossing of wheat began in 1906. The first trials were made on wheat of northern India, Muzaffarnagar bearded variety of high yielding power; the grains were however, soft and weak. Two early crosses in 1906 with Pusa 6 and Pusa 22 gave two successful hybrids, Pusa 100 and Pusa 101. These retained the high yielding qualities of the Muzaffarnagar but the straw of Pusa 101 proved not to be strong enough to support the heavy ears and this variety was eventually superseded by the favorite Pusa 4. Pusa 100 was found to suit the conditions in certain parts of the Central Province; twenty years later it was reported as still holding pride of place and as averaging nearly 70% more than the native ‘Kathia’. A second series of crosses from Muzaffarnagar resulted in ‘a very fine series of wheat’; among them Pusa 104 and 107 were some of the best looking wheat ever bred at Pusa, and when sent to Australia became exhibition wheat. Pusa 107 obtained the maximum number of points and eventually won the first prize at the Royal Agricultural show at Sydney. Many of the characters of agricultural importance are not simple unit characters but are combinations, which readily break up on hybridization. This means that an enormous number of plants must be handled before a new hybrid combining all the desirable characters can be obtained. Further, the various types of wheat used as parents disclose very great differences in their power of transmitting their grain characters. Certain wheat can always be relied on to transmit some desirable characters unimpaired. With others, the desirable characters break up on hybridization and the chances of recapturing them intact in later generations are small. In order to select effectively in the F_2 and succeeding generations, it was found necessary to adopt a definite policy as to which character were essential and which were desirable. At Pusa the following standards were therefore maintained: (i) the characters essential for an improved wheat were vigour, high-yielding power, strong straw and good rooting power, rust resistant, smooth chaff, white translucent grain equal in quality to that of the better parent employed, ability to hold the grain; (ii) the desirable characters were some attribute such as red chaff or the peculiar shape of the ear by which the variety could be readily distinguished in the field. In the third and succeeding generations the seed of the best-selected single plants was always sown in small rectangular blocks next to next. These small pots were then periodically compared in the field by eye as regards vigour, standing power and rust resistance. As a rule, this was repeated three or four times during the growing period and careful record made. The most promising pots were then marked and the single plants for the next generation were selected from these pots only. The rests were rejected.

Rusts were the most important diseases of wheat in India. Since rusts varied greatly from year to year and it was impossible to get an accurate estimate of the annual loss. Sleeman in 1839, speaking of rusts in the Central Provinces, wrote, "I have seen rich sheets of uninterrupted wheat cultivation for twenty miles by ten in the Valley of Narbudda so entirely destroyed by this disease that people would not go to the cost of gathering one field in four. I believe that the total amount of wheat gathered in the harvest of 1827 in the district of Jubblpore was not equal to the quantity of seed that had been sown"[24]. The damage caused every year by this disease far exceeds that resulting from all the other wheat pests put together. In this respect India was no exception to other wheat growing tracts of the world like United States, Europe and Australia where the rust problem was as great a question as in India. In 1883 the subject received attention from the Government of India. A paper dealing with wheat rust by Carruthers[25] was reprinted and circulated widely in India. Specimens of wheat rust and other diseases were collected in the various Provinces and sent to the Royal Agricultural Society of England for examination by the Society's Consulting Botanist. In India A. Barclay made the first investigation of rusts in wheat. The main portion of his work was not of an economic character but dealt with the scientific aspect of the various rust fungi found growing on wild plants in the Simla district. In his paper on wheat rust Barclay drew attention to the great differences in weight between the seeds from healthy and those from rusted plants. He further dealt at length with the influence of weather on rust and summed up his conclusions in the following statement, "The weather during January, February and March is most important in this connection, not only because it has a maximum effect on the growth of the wheat plants but also because this is the season during which rusts attack these plants". Watt published a general account of Barclay's work together with a review of the literature of some of the blights of Indian crops in 1895. In 1896 D.D.Cunningham and D.Prain at the instance of the GOI did a more extended investigation of wheat rust[26]. In 1897, Prain at the request of GOI also published a digest of the papers[27] relating to the five Inter-Colonial wheat-rust Conferences held in Australia from 1890 to 1896. Besides this information, the paper contained interesting comments on the bearing of Australian experience on wheat-rust question in India. The great importance of rust-resistant wheat for Indian conditions was recognized by Prain and referred to in his summary of the Australian literature as follows: " Practically the only hope for India in combating rust in wheat is to adopt the method of selecting from among the various kinds of wheat those that show themselves little liable to rust. For, probably no wheat is absolutely immune, it is a recognized fact that in certain areas particular wheat is relatively proof against rust. By a system of crossbreeding with kinds valuable on other accounts, new kinds can be made that will combine these qualities with the character of resistance to rusts"[19]. In 1903, E.J.Butler published a general account of the wheat-rust problems in India. Again in 1906, Butler and A.Hayman's paper on Indian wheat rusts appeared together with a note on the relation of weather to rust in cereals[28]. Butler and Hayman observed three distinct species of rust that used to attack wheat in India:

Black rust – *Puccinia graminis*,

Yellow rust – *Puccinia glumarum*

Orange rust – *Puccinia triticina*

Black and Yellow rusts were found to occur in all the wheat growing districts while the orange rust did occur principally in Bengal and United Provinces. The research dealt not only with the characters and distribution of the various wheat rusts in Bengal and Northern India, but also with the possibility of a connection between these rusts and that found on the common weed of wheat fields – *Lallnea asplenifolia*, known as "*tikchana*" in Bengal. However, no connection was found between the rust on this weed and those on wheat. Later Butler and Hayman showed by direct infection experiments that none existed.

As in other parts of the world, attempts were made in India to check the ravages of rusts by direct means. About the year 1900 the statement was brought to the notice of the GOI that some of the Australian agriculturists had found that two-year old wheat seeds gave rise to a crop more resistant to rust than that derived from one-year old seed. Experiments to test this idea were accordingly carried out on the Kanpur and Nagpur farms. At both of these stations it was found that two-year old seeds germinated so badly that very thin plots resulted. Rust appeared in due course at the Kanpur station where it was found that the plants from the older seed were attacked to a similar extent to those from the fresh seed. Pickling the seeds with copper-sulphate solution gave negative result as far as rust was concerned. Spraying the growing crop with solutions of copper-sulphate and iron-sulphate proved useless. The only real remedy in combating rust was cultivation of rust-resistant varieties. Several wheat cultivated in India were said to be rust-resistant to some extent, e.g., Mundia Pissi, Bansi and the Nagpur hybrid in the Central provinces, Bakshi in the Western Deccan and Majhi in Bengal. However, these varieties by no means were immune to rusts. Therefore, it was found necessary to produce new varieties by hybridization, which would be much more resistant than any of those cultivated at that time. In this connection Biffen who had produced by crossing rust-resistant wheat, which possessed all the other desirable qualities as well, had made a very promising discovery in England. The method adapted consisted in crossing ordinary rust-liable wheat with Einkorn – a variety from the mountainous districts of Eastern Europe which belonged to spelt group of wheat and known botanically as *Triticum monococcum L*. Einkorn had been found to resist rust to a greater extent than any other cultivated wheat. When this form was hybridized with other rust-liable wheat, some of the offspring were found to possess the rust-resistance of the spelt-like parent and the good qualities of the other. Work on these lines was commenced by Howard at Pusa and extended to the wheat of Northwest at Lyallpur Experiment Station. At the Poona Farm a further input was given to hybridization work by Mr.J.Mollison, who visited the United States in 1901 to study the method of agricultural improvement in use in that country. A large number of crosses were made at Poona, but no new variety was obtained. At the Nagpur Farm in the Central Provinces, some crossbred wheat was produced in 1895-96 among which one was found to be rust proof (Haura X Mundia Pissi). It was later found by Howard, who obtained single plants of this wheat from the Hosangabad Farm in 1906, to be the ordinary bearded Pissi wheat of the Narbada Valley. It was not a new form at all, but simply the Narbada valley bearded Pissi under another name. However, both forms were destroyed by yellow rust at Lyallpur Farm in 1907.

The indigenous selection of wheat Pusa 4 (later known as NP 4) was released and was followed by many other varieties. The local scientists assisted the Howards in crossing several Indian wheat with the best rust-resistant wheat varieties of northern Europe. The difficulty of the different flowering periods of the wheat was overcome by sending the Indian parents at Cambridge for spring sowing and by carrying out the actual crossing with Biffen's new hybrids in England. From the crosses thus obtained Howard was able to obtain several lines that proved to be superior to "Pusa 4" and "Pusa 12", which had been the best varieties in India till Independence. In 1910, Mrs. Howard in addition to her domestic duties joined her husband in his work on the wheat improvement program. After working for about five years in India the Howards came upon a unique idea so that the time required to breed a new wheat variety could be cut to half. They harvested the experimental seed at Pusa and then rushed to Quetta (now in Pakistan) in Balochistan desert where a special station was opened. Sir Albert was in charge of the Quetta sub-station where another generation of the wheat varieties could be grown and selected. Thus, they were able to get two harvests per year, accounting for rapid advance in wheat-breeding program between the years 1910 and 1916. The runaway success of these wheat meant that seed were in great demand and far exceeded supply. In fact, in 1917 the Maharaja of Kapurthala, Charanjit Singh, asked the British to loan him the services of Howards. Many other princely states also adopted the Pusa varieties. Howard was made Companion of the Indian Empire (CIE) in 1914. In recognition for her work on breeding of new Indian wheat known as Pusa wheat, Mrs. Howard was appointed Second (after her husband) Imperial Economic Botanist to the GOI in 1913 and was awarded the Kaiser-I-Hind Gold Medal. The very success of the breeding of wheat had revealed the dilemma as to whether the soils of India could support the high nitrogen requirements imposed by improved varieties of crops being introduced from Europe. Howard estimated that a better variety of crop might yield 10% of increase, but the better cultivation practice of that same variety would result in anything up to another 90%. He observed that cow-dung, which was needed for raising soil fertility to achieve better cultivation, were used in India for non-agricultural uses such as fuel, hut-building, etc. However, Howard for many years investigated the practices of green manuring carried out by the Indian cultivators, but a further step was needed. Previous experiments for the treatment of organic wastes had engaged his serious attention from time to time[29]. The wheat research progressed through the efficient research activities of Albert Howard and his wife Gabrielle Howard at the IARI. They left Pusa Institute in 1924 and joined the Indore Experiment Station to carry out research.

Howard's Research on Modern Compost

As the Director of the Institute of Plant Industry at Indore he developed a way of creating manure from unused agricultural wastes like cotton stalks, grass, hay, leaves and urinated earth, mixed with some cattle dung. His European peers ridiculed him for his faith in the 'Indian agricultural waste'. At Indore, an Indian chemist, Yeshwant Wad assisted Howard. Wad was a senior member of his staff and handled the chemical side of the work. He provided the significant rigor of a trained chemist in the carefully documented composting experiments. The invention of modern composting is attributed to Albert Howard. The work was developed slowly and along with experiments went tests of results in the field. Eventually, 1000 carts of compost were made at Indore each year with the collection and admixture of vegetables and animal wastes of the area farmed in to pits. The degree of moisture was maintained for a period of three months after which emerged a rich, crumbling compost containing a wealth of plant nutrients and organisms essential for plant growth. Howard had acknowledged the lessons he had learnt from the centuries-old experience of the Indian farmers, whom in later life he most happily named his ‘professors’. He was a firm believer that to impose Western methods on Indian agriculture would be a fundamental error and that the only correct thing to do was to improve Indian agriculture along its own line[30]. In 1931, he published a book “The Waste Products of Agriculture: their utilization as Humus”, co-authored with Wad. This book (reprinted in 2004) was a valuable gift to agricultural science to the people of India. The work of composting both town and village wastes was initiated on a nation-wide scale by the GOI under Dr. A.C.Acharya after 1931. The application of high doses of nitrogen to increase yield was destined to become the starting point of a new outlook in world agriculture leading to ‘green revolution’ was, however, could not have been foreseen at that time. Nevertheless, it was one of the most significant and successful instances of the coming together of Western knowledge and Eastern wisdom accumulated over centuries. Howard believed that the introduction of improved crops and better soil management could improve the total agricultural out put of India. According to Louisa Howard, his second wife, Howard saw in India a ‘vast laboratory of composting’. Howard traveled to Baluchistan and Kashmir, Sikkim and Nepal and into Sri Lanka and noticed that agriculture in the countryside were average but “where human excrement was daily deposited, was infinitely richer”. For some reason, Wad is never credited as a co-founder of modern composting. At least Howard had the courage to work with an Indian chemist and list him as a co-author to ‘The Waste Products of Agriculture’. Albert Howard was awarded ‘Knighthood’ in 1935 after he completed his work in India and returned to England.

Rice

Rice or paddy as it is commonly known is a grass of *Gramineae* family. The two cultivated species are *Oryza sativa Linn*. and *Oryza glaberrima Steud*.

The former is by far more important and O. glaberrima is confined to small areas in West Africa. *O.sativa* is widely grown in tropical and sub-tropical regions. *Oryza sativa L.* is divided into four sub-species – *Indica, Japonica, Brevindica* and *Brevis.* The morphological basis for distinguishing these sub-species is often obscure owing to the great number of intermediate forms and hybrids. Their status is therefore debatable except that there are good physiological and genetic grounds for separating the sub-species *indica* and *japonica.* The *japonica* forms are typical of the more northerly (and southerly) areas of paddy cultivation and flourish under very long photoperiods. Seedlings of cold-water tolerant *japonica* varieties may grow and develop faster than seedlings of *indica* varieties when the temperature of soil or water is low. Further these sub-species are distinguished by the partial sterility of the progeny of *japonica x indica* hybrids. Though the chromosome numbers are the same and no morphological differences can be distinguished between the chromosomes of the two sub-species, there is clearly some incompatibility between the genes of the two forms.

Rice was the most important food crop of India during colonial period. Nearly three-fourth of the people in this country subsisted on it. The cultivation was concentrated mostly to Assam, Bengal, Bihar, Orissa, Madhya Pradesh, Andhra Pradesh, Madras, Mysore, Maharashtra, Gujerat and Uttar Pradesh, which together accounted for about 95 percent of the country's production. India's share of the World production of rice at the beginning of the twentieth century was about 46 percent and she was the largest exporter of rice in the world at that time. The crop was, however, grown under diverse conditions in the country from almost sea level to elevations of 600ft. The soils varied from loams and clays to shallow laterites, with reactions ranging from extremely acidic to highly alkaline. At places cultivation was done in 15 to 20 ft deep water; at others it was carried on with a meager rainfall of 20 inches. In some areas a single crop was taken once a year, in other areas, three paddy crops were grown in summer or autumn or winter. As a result of this great diversity, research workers faced problems on the improvement of this crop. As rice was the staple food of such a vast population, an improvement in its nutritive value attracted attention of the agriculturists. In 1891 Watt initiated botanical studies on rice in India. With gradual establishment of agricultural research stations in different states, these studies were extended. Research on rice in India may be said to have started in 1911 with the appointment of Dr.G.P.Hector, Economic Botanist in undivided Bengal with headquarters at Dacca (now in Bangladesh). At Dacca, Hector classified rice varieties on the basis of 'leaf-sheath'. Subsequently, in 1912, a crop specialist was appointed exclusively for rice in Madras Province. Prior to the establishment of the Indian Council of Agricultural Research (ICAR), Bengal and Madras were the only provinces, which had whole time botanists exclusively for rice crop. In view of the significant role played by rice in the economy of the nation and recognizing the need for stimulating research on the crop, the Council sponsored and aided rice-breeding projects in different States as one of its major schemes. It was with the help of the Council that States like Bihar, Orissa, Madhya Pradesh (M.P.) and Uttar Pradesh (U.P.) were able to appoint special staff and institute for rice-breeding work. Though the oldest Agricultural Research Station at Samalkot in Andhra Pradesh (A.P.) was opened in 1902 mainly for the study of sugarcane, work on rice at the station started in 1909 and 19 improved strains from the more important local varieties were evolved. However, the main Government Agricultural Experiment Station at Himayetsagar established in 1928 became the chief center for rice research in A.P. Other research stations in A.P. for the breeding of high yielding, disease and drought –resistant strains, took up the work on rice. Twelve improved strains from the local varieties to suit different conditions in the tract were released. In Assam, Dr.S.K.Mitra, the Economic Botanist at the Rice Experiment Station at Karimganj, established in 1913 was in charge of the rice work. In the early years Mitra evolved a number of improved strains at this Station. He also contributed to the genetics of rice. From 1921 research work on *ahu* or summer and autumn rice, *bao* or medium and deep water rices and *sali* or transplanted winter rices of the Surma Valley were taken up. The Rice Experimental Station at Titabar was established in 1923 for work on *ahu* and *sali* rice of the Brahmaputra Valley. The work on rice started in Bihar as far back as 1914-15 at the Sabore Experiment Station. The early work on rice in the State was controlled by the Deputy Directors, and was mostly devoted to the varietal trials and agronomical investigations. Selection work of the local varieties was undertaken that resulted in the production of some improved strains. Mr. Alam was the first Rice Research Officer who led most of the breeding and genetic investigations. Work on rice formed an important activity of the Agricultural Department at Madras from the very beginning. Intensive research on the crop started with the appointment of an Economic Botanist, F.R.Parnell in 1912 (later designated Paddy Specialist). Dr. K.Ramiah succeeded Parnell, the first Paddy Specialist in 1924. Ramiah had been associated with Parnell from the beginning and the breeding work done in Madras was very largely due to the efforts of this pre-eminent worker in the field of rice research. Ramiah's great contribution to genetics and other fields of research on the crop had considerably widened the knowledge of the rice plant. The Paddy Breeding Station at Coimbatore was started in 1913 and was the chief center of rice research in the State. Twenty-five improved strains from local varieties and five hybrid strains were released. Considerable genetic and agronomic work was carried out at this Station. The Agricultural Research Station at Aduthurai was opened in 1922, the first sub-station to be started in pursuance of the policy to provide facilities for the improvement of the crop in each of the most important rice tracts. Twenty-two improved strains from the local varieties and three hybrid strains were released from this Station. There were two rice research stations in M.P. located at Raipur and Bagwai. The Station at Bagwai was opened in 1908. In the early years, most of the experimental work at this station was confined to agronomical investigations. The Economic Botanist, Dr. R.J.D.Graham with his headquarter at Nagpur, could only devote part of his time to rice research because he had to pay most of his attention and time to wheat research at this research station.. However, some progress was made in evolving improved strains of rice. With the retirement of Dr.Graham in 1915, there was a setback in rice research at the Station. Later a second Economic Botanist was appointed in 1924 and fresh stimulus was given to the work on rice. At the Raipur Station a full time Rice Research Officer, B.B.Dave, was appointed in 1932 to look after the rice breeding work. Dave was responsible for breeding some valuable strains at this station. When ICAR terminated its assistance to this station the rice development work received a setback. However, the work was renewed after the independence of the country. The collection of samples of rice varieties grown in the U.P. started in 1924 at the Kanpur Research Station. About 1300 samples were collected and grown at this Station. However, Kanpur was found unsuitable for growing rice. In 1932 the rice research was shifted to Nagina and placed under R.L.Sethi, the Economic Botanist. He contributed to the breeding, genetic and agronomical work on rice. In 1932, the Rice Research Stations at Chinsurah and Bankura in West Bengal (W.B.) were started under a scheme financed by the ICAR. The Chinsurah and Bankura Stations used to serve the alluvial tracts and the laterite region of the State respectively. These stations were started with the object of breeding the local varieties to improve the quality of *patnai* rice and the trade varieties other than *patnai*. Patnai rice was a quality table rice of Bengal that had a foreign market at that time. The chief rice research center of Orissa in the early days was located at Cuttack. The Station was started in 1932 as a sub-station of the main rice research station of the province at Sabore (Bihar) when Orissa and Bihar was a single administrative unit. With the formation of Orissa as a separate province in 1936, Cuttack became the main rice research station of the new State[31].

Scientific researches were conducted in India on the use of plant nutrients in the soil. As early as 1913-1916, Harrison and Aiyer[32] explained how nitrogen fixation took place and how the roots of paddy plant – a dry land root and not an aquatic – were provided with the necessary oxygen. They showed that the chief gases produced during fermentation were methane, hydrogen, carbon dioxide and nitrogen. These, on rising to the surface, encounter active aerobic bacteria, which oxidize methane to carbon dioxide and hydrogen to water. The green algae present on the soil surface plays an important role in taking up the carbon dioxide and liberating oxygen. Thus the undesirable gasses are removed and only oxygen and nitrogen are evolved for the root system. They also showed that plant roots assist in facilitating oxidation changes in the soil. Nitrogen is the key element for increasing yield of rice. Scientists observed that the paddy plant depends mainly for its nitrogen upon the decomposition of organic matter under anaerobic conditions and in the early stages of growth takes up nitrogen in the form of ammonia. Many experiments showed that the application of nitrogen in the form of nitrates in the early stages of growth was without effect or even deleterious to the plant, owing to its conversion to nitrites. In the later stages of growth, fertilizing with nitrates proved to be satisfactory. A good deal of work was done on manures for paddy. The general experience was in favour of green manuring for transplanted paddy. Bone meal was reported to vice good results. General experience was, however, against chemical nitrogenous manures except cynamide and sulphate of ammonia. But the cost of these was a serious handicap to their general adaptation. A limitation on the use of artificial manures were imposed for the fact that as the fields remained covered with water, the soluble manures would easily be washed off without doing any favour to the plant. A remarkable achievement in connection with rice was the introduction of transplantation of paddy by Mr. Clouston. Till the last decades of the nineteenth century, the custom of broadcast sowing was universally practiced. About 100 lb of seed per acre were broadcasted and the young seedlings were subsequently thinned out by ploughing with the result that most of them were killed. After a series of experiments on the Raipur farm adopting transplantation instead of broadcasting it demonstrated that a profit of about Rs.15 per acre could be achieved by this method. Steps were taken to bring this improvement to the notice of the cultivators. The new method was demonstrated in thousands of villages by the staff of trained men under Agricultural Assistants. The work accelerated due to the cooperation of the district authorities and within a few years was so firmly established that it was handed over to the revenue staff that worked side by side with the agricultural assistants. The area of transplanted rice rose to over 30,000 acres and that gave a profit of 4.5 lakhs of rupees per annum to the cultivators. There was no new discovery involved in this process. However, the credit went to Clouston for the patience and tact with which he had managed to improve so materially the agricultural practice of the conservative farmers in India[33].

Rice population commonly found in the fields consists of plants of different types, habits and yielding power. Natural crossing between these types produce plants which are heterozygous and which do not breed true but continue to add to the mixture at each generation. This mixed population offered a promising field of works on crop improvement, since, if the highest yielding and more desirable forms are cultivated, yields could be greatly increased and quality improved. The agricultural research stations in India used the ‘pure line method’ of selection and 445 improved varieties were released. These varieties were of various kinds such as: Earliness, Deep-water and Flood Resistant, Lodging Resistant, Drought Resistant, Non-shredding of grains, Dormancy of seed, Control of wild rice, Disease resistant and Higher response to heavy manure. This possibly encouraged research on crops in different provinces. After the establishment of the CRRI, research and training received an added impetus. There had been a systematic screening of exotic types from the genetic stocks. The hazards of drought and flood in paddy cultivation in India were very great and the annual loss of crop attributable to these causes was considerable. Drought as applied to paddy cultivation usually means insufficient water for the needs of the varieties grown in the area. The drought resistance of rice varies enormously – from dry land conditions for ‘hill’ paddy to very deep water for ‘floating’ rice. Drought resistance is an inherited character associated with certain morphological characters, such as highly developed root system. Hybrids with the shortest duration of flowering are said to be the most drought resistant. It follows that among the ‘wet’ rice there is considerable variation in resistance to drought and flooding. R.J.D. Graham in his article “Preliminary note of the classification of rice in the Central Provinces” published in 1913 placed such varieties in three categories in regard to their water requirements, viz. drought-resistant, normal and flood-resistant. He stated that the highly drought-resistant varieties could exist twenty days to one month without water, while the longest period that a paddy could withstand submergence would be about fifteen days. He suggested a probable explanation of the phenomenon –"that among the late varieties both drought-resistant and flood-resistant varieties are met with, may be that the danger of flooding to which late varieties growing in the lowest fields are exposed in their early stages, and the late date of maturing after the seasonal rainfall has ceased have evolved a type which may be both flood and drought-resistant". Ramiah reviewing the work on the physiology of drought resistance had cited the work of Hector in Bengal who found that drought-resistant or upland varieties had higher osmotic pressure in their cells than the non-resistant or lowland varieties. Hector also found that application of phosphatic manure reduced the water requirement of rice plants. It was observed that drought-resistant varieties had a consistently lower water requirement than the non-resistant varieties. A number of research works was done in different research stations in India on physiology of rice varieties resistant to drought and resistant to salinity. Hybridization for the purpose of producing new and improved types involves a delicate technique. The anther is removed before they mature and pollen from another variety is used to fertilize the stigma. This fertilized stigma is then protected to prevent further cross-fertilization from neighboring plants until the flowering period has passed. Many investigators have evolved their own technique of emasculation for rice hybridization. However, Ramiah[34] developed one of the commonly used methods of rice hybridization technique. He was the first scientist in India to begin the systematic hybridization program in rice. Prior to the first crosses he made in 1917-18, rice varieties improvement in India was mainly limited to pure line selection. He was deeply interested not only in varieties improvement but in understanding the genetic basis of yield, pest resistance and grain quality. The insect pests and fungus diseases of paddy presented a vast field of work and there was need in the increase of the entomological and mycological staffs in the Agricultural Department of the GOI. The fungal diseases of paddy, which fortunately were not very numerous in India, was investigated by Dr. Butler and concerted action was taken against ufra in Bengal. Ufra is a disease supposed to be caused by an eelworm. Though many of the insect pests of paddy were discovered, any solution was yet to be found for controlling them in the enormous affected tracts[35].

Concluding Remarks

India had a system of agriculture for centuries that was entirely different from anything to be found in the West. The crops were raised by a multitude of small cultivators who were conservative in their outlook and for the most part poor. As a result their leading idea was to play for safety. The cultivator was not prone to either change his methods of agriculture or the local varieties of crops to which he was accustomed. The Indian cultivator was a grower of crops and he usually regarded his livestock as mere aids to cultivation and in the feeding of the family. It was a country of climatic extremes not only as regards the rainfall but also with reference to temperature, to floods and high winds. Except certain favoured localities the annual crop was always at the mercy of a variety of circumstances quite beyond the control of the cultivator. Though the average yield per acre was found to be low it was remarkably constant. Vast areas under paddy had been under cultivation annually in Asian countries without the application of either manures or fertilizers, yet the yield remained fairly constant although at a low level.

The problems of agriculture and food supply to the hungry nations were of prime importance from the beginning of the 19th century. In a report dated 6th June 1805 to the Board of Directors of the East India Company, it is stated, "It is an undisputed fact that the produce of the soil is definitely below what it is capable of yielding under proper management"[15]. However, the problems of agriculture despite their true complexities appeared at the first glance to be a simple job, but it was observed that the nature of farming must first be understood and appropriate measures were to be developed to feed the vast population. At the beginning of the nineteenth century the British colonial ruler in India did not take any initiative to raise the farm productivity and no new innovations in the form of technological changes were introduced. Historical records show that yields in India were about 50 percent higher during the Mughal period than during the 1930s. However, it is probable that with the smaller population at that time, cultivators confined their energies to cultivation of the more fertile lands[36]. The agricultural progress was hampered when the British imposed taxes to the farmers that resulted in the destruction of the century-old water management structure and the cultural tradition, which had helped to build and preserve the farming techniques over centuries in states such as Bengal, Bihar, Karnataka, Tamil Nadu and others. However, Botanical Gardens were established in different parts of the British India to explore the diversity of soil and climate that offered great capabilities of successfully introducing the valued productions of many different parts of the world to this country. British colonial rulers felt the need for scientific enquiry in the field of agriculture when there was a series of devastating famine that caused a heavy and severe damage to agricultural production of the country during the nineteenth century. Moreover, the impact of agricultural research following Liebig tradition using artificial manures with nitrogen, phosphorous and potassium caught the fancy of the farming world in the West. The British colonial rulers were in the possession of a virgin land in India where no scientific agricultural research following Liebig's tradition had been carried out before. Moreover, Voelcker's Report provided the impetus for applying the teachings of agricultural chemistry to Indian agriculture. However, it is interesting to note that after visiting different parts of India and meeting the representatives of all the provinces, Voelcker wrote a book titled "Improvement of Indian Agriculture" where he did not share the commonly held view that Indian agriculture was primitive and backward. He remarked that the lack of facilities was responsible for inferior agriculture in India. Sir Albert Howard expressed the same view in his writings on Indian agriculture.

Therefore, when the Indian Agricultural Department was formed and operations began, the attention of its members was mainly directed towards the study of the crops of the country. The investigators soon realized that they were in a new world and the easiest line of advance in improving production would lie through the plant. The problem was successfully attacked in two directions, namely, by the provision of improved varieties and the study of the factors influencing the plant growth. In working out improved methods of producing a crop, the economic botanist was concerned with the physiological aspect of the plant. Perhaps no country in the world offered better scope than India for such work. The great growth factor had left their impression on the characters and distribution of cultivated plants. Besides, the range in conditions between the various parts of the country was very considerable and these circumstances greatly assisted the investigator in the study of the physiology and biochemistry of crop production and in the deduction of some of the factors that were in operation. However, the wide range of problems presented by the country was complex and their solutions involved knowledge of science and of practical agriculture. We are indebted to Lord Curzon for the establishment of the Imperial Agricultural Research Institute at Pusa-Bihar in 1905 where much research was carried out for the improvement of crop production. All notable advances in agriculture during the colonial period in India had been initiated by individuals who worked at the Imperial Agricultural Research Institute at Pusa and at the Experiment Stations built at different states. Though attempts were made from time to time to carry on the results of the agricultural investigations to the cultivator's field, the progress was very slow and the work thinly spread. The bulk of the knowledge gained by the research workers remained unknown and no adequate efforts were made to take it to the actual tiller of the soil in a readily understandable and coordinated form.

There is good reason to believe that the “Pusa Wheat” obtained either by selection and pure culture or by hybridization became the future wheat of India. However, the ultimate judge of the export market was the baker who wanted strong wheat capable of making well-piled loaf. To this ultimate test the Pusa wheat was tested by an expert – Mr. A.E.Humphries and emerged triumphantly. As milling and baking wheat, Pusa wheat had been placed above all the wheat of India and ranked by some of the trade with Manitoba Spring wheat (MSW). MSW was in greatest demand for bread making in England and command the highest price at that time. The special qualities of the new wheat were welcomed by the local consumer who was the person principally affected by the change in the quality of his staple nourishment and also suited the English millers requirements. Numerous enquiries and tests were conducted and it was found that the Indian consumers expressed a preference for the new varieties. Finally when question arose whether Pusa wheat would be equally successful in the new environment of the other provinces, extensive experiments demonstrated that samples from stations so far apart and distant from Pusa as Lyallpur, Mirpurkhas and Gurdaspur were pronounced to be even better than those rose at Pusa. Thus, high grain quality was expected to be obtained in all the great wheat-growing tract of India by applying the scientific methods in agriculture. In 1922 the classification of the wheat of Bihar were carried out as far as the unit species and very interesting and valuable types were found in that series. Since, India was the largest exporter of rice in the world at that time, not much scientific research was done on the subject at IARI and other agricultural stations during the colonial period. However, as rice was the food of a vast population, it could have received attention to increase the nutritive value of rice. It is probably due to the magnitude and complexity of the subject that little progress had be made with this crop in this regard. We are indebted to Sir Albert Howard for writing the book - “An Agricultural Testament”, describing in detail about the agricultural research in India during his time[37].

The direct outcome of the application of science to practice can be described as the accurate knowledge of facts and the discovery of their causes. When science set to work to find out the causes of well-ascertained facts in practical agriculture, progress at once became rapid. Formerly it was enough to know empirically that certain practices were good, that certain kinds of soil were suited to particular crops, that certain foods were useful for the cattle, but no one could say more than that these things were so, and not why they were so. Biochemical studies on plants have enriched our knowledge about the connection between soil, air, plants and animals. It became easier for us to know in great measure what plants were composed of, when and how they drew nourishment from soil, air and water and in what form it must be supplied to them. It enabled us to provide the needs of field crops by using suitable manures, to repair the demands made upon the soil, to cultivate lands on other than stereotyped lines. In short, a definite knowledge of the process taking part in the practice of fruitful agriculture has been obtained through the medium of scientific enquiry.

ACKNOWLEDGEMENT

The author is grateful to the Indian National Science Academy, New Delhi for financial support and to the Asiatic Society, Kolkata for academic support to carry out the research work. Thanks are also due to the Indian Agricultural Research Institute, New Delhi for providing me with the photographs.

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