THE EMERGENCE AND INSTITUTIONALIZATION OF AGRICULTURAL SCIENCE

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ABSTRACT
The nineteenth century witnessed the emergence of new theories, the transformation of old ones and the establishment of new institutions. As far as such processes refer particularly to agricultural science, a key role was played by the German chemist Justus von Liebig. This paper looks at the reasons why it was chemistry which gave rise to agricultural science and why this eminent chemist with international reputation became interested in agriculture. It also sheds some light into the strategies used for the institutionalization of the field in a worldwide basis.

A EMERGÊNCIA E A INTITUCIONALIZAÇÃO DA CIÊNCIA AGRÍCOLA

RESUMO
O Século 19 presenciou o surgimento de novas teorias, a transformação das velhas e o estabelecimento de novas instituições. No que se refere a tais processos, particularmente na ciência agrícola, um papel-chave foi protagonizado pelo químico alemão Justus von Liebig. Este estudo examina as razões pelas quais foi a química que deu origem à ciência agrícola, e por que este eminente químico, com reputação internacional, tornou-se interessado pela agricultura. Também revela as estratégias utilizadas na institucionalização deste setor em bases mundiais.

INTRODUCTION

The practice of agriculture existed thousands of years prior to the inception of science and it was gradually rationalized and scientized in the Western world during the 19th and 20th centuries. It emerged directly out of folk knowledge and social needs in contrast to the origin of basic natural sciences in intellectual traditions.

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From about 9000 years ago, when the deliberate sowing and tending of plants began – at about the same time, apparently independently, in both the Old and the New World – until today, man has made countless attempts to change agricultural practice (Bunting, 1971). Every attempt by man to make changes in agricultural practice, whether by individuals who themselves tilled the soil or by learned men prompted by scientific curiosity, can be considered as agricultural experimentation (Arnon, 1968).

There are plenty of records of how primitive and Middle Age peoples succeeded in increasing plant and animal productivity by creating and ameliorating techniques and devices. Thus, as early as 300 years BC, Theophrastus of Lesbos, a pupil of Plato and Aristotle, whose *Historia Plantarum* and *De Causis Plantarum* have earned him the appellation "father of botany", had already made references not only to disease in plants, but also to seasoning and predisposing factors which favour these diseases, and to practical ways of controlling them in order to increase crops productivity (Ainsworth, 1981).

This fact notwithstanding, it was only towards the middle of the 18th century that the first isolated attempts to apply "systematic knowledge" to the improvement of agriculture began to be made in Europe. As Arnon (1968) reports, Jethro Tull carried out experiments on row-seeding and inter-row cultivation, invented a seed-drill and, perhaps more important for its novelty, reported on the results in a book called *The Horse-hoeing Husbandry*, first published in 1731. Tull also paid attention to plant diseases and designed "experiments" to determine their causal factors. For instance, he attributed wheat bunt to cold wet summers, an explanation he considered he had confirmed by inducing the disease by overwatering (Ainsworth, 1981). Similarly, Lavoisier is also reported as having carried out field experimentation on a large estate that he managed during the 1760's and 1770's (Arnon, 1968). Nonetheless, it is widely accepted by historians of science that the technical innovations of the agrarian revolution of the 18th century were not at all dependent upon the science then known[3] (Mason,1962).

By this time there already existed a programme of rational husbandry conducted by Wallerius in Germany, which culminated in the early

[3] Such technical innovations include notably the new agricultural machinery introduced by Tull, the four-course system of crop rotation practised by Lord Townsend, and the stock-breeding improvements of Robert Bakewell.

nineteenth-century "rational agriculture" of the Thaer School. This programme, in which the economic aspects of improved farm management took precedence over the technical, consisted of the intensification of traditional farming and was based on methods which exhausted the fertility of soils (Krohn & Schafer, 1976). Despite the inadequate attention to the environment, resulting in declining fertility of the land, which characterized agricultural practice in that period, it relied on reason and on the realization that man could actively intervene in nature. Examples of such intervention were: rows served as demarcations during planting; irrigation controlled erratic rainfall; animals were bred to possess specific characteristics. There was, however, a question awaiting to be answered: how do the plants grow from the soil?

It is true that by the 1830's there was a standard, though increasingly inadequate, corpus of knowledge on agricultural chemistry which grew mainly out of Davy's *Agricultural Chemistry* of 1813 and subsequent editions[4] (Rossiter, 1975). Also, due to the work of Priestley, Ingenhousz, Senebier and Saussure – the foremost man in the new era of plant physiology – on photosynthesis and gas chemistry, a great deal was known about the water, oxygen, light, and carbon dioxide relations in the plant.

Thus, by the latter part of the 18th and beginning of the 19th century there had already emerged the belief that nature can be controlled and there existed both a "rational" view of plant-soil relationships and of plant physiology. However, no standard experimental procedures had yet evolved, so that most of the experiments were irreproducible and, more to the point, their practical impact on agriculture was very small.

The turning point came towards the middle of the 19th century with Liebig, who not only developed new chemical knowledge but also attempted to apply it to agriculture. In doing so, Leibig established agricultural chemistry as a new field for scientific investigation and played a key role in the institutionalization of the discipline. In fact, there is wide agreement amongst those who have written about the history of the agricultural science, that it was the agricultural chemistry proposed by Liebig which eventually emerged as the leader in terms of its theoretical contribution to agriculture (Rossiter, 1975; Ordish, 1976; Krohn & Schafer, 1976, 1982,

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[4] This work was a compendium of views and experiments by Theodore de Saussure, Albert von Thaer, J.L. Gay-Lussac, Louis Thenard and others. It was popular in the United States and England but not in Germany, where different ideas were prevalent.

1983; Ainsworth, 1981). In view of this, it seems reasonable to assume that to talk about the emergence of agricultural science is the same as to consider the development of modern agricultural chemistry, which began in 1840 with the first edition of Liebig's "Organic Chemistry and its Applications to Agriculture and Physiology", which appeared at the same time in Germany and England.

Assuming the above as correct, this paper aims to analyze a number of related points. Firstly, it looks at the reasons why it was chemistry and not plant physiology or rational husbandry which gave rise to agricultural science. Considering that Liebig was the main conductor of this process, the paper also offers some hints into why this eminent chemist with international reputation became interested in agriculture. The argument put forward is that Liebig was pushed into agricultural chemistry not only by the cognitive challenges it offered but also – perhaps mainly – by the social needs of the time. Such interconnection between social needs and cognitive patterns provided agricultural science with both pure and applied aspects: a characteristic which played a very important role in the institutionalization strategies of the discipline in Liebig's Germany and was reproduced in a worldwide basis.

ORGANIC CHEMISTRY AND AGRICULTURAL CHEMISTRY

As was expected in the beginning of the nineteenth century, Liebig' agricultural chemistry drew heavily on the foundations set forth by inorganic chemistry. These may be shortly listed as: the definitions of the chemical elements and chemical bonding into compounds; the principle of conservation of matter established by Lavoisier which led to the elaboration of several empirical laws in chemistry (Richter's law of equivalent proportions and Proust's law of constant compositions). Such laws made possible for the chemists to characterize new compounds and new elements and paved the way to the atomic theory put forward by Dalton. This was followed by Gay-Lussac's law of combining volumes, a usable theory of constitution, at least in taxonomic terms; and finally, the precise determination of atomic weights proposed by Berzelius (Mason, 1962; Krohn & Schafer, 1983).

The fundamental findings of inorganic chemistry, however, did not provide the only basis for agricultural chemistry; a number of successes in the field of organic chemistry also made a contribution. These include the development of methods in the pre-1840 period, which permitted the isolation and quantitative determination of the elements of organic compounds. In this field, Liebig played a very important role, for his method and new apparatus of elementary analysis was simpler, faster, and more reliable than the ones that preceded it. Such method for organic analysis quickly changed research practices in the field at large, being accorded by historians a decisive role: “it [the method] permitted the production of knowledge in a regular routine way, made possible in a few hours analyses that had hitherto taken days and weeks, enabled large numbers of young persons of moderate talent to do significant investigations, and reduced the analyses to assembly-line work” (Holmes, 1989: p.132).

The conjunction of a structuring theory and a set of systematic procedures and experimental techniques formed the essential precondition for the development of agricultural chemistry, paving the way for the huge number of experiments required to establish the nature and properties of the multiplicity of phenomena involved -plants and their parts, soils and air.

Furthermore, it was precisely because traditional agricultural chemistry, plant physiology and rational husbandry lacked either the theoretical or the methodological maturity of inorganic and organic chemistry that they did not take the lead in applying science to agriculture and remained simply as disciplines with aspirations of utility in agriculture.

Traditional agricultural chemistry was dominated by vitalistic ideas, which considered the humus to be the main food of plants, and committed to phlogiston chemistry, lagging behind developments in chemical theory. Only Sprengel was interested in the minerals in the soils and did extensive studies on them, but he too was a German vitalist. Then came Davy who tried to reconcile Saussure’s recent data, which showed that minerals played a role in plant life, with the old vitalistic theories and arrived nowhere but in ambivalence. By lacking a consistent body of theory, agricultural chemistry before Liebig found itself in a very difficult position to explain the contradictions between its old assertions and the new facts observed in every day agriculture (Rossiter, 1975; Busch, 1981).

The beginning of the 19th century witnessed a fundamental contribution to plant physiology through the work of Saussure who advanced considerably earlier developments by Ingenhousz. The latter, a Dutch engineer who worked in London, published his *Experiments upon Vegetables* in 1779 which contains a demonstration that the green parts of plants, when exposed to light, fix the carbon dioxide from the atmosphere and that plants have no such power in darkness, but that they give off, on the contrary, a little carbon dioxide. This most significant concept laid down the foundations of the economy of the world of living things and, taken up by Saussure, demolished the old theory that plants derived their substance from the humus of the soil (Singer, 1959). Also in 1817 Pelletier and Caventou isolated chlorophyll and in 1837 Dutrochet showed that carbon dioxide was absorbed only by the green parts of the plants in the presence of light, thus also building upon earlier work by Ingenhousz (Reed, 1942).

In spite of the above developments, it was not until 1842 (after the publication of Liebig's book) that this corpus of knowledge in plant physiology invoked additional studies, mainly by Boussingault. Moreover, plant physiologists were not particularly committed to apply their knowledge to agriculture, a task which was taken forward by the chemist Liebig (Mason, 1962). The most acute problem with plant physiology, however, was the lack of a well established and systematic methodology. The experimental data of Saussure, for instance, were not precise enough or numerous enough to preclude generalization in time and space. In his book of 1940, Liebig explicitly accused the plant physiologists of conducting experiments which were "valueless for the decision of any question" because they had no theory of procedures to control their experiments (Liebig as quoted by Krohn & Schafer, 1982, p.198).

Rational husbandry concentrated its efforts on obtaining higher profits through the adaptation of modern, and in particular mechanical, techniques to the specific conditions prevailing on individual farms. Higher yields could be attained either through improved technology or more rationalized farm management. Two theories dominated the work in the field: the humus theory and the economic theory of farm location. Although the progressive isolation of all the variables relevant to agriculture created a disciplinary background for the emergence of agricultural chemistry, the approach was married by a number of major theoretical deficiencies – particularly the neglect of the ecological problems associated with the intensification of agriculture – and the experimental findings could not be applied beyond the immediate geographical setting in which they were made (Krohn & Schafer, 1976).

In summary, during the first four decades of the 19th century, none of the "logical" approaches to agriculture – the technical-mechanical, the economic-management, the physiological and the chemical – had taken a decisive lead. The publication of Liebig's *Organic Chemistry and its*

Applications to Agriculture and Physiology in 1840 changed this situation radically: chemistry emerged, through the work of Liebig, as the science able not only to explain the processes of agriculture but also to make a difference in agricultural practice.

LIEBIG'S FORMULATION OF AGRICULTURAL CHEMISTRY

In the beginning of the 1800's there was much confusion about the action of soils and manures in plant nutrition. In this context, Liebig was able to identify the key questions and their solutions by drawing on organic chemistry, plant physiology, economic and technical knowledge. In the new fields Liebig entered after 1838, such as agricultural chemistry, he was more of a synthesizer and propagandist than an experimentalist (Holmes, 1989). Leibig himself expressed this metaphorically in later editions of his book: "In my agricultural chemistry I have simply tried to put a light into a dark room. All the furniture was there, even tools and objects of comfort and fun; all these things, however, were not clearly visible to the society using this room for their welfare and to their advantage" (Liebig as quoted by Krohn & Schafer, 1976: p.35).

Liebig was concerned with the practical problem of plant nutrition mainly in terms of the sources of minerals essential to plant growth. He organized his "Organic Chemistry and its Applications to Agriculture and Physiology" book as an argument focused on three essential points: 1) the destruction of the humus theory, 2) the elaboration of the principle of cycles of reproduction of organic structures, and 3) the explanation of the role of minerals (Rossiter, 1975).

Liebig's critique of humus theory pointed to a number of flaws it presented, particularly to: humus was called by different names by different investigators whose analysis had shown it to contain 58-72[5] percent carbon and types of soil seemed to make little difference in the amount of carbon in the plants grown on it. Then, working considerably with numbers, subjecting a rather vague concept like the humus theory to chemical scrutiny, and putting plant respiration within a larger context he proposes that plants complete a cycle, taking in carbon dioxide and emitting oxygen. Consequently, Liebig shows that the carbon dioxide in the atmosphere,

[5] Such variation might have been tolerated earlier, but organic analysts by the 1840's were arguing over differences of 1-5 percent.

rather than the carbon in the humus, contributed to the carbon in plants. In doing so, Liebig accomplished at the same time two lasting achievements that cleared the way for more detailed analyses of plant nutrition: the destruction of humus theory and the discovery of the interdependent oxygen-carbon cycle (Rossiter, 1975; Krohn & Schafer, 1976).

After dealing with humus, Liebig formulated the concept of the reproduction cycles of organic processes. He argued that, since plants could not create mineral salts, they must obtain their inorganic constituents from the soil, and what they took from the soil must be restored if fertility were to be maintained. This formulation, however, excluded nitrogen for Liebig believed that it was the ammonia of atmosphere which furnished nitrogen to plants. This idea was incorrect and was responsible for the failure of the manure patented by Liebig which did not contain nitrogen compounds. But by being wrong, it stimulated others like Lawes and Gilbert in England to investigate the use of artificial fertilizers in agriculture, which elucidated the unknown stages in the nitrogen cycle of nature (Mason, 1962).

Liebig's third stroke was to explain the role of minerals in plants. Succeeding decades had seen many plant and soil analyses which Liebig began to pull together and compare with his own. This work led him to a complete new interpretation of Saussure's experiments: minerals, despite their small quantities, were not trivial; they are essential for plant nutrition (Rossiter, 1975). Besides showing that plant growth is determined not by the organic but by the mineral components of the soil, Liebig pointed out: 1) that the elements contained in the nutrient mineral salts are not mutually interchangeable, and 2) that plant growth depended on the availability of the rarest mineral substance – the law of the minimum.

The role of minerals in plants was only dimly perceived before Liebig and it was his lasting achievement not only to formulate it as a problem but also to explain it and offer practical suggestions on how to solve it. Assuming minerals to be essential to plants, he was then able to explain the action of manures, to suggest and to attempt the production of artificial fertilizers.

In brief, Liebig managed to put together a wholly new approach to agricultural chemistry, which represented a special scientific achievement requiring the development of especial theories and methodological procedures. It integrated elements of chemistry, agronomy and physiology, without at the same time being exhausted by these individual disciplines. This is the reason why Liebig's *Organic Chemistry and its Applications to*

Agriculture and Physiology may be seen as the landmark of the so-called agricultural science, as “probably one of the most important scientific books ever published and marks the beginning of a scientific revolution” (Rossiter, 1975: p.25).

LIEBIG’S MOTIVATIONS TOWARDS AGRICULTURAL CHEMISTRY

The motivations that drove Liebig to agricultural chemistry are not altogether clear. Firstly, many authors have suggested that the opportunity for his approaching agricultural chemistry arouse with the invitation to address the annual meeting of the British Association for the Advancement of Science in 1837 (Bernal, 1937; Mason, 1962; Rossiter, 1975; Krohn & Schafer, 1976). There is considerable controversy, however, about what specifically the BAAS asked him to do. Mason (1962) points out that the lecture that he presented at the meeting of the BAAS in Liverpool in 1937 was already on agricultural chemistry. Others argue that during his visit to England that year the chemical section of the BAAS requested that he prepared a topical progress report which he delivered three years later in the form of his book on agricultural chemistry. According to Bernal (1937), the BAAS explicitly requested a report on agricultural chemistry, “ task which diverted Liebig’s interest to the practical problems of food production” (p.561). For Rossiter (1975) and Krohn & Schafer (1976), however, the BAAS requested Liebig to write a review of the state of organic chemistry and certainly did not direct him to the topic of agricultural chemistry. Thus, it was his choice to discuss agricultural chemistry exclusively in his book.

Other explanation is that Leibig was attracted to the study of agricultural chemistry after Saussure published a paper on fermentation which discussed the humus. Liebig used it to bolster his own arguments for an oxidative-catalytic theory of fermentation. According to this view, Liebig was driven to agricultural chemistry by the scientific challenge of explaining the complex and controversial process of fermentation (Rossiter, 1975).

A different source of Liebig’s interest in agriculture in 1840 may have been the social and economic situation at that time. This argument is put forward by a historian and two sociologists of science in slightly different forms. The former (Rossiter, 1975) points out that in the 1830’s and 1840’s, Gießen -the city in which Liebig had his laboratory- was at the very heart of an extremely poor agricultural area of Germany. The social and economic conditions were so difficult that many impoverished families fled to

America. It may well be that Liebig believed that by attempting to apply chemistry to agriculture he could help to improve agricultural production and, consequently, living standards.

The latter (Krohn & Schafer, 1983) attribute a much clearer importance to economic and social conditions – in Europe and not specifically in Gießen only – in driving Liebig to agricultural chemistry. They provide considerable evidence in favour of their argument which assumes that:

> "Liebig's application of chemistry to agriculture and physiology was not undertaken with the aim of solving the scientific question of the nutrition of plants, but with overcoming the social problem of the nutrition of people" (Krohn & Schafer, 1983: p.19)

In trying to further their argument, these authors point out that the "context of discovery" for agricultural chemistry is constituted by two circumstances: on the one hand the interdependence of population growth and subsistence crisis, and on the other, Liebig's consciousness of this situation (Krohn & Schafer, 1976). In relation to the first, there already existed at the beginning of the 19th century a widespread concern about population explosion which, combined with the impact of Malthus' theories of the catastrophic disparity between the growth in population and the increase in means of subsistence due to conservative food production, could foresee only two solutions: either drastically reduce the growth in population or increase the production of foodstuffs far beyond the yields obtained from the traditional agriculture. The alternative presented by Malthus was a "natural" regulation of the gap between the surplus population and the available food supply; in other words, a dramatic increase in mortality (Krohn & Schafer, 1983).

Liebig was aware of the threat of a secular subsistence crisis and, along with Malthus, had recognized the limitations of traditional agriculture in regard to the demographic factor, as evidenced in his numerous controversial writings. However, contrary to Malthus, Liebig did not believe in "preventive checks to population"; rather, he sought for an alternative to "present husbandry" and asked whether chemistry could achieve the conditions necessary for obtaining "big and ever increasing harvests lasting eternally" (Liebig, as quoted by Krohn & Schafer, 1976). This recasting of Malthus' gloomy vision consequently became the starting-point, and the *leitmotiv*, for Liebig's scientific project of agricultural chemistry.

In conclusion, there seems to exist different explanations for the interest Liebig developed in agricultural chemistry. Some may be said to be “internal” to science, others may have appeared by chance, while still others can be clearly related with conditions “external” to science, that is, stimulated by defined social needs. Thus the science of agriculture is one of the first examples of how human needs and interests explicitly take part in forming the subject field of a science. Therefore, agricultural science emerged as a typically applied science with particular features which required specific strategies to be institutionalized.

THE INSTITUTIONALIZATION OF AGRICULTURAL RESEARCH

The institutionalization of a scientific discipline is referred to here as the process whereby it is socially recognized as a specific field of research in need of its own institutions. To be “ripe” for institutionalization, a scientific discipline must ideally exhibit a number of features which include: a charismatic leader, a distinctive research approach, simple research techniques, a pool of talented recruits, control over publications and financial support (Geison, 1981).

The agricultural chemistry which emerged with Liebig fulfilled all such conditions. Since he went to Paris in 1822 to study under Gay-Lussac, it was clear that he had high promise as a creative research chemist. By 1840 when his book on agricultural chemistry was published, not only Liebig (who was 37) but also his laboratory in Gießen were internationally famous. At this time he already was one of the leading organic chemists of Europe.

The conjunction of a structuring theory and a set of systematic procedures and experimental techniques put forward by Liebig formed the essential precondition for the development of agricultural chemistry. Moreover, the Gießen laboratory created by Liebig is said to be the place in which systematic instruction in experimental chemistry was introduced for the first time. It became a highly productive research centre and it trained many chemists, some of whom became the outstanding chemists of the next generation (Holmes, 1989). Using his considerable influence in the leading international journal of organic chemistry at that time – the *Annalen der Chemie und der Pharmacie* – Liebig succeeded in modifying its traditional classification so as to open up a special section for agricultural chemistry. He also ensured that the discipline was given a prominent place in many of the handbooks and textbooks published (Krohn & Schafer, 1976). Finally, research funds were not a problem for Liebig since he and his laboratory started to show results.

Even under such favourable conditions, it was not without a lot of struggle and persistence from Liebig that agricultural chemistry was institutionalized in Germany. It took some twenty years before artificial manure was successfully obtained and until then, he had to explain the failure of his manure and battle against the "practical men" of rational agriculture over acceptance of his claims. The necessity to be recognized by society at large and not only by the scientific establishment derives from the fact that agricultural chemistry was an applied science and as such it had to reconcile the complexities of its cognitive developments with the public demand for practical benefits.

The institutionalization of agricultural chemistry was nearly complete in 1862 when its first professorial chair was established in Halle, followed by a number of others in different German universities (Krohn & Schafer, 1976). However, it became clear that long-term experimentation in agricultural problems was essential if improvement in agricultural production was expected. Such experimentation demands the observance of *in vivo* conditions during many cycles of the culture. Due to these features, agricultural experimentation does not fit well within the "profile" of the universities and a special institutional framework was designed to attend it: the agricultural experiment station. The universities, however, kept the task of developing the "basic" aspects of the science of agriculture and of training agricultural scientists.

The first agricultural experiment station in Germany was also established in 1862. It was an initiative of landowners, subsequently legalized by the government and to which an annual state appropriation was approved. In its charter it was specified that "the station would be devoted to the advancement of agriculture by means of scientific investigation carried out in close connection with practical experimentation", and stressed the importance of co-operation between scientists and farmers in order to achieve this aim (Arnon, 1968: p.4).

The German model for the institutionalization of agricultural research spreaded out to Europe and to the rest of the world. Thus, in England it was created the Rothamstead Experimental Station in 1843, which began as a private venture by Sir Lawes and Gilbert, who had studied under Liebig in Gießen. (Ainsworth, 1981). However, it was only shortly before the First World War that the British government, searching for means to overcome the depression in which agriculture found itself, decided to support agricultural science. This support was on a small scale, in the form of grants to universities and divided amongst a number of institutions, working in separate fields. In spite of this, agricultural research became a full-professional occupation and contact with farmers was very close (Russel, 1966).

Other European countries had also institutionalized some sort of agricultural research by the end of the 19th century. The process whereby agricultural research was established in most European countries exhibits certain similarities. Firstly, agricultural research usually had its beginnings in universities and then agricultural experiment stations were created in order to carry out the more “practical” work.

On the other side of the Atlantic, American scientists, inspired by the European experience in applying research to agriculture, started propagandizing the need for establishing experiment stations in America. This was during the 1870’s and 1880’s and at this time, “career opportunities for American scientists were severely limited […] and those committed to serving America’s agricultural community faced a particularly bleak future” (Rosenberg, 1977: p.403).

In fact, the Morril Act of 1862 which created agricultural and mechanical colleges -at least one in each state, the so-called land grant colleges- had failed both in attracting students and in improving agricultural productivity. These colleges were mainly concerned with teaching and experiment was viewed by many college administrators only as an aid in student training (Arnon, 1968). At the same time, science offered at least the possibility of economic application and, thus, public support. The application of science to agriculture promised to raise American farmer’s standard of living and status in society as it improved his economic position. Such rhetoric fitted neatly and complemented the professional ambitions of scientists and administrators who started to agitate for state support for establishing a national system of experiment stations. This culminated in the passage of the Hatch Act in 1887, a measure providing each state with an annual subvention of $15,000 from the federal government for the support of an agricultural experimental station (Hadwiger, 1982). The earlier stations to be created had no organic connection with a university but, later on, due to increasing demands from research-minded professors, some of the federally subsidized stations were established as departments of the land grant colleges (Rosenberg, 1977).

In the meanwhile, the creation of a federal Department of Agriculture was being debated and finally came into being through the Organic Act of 1862, and became known by the name of USDA, with the aims of both conducting practical and scientific experiments and duties of a non-scientific nature (National Science Board, 1978). The passage of the above mentioned Hatch Act posed a number of administrative problems, but none was more urgent than that of establishing a pattern of formal relationships between the several state stations and the USDA. In an effort to solve this problem, Congress sanctioned the creation in 1888 of a division within the Department of Agriculture to coordinate experiment station work -the Office of Experiment Stations (OES). Finally, by the late 19th and early 20th centuries, agricultural science was fully institutionalized in the United States.

Up to this date, however, the work carried out at the experiment stations did not involve much research. The Office of Experiment Stations tried very hard to narrow the interpretation of permissible expenditures under the Hatch Act which was suffering abundant infringements of its intent: agricultural colleges used the act’s endowment for everything from paying fire insurance premiums to the purchase of fish and cats for dissection in student laboratories (Rosenberg, 1976).

Besides the ill utilization of funds and personnel, research was not perceived as being much promising or to guarantee immediate practical results, except in the case of agricultural chemistry and soil science. Actually, it was only with the rediscovery of Mendel’s classic experiments on the heredity of garden peas in about 1900 and the emergence of a true science of genetics, that the plant breeder developed a clearer vision of how to proceed with crop improvement (Wilkes, 1988). And even then the insights of Mendel and De Vries, although implying the creation of a new discipline, were still regarded as “adding little or nothing to the technical armamentarium of the skilled empirical breeder” (Rosenberg, 1976. p.167).

It was not before the Adams Act of 1906 – which increased the state’s appropriation to US&30,000 and restricted its use only for “original” scientific research – that the much-needed support for the new and centrally important discipline of genetics was guaranteed. This was to replace the empirical system of intuitive selection and judicious inbreeding and outbreeding performed by breeders at the agricultural colleges and experiment stations up to that moment. The reaction to the Mendelian insights among plant and animal breeders, together with the passage of the

Adams Act which opened up a number of positions to these professionals in agricultural colleges and experiment stations, plus the immense influence and scientific leadership exerted by the academic cytologists and embryologists in the new-model genetics, all contributed to the establishment of scientific genetics and plant breeding in the colleges of agriculture even before World War I. The more enterprising among research-oriented college and station leaders were able to utilize their locus of institutional security to support research programmes in plant and animal breeding since the passage of Adams Act. From this time on, the craft of plant and animal breeding became less of an art and more of a science and played an increasingly important role in the stabilization of agricultural research activities (Rosenberg, 1976).

By 1900 over 800 agricultural experiment stations of varying size and competence were in operation around the world. During the period from 1900 to about 1931, the number of experiment stations increased to over 1400 worldwide. Moreover, by 1930 nearly all British colonies and most French colonies had at least one station (Busch & Sachs, 1981).

Latin American countries also followed suit. Research activities and technical change in Latin American agricultural production had been in evidence since the beginning of this century. Examples include the cattle cross breeding in the Rio de La Plata Basin; the development of cattle ranchers specialized in the selection of breeds; and the creation of the Instituto Agronômico de Campinas in 1887 in Brazil, the first agricultural research centre in Latin America. However, it was only towards the 1930's that the public sector began to participate actively in the process of generating technology, creating and supporting agricultural experiment stations through the ministries of agriculture (Trigo & Piñeiro, 1981). In Mexico, for example, an Office of Experiment Stations was established during the 1930’s by the Cardeñas government (Busch & Sachs, 1981) and in Brazil the National Department of Agricultural Research was created in 1938, implementing a network of research units covering practically the whole nation (Malavolta, 1982).

The common feature of the agricultural experiment stations established in peripheral countries was that they tended to focus upon export crops. Thus “luxury” goods such as sugar, tea and coffee were the objects of both research and export whereas food crops, rarely exported, were consequently less researched. Especially in the British, French and Belgian colonies of Africa, it is apparent that little emphasis was placed on research on local food crops (Busch & Sachs, 1981). Moreover, research was conducted in these countries almost entirely by European scientists whilst only the technicians were natives of the countries concerned (Arnon, 1968).

In the case of most Latin American countries, although politically independent, research efforts in agriculture also privileged export crops because "wealthy capitalist farmers growing for export were able to apply pressure on government for support for research" (Busch & Sachs, 1981, p.136). For example, Evenson & Kislev (1975) note that sugar cane experiment stations were generally established in countries where grower organizations were strong.

At the same time that agricultural research stations were being created in peripheral countries, agricultural colleges were also established. In Latin America, for example, the first agricultural college appeared in 1854 in Chapingo, Mexico. By 1920 there were over 20 agricultural colleges in Latin America (Malavolta, 1982).

Summarizing the above account of the institutionalization of agricultural science in different countries, it appears that it rarely developed according to a planned blueprint. In most cases clashes of interest among ministries, departments, institutes, personalities or group pressures have had more influence on shaping the organization than has objective planning according to the specific needs of each country. This fact notwithstanding, the processes of institutionalization of agricultural research in most of the countries show some common features. Particularly, it seems that it was generally funded and supported by governments because it was expected to bring economic returns and/or to solve pressing social problems. Moreover, as agricultural science involves both the development of fundamental theories and the consideration of social goals, it has both pure and applied aspects. Because of this feature, the process of institutionalization of agricultural research had to take place in two quite different settings: the science-oriented universities and the technology-oriented government experiment stations.

In fact, the nature of agricultural research carried out in colleges of agriculture is not necessarily different from that in agricultural experiment stations. However, scientists in the two contexts differ in fundamental aspects of their social organization and, consequently, in the research goals they pursue; in the freedom to choose their research topics; in the audience for the research results they produce; in the system of rewards; in the structure of authority under which they work.

Such differentiation of research contexts have been instrumental to agricultural science in many moments. As Rossiter (1975) points out: “Spokesmen for the field could respond to the changing moods and demands of society and of its own practitioners by shrewdly stressing its practical applications at one moment and then its contributions to pure science at the next” (p.11).

This notwithstanding, the “division of labour” in the agricultural science – whereby government experiment station researchers are expected to do applied work and more fundamental agricultural research is seen as the province of university scientists – has created many problems for the field and its practitioners. Thus, agricultural researchers in experiment stations are constantly criticized for not doing fundamental research while their colleagues in the universities are accused of not doing relevant work deemed to solve the real problems of agriculture.

Far from trying to solve this artificial dichotomy, it is more important to understand that exactly because human needs and interests take part in forming the subject field of agricultural science, its study can reveal a great deal of a society’s attitude toward science.

REFERENCES

AINSWORTH, G.C. **Introduction to the history of plant pathology**. Cambridge: Cambridge University Press, 1981.

ARNON, I. **Organization and administration of agricultural research**. Amsterdan: Elsevier, 1968.

BERNAL, J.D. **Ciência na História**. Lisboa: Livros Horizonte, 1937.

BUNTING, A.H. Agricultural Science. In: LEAGANS, J.P.; LOMMIS, C.P., ed., **Behavioral change in agriculture**. Ithaca: Cornell University Press, 1971. p.439-452.

BUSCH, L. **Science and agricultural development**. Allanheld: Osmun, 1981.

BUSCH, L.; SACHS, C. The agricultural sciences and the modern world system. In: BUSCH, L. **Science and agricultural development**. Allanheld: Osmun, 1981. p.131-156.

EVENSON, R.E.; KISLEV, Y. **Agricultural research and productivity**. New Haven, Conn.: Yale University Press, 1975.

GEISON, G.L. Scientific change, emerging specialties, and research schools. **History of Science**, v.19, p.20-38, 1981.

HADWIGER, D.F. **The politics of agricultural research**. Lincoln: The University of Nebraska Press, 1982.

HOLMES, F.L. The complementarity of teaching and research in Liebig's laboratory. **Osiris**, v.5, p.121-161, 1989.

KROHN, W.; SCHAFER, W. The origins and structure of agricultural chemistry. In: LEMAINE, G. et al., ed. **Perspectives on the emergence of scientific disciplines**. Paris: The Hague, 1976. p.27-52.

KROHN, W.; SCHAFER, W. Agricultural chemistry: a goal oriented science. In: BARNES, B.; EDGE, D. **Science in context**. Milton Keynes: The Open University Press, 1982. p.196-211.

KROHN, W.; SCHAFER, W. Agricultural chemistry: the origins of a finalized science. In: BOHME, G. et al., ed. **Finalization in science**. [S.l]: D. Reidel, 1983. p.17-52.

MALAVOLTA, E. As ciências agrícolas no Brasil. In: MOTOYAMA, S., ed. **História das ciências no Brasil**, v.3, p.105-150, 1982.

MASON, S.F. **A History of the sciences**. New York: Collier Books/Macmillan, 1962.

NATIONAL SCIENCE BOARD. **Basic research in the Mission Agencies**; report of the National Science Board. [S.l.: s.n.], 1978.

ORDISH, G. **The constant pest**: a short story of pests and their control. New York: Charles Scribner's Sons, 1976.

RANDOLPH, S.R.; SACHS, C. The establishment of applied sciences. In: BUSCH, L., ed. **Science and agricultural development**. Allanheld: Osmun, 1981. p.83-111.

REED, H.S. **A short history of the plant sciences**. Waltham, Mass.: Chronica Botanica, 1942.

ROSENBERG, C.E. **No other Gods**; on science and American social thought. Baltimore: The Johns Hopkins University Press, 1976.

ROSENBERG, C.E. Rationalization and reality in the shaping of American agricultural research. **Social Studies of Science**, v.7, p.401-422, 1977.

ROSSITER, M.W. **The emergence of agricultural science**. New Haven: Yale University Press, 1975.

RUSSEL, E.J. **A history of agricultural science in Great Britain**. London: Allen & Unwin, 1966.

SINGER, C. **A short history of scientific ideas to 1900**. New York: Oxford University Press, 1959.

TRIGO,E.J.; PINEIRO. Dynamics of agricultural research organization in Latin America. **Food Policy**, p.2-10, Feb. 1981.

WILKES, H.G. Plant genetic resources over ten thousand years: from a handful of seed to the crop-specific mega-gene banks. In: KLOPPENBURG, JR., J., ed. **Seeds and sovereignty**; the use and control of plant genetic resources. Durham: Duke University Press, 1988. p.67-89.