Science and the Improvement of Indigo Dye in Colonial India, c. 1860-1913

(Prakash Kumar)

Abstract

This paper explores the transition to synthetic dyestuffs through a primary focus on developments within the last major holdout of the natural dye industry, the blue colorant indigo. It starts by looking closely at existing practices for the cultivation and manufacture of the natural dye in colonial India in the second half of the nineteenth century. Furthermore, it develops a case study based on targeted efforts to scientifically improve plant-derived indigo, the blue dyestuff across laboratories and experiment stations in colonial India and imperial England. These experts attempted to increase yields and enhance the purity of the natural dye in order to meet the competition of cheaper and purer synthetic indigo that was launched on the international market by two German firms, BASF and Hoechst in 1897. The paper explains the patronage of science by European planters, the colonial state, and the metropolitan government and analyses the nature of science that emerged in the colonial-imperial nexus.

1) 'A Stranger in a Strange Land': Indigo Planters and their Science

In the early twentieth century, the seasoned indigo planter Minden Wilson, having spent several decades on the Bihar plantations, recalled how he had felt like a 'stranger in a strange land' when he first reached India in1847. The young British prospector had arrived in the port city of Calcutta from Mauritius after spending five weeks at sea. As the steamer carrying Wilson began the onward journey upstream on the Hughly River to the indigo growing districts of Bihar, it passed the 'Albatross', the American ship that had brought him to Calcutta. On seeing Wilson, the sailors hoisted the ship's flag and dropped it as a mark of parting salute to him.[1] It was a poignant moment for the expatriate, symbolizing and emphasizing separation, which, as he later described, made him wonder about his destiny in a foreign land away from home and family.

But Wilson's musings apart, he and his fellow planters in colonial India belonged to an affluent class (although not 'empowered' in an absolute sense, as pointed out at the end of this section). They willingly came to the distant land with dreams of striking it rich. The attraction of employment in the indigo factories was sufficiently strong enough. The prospect of part or complete ownership of a business and the lucrative profits to be had from it were well known and attracted a regular stream of émigrés. In the decades following his arrival Wilson moved from one indigo factory to another, rising in the ranks from an Assistant Manager to a Sub-Manager and a

Manager supervising, in common with hundreds of other Europeans, the cultivation of the indigo plant, the extraction of the blue dye, and preparation of indigo cake for export. [2]

Minden Wilson's case was by no means unique. In the second half of the nineteenth century the indigo tracts of Bihar in colonial India – the districts of Muzaffarpur, Darbhanga (both subsumed within the Tirhut division), and Saran and Champaran – were a refuge for the surplus middle classes from Britain. Indigo manufacturing by the European planters in India began in the last quarter of the eighteenth century.[3] Benoy Chowdhury has described the early history of indigo manufacture at a time when the industry was centred on East Bengal. [4] Agitation by native growers against unjust wages that had continued to simmer through the 1850s and erupted into open rebellion in the early 1860s drove most planters out of the region.[5] The plantations in Bihar were first populated as an overflow from the Bengal districts, and grew rapidly from mid-century as the industry retracted from Bengal.[6]

In 1897, when the cheaper and purer synthetic indigo of German origin made its way into the international market, it threatened to displace the plant –derived dye. The synthetic substitute could potentially decimate substantial colonial capital invested on the plantations in India and disrupt the lives of the planting elite. The nodes of the natural dye industry were spread far and wide to include not only activities in India but also trade and commerce in Europe. At the end of the nineteenth century, Sir W.B. Hudson, a large planter, claimed that £4.5 million was invested in the indigo industry.[7] This capital was sunk in separate areas such as land, monetary advances to indigo growers, and in factory building and manufacturing materials. In a more liquid form the capital was used to pay wages to the coolies (Indian labourers) who worked in the factories, and to meet distribution costs like brokerage and, significantly, shipping. Statistical survey reports indicate that between £250,000 and £300,000 was invested in factory outlays in the Tirhut division alone. [8]The indigo industry was financed with credit advanced by agency houses and managing companies based in Calcutta. These business houses in turn represented the surplus capital of manufacturing and merchant interests in Manchester, London, Glasgow, and Bristol.[9]

The planters living in the indigo districts had also assiduously recreated an English lifestyle for themselves marked, for instance, by English dining, consumption of favourite liquors imported from home, organization of dancing balls, and New Year, Christmas, and miscellaneous other parties. As an affluent class in the orient the planters lived in sprawling bungalows serviced by a cortege of natives; their ostentatious living included amusements such as conspicuous hunting expeditions.[10]With the arrival of synthetic indigo the planting interests feared decimation of their capital and disruption of their settled lives. [11]

It is thus hardly surprising that a resolute response to defend the natural dye shaped up throughout the relevant sectors of the imperial-colonial axis. Support for the natural dye was ordained by political economy. The groups associated with the natural indigo industry were well represented within the state structure at home and in the colony. They made a determined attempt to save the natural dye and, in their efforts, also received the qualified support of different arms of the colonial and metropolitan governments. Any reduction of wages on the plantations was not possible given the current level of disaffection among the peasantry.[12] The demand for tariff protection to natural indigo in the British markets ran against well-established principles of free trade in imperial Britain at the time, and was consequently denied. But, with support from the colonial state and the metropolitan government, the planters sponsored a sophisticated program of scientific research to improve the natural dye. This science aimed to reduce the price of natural indigo by improving the yield of the crop and enhancing the amount of color extracted from leaves, and to raise its purity by streamlining the process of production.

The extensive patronage of science in efforts to improve natural indigo has not previously received serious analysis by scholars in their study of the indigo industry or of colonial science. The epithet ‘stranger in a strange land’, which was actually inaccurate in representing the circumstances of transplanted Britons engaged in a profitable commerce, does however appropriately describe the wilderness of planters and their indigo science in the landscape of historiography. Historians of modern India have produced a rich account of the political and economic dimensions of the natural indigo industry in colonial India. But much of this literature examines the cultivation and manufacturing of indigo for purposes of explaining colonialism and nationalism, and the nature of peasant movements. [13]Those analysing laboratory sciences in the colony have also given a short shrift to the study of indigo science. The concerned historians critique state's efforts in promoting research into the production of a commodity such as indigo because, in their opinion, those policies served the interests of European investors and not India's masses. Once that fact is established, they do not continue to examine the nature of experiments conducted at the research stations.[14] Certainly, whatever little analysis exists of the indigo experiments is of an indirect, limited, and partial nature. Peter Reed, a historian of chemistry, has briefly commented on the indigo experiments that were organized in India and Britain. In his study of the dye trade in Britain he portrays the indigo planters in India as sceptics who hesitated on the question of adopting scientific results coming out of the natural dye laboratory at the University of Leeds. But this paper will argue that Reed's interpretation that the planters were 'hostile' to science is exaggerated.[15] Reed seems to have uncritically accepted the views of a few biased actors in the metropolis who did not have an accurate understanding of the situation in India and who, in trying to figure out reasons for Britain's loss of monopoly of the dye trade to Germany, incorrectly made the planters scapegoats. Thus in the rhetoric of these campaigners the planters were anti-science, responsible for the indigo trade slipping out of British hands, and for compromising British imperial economic interest and prestige. [16]

This paper re-tells the story of the efforts to improve the natural dye from the perspective of indigo planters, and thus pulls out planters and their indigo science from the obscurity that befell them in the transition to synthetic colorants. The analysis style adopted in this study is deeply inspired by the clarion call of Colonial Studies scholars Ann Laura Stoler and Frederick Cooper for a consideration of internal dissensions within the ruling class in a colonial context as well as for utilizing the specific vantage point gained by the treatment of the metropolis and the colony together as a 'single analytic field'.[17] To talk of the powerlessness of European planters is also to go against the grain within the historiography of modern India. Much of the scholarship on the British Raj described all colonial classes as empowered and active agents who always set the agenda for major political, social, and economic developments in the colony.[18] This study departs from those trends. Stoler's emphasis on paying attention to the 'fault lines' of interest between different categories of colonial actors has immense value. Such a line of query illuminates the fractured internal structure of the ruling classes. Specifically, it enables an understanding of the relative powerlessness of European planters vis-à-vis other colonial and imperial actors. A study of classes and institutions in the metropolis and in the colonial outpost also allows capturing the tensions between imperial and colonial science in its entire complexity.

2) Craft and Science on the Bihar Plantations

Figure 1

Indigo Manufacturing Cycle

Steeping vat	→	**Beating vat**	→	**Boiler**
Leaves dipped in water; a greenish-yellow solution results		Beating of the solution; pulpy precipitate settles down, which is indigo		Boiling/cleaning

The production of indigo dye on the colonial plantations involved separate agricultural and manufacturing operations. Cultivation of indigo took place on the loamy soil of north Bihar floodplains, since the softness of the earth here was suitable for deep taproots of the *indigofera* plants. As soon as the crop was ripe, the planters transferred the harvested material to the manufacturing units located on the plantations. The processing of natural dye followed clearly defined procedures (Figure 1) that basically involved chemical changes to convert the glucoside of indigo leaves to indigo, the blue colorant. The production cycle started with the immersing of leaves and branches into water in the steeping vat. The enzymes naturally present in the leaf caused the fermentation of the glucoside. The greenish-yellow solution obtained after fermentation was transferred to the beating vat. There, the liquor was oxidized by passing through a stream of air that caused the water-insoluble blue dye to precipitate to the bottom of the tank. The dye was then scooped out and cleaned by boiling and stirring in large containers during the third and final stage of production. After washing indigo was dried and cut in the form of cakes. This primary three-stage process of manufacturing was generally followed in all its details more or less without variation across all sub-regions in Bihar.

While the technical detail has not been discussed, the nature of cultivation and manufacturing on the indigo plantation has been uniformly criticized in the economic history of modern India. Benoy Chauwdhury's study of the indigo enterprise in the eighteenth and early nineteenth centuries revealed a deep capitalization of the industry, but also found that profits from the capital were not ploughed back into cultivation. The foreign capitalist tried to make maximum profit on his investment and repatriated his earnings to Britain. Such a process of appropriation 'prevented the normal accumulation of capital' locally. In his study of indigo peasantry Jacques Pouchepadass centred his analysis on 'the exploitation of indigenous human labour' and the generally 'labour intensive' trait of plantation economy to suggest that the nature of cultivation and production in the indigo districts was antiquated. These historians definitively demonstrate the appropriation of indigenous resources by foreign capital. But these analyses do not proffer an understanding of the science and technology of indigo cultivation and manufacturing. Falling in the shadow of these analyses are the minutiae of improvements actually implemented on the indigo plantations. In particular, these perspectives do not consider the difficulties in streamlining the manufacturing processes in the absence of a sound knowledge of indigo chemistry during the period. [19]

The characterization of the indigo plantations in colonial India as a repository of scientific and technological conservatism does not pass muster in light of deliberate and organized circulation of experience and expertise across the imperial and colonial worlds. The basic parameters of plantation agriculture had evolved over previous centuries. The process of turning over tropical and sub-tropical lands to plantation crops by the European planters began in the early sixteenth century. While the earlier expansion of plantations transpired in the Western hemisphere, in the regions of Brazil, West Indies, and America more specifically, by 1800 the most rapid accretion took place in South and South-east Asia. [20] The cumulative knowledge gain was hardly specific to a crop, and had moved forward experientially by the planters of European origin moving between the continents. European migrants from the West Indies specifically introduced indigo planting and the 'vat system' of indigo manufacturing into Bengal in the last quarter of the eighteenth century.[21] Among the subsequent waves of Europeans replenishing the stock of planters, a few had prior experience with plantation agriculture in other continents, including Minden Wilson, who was involved with the sugar plantation in Mauritius before coming to India. Others were new entrants to the indigo business. Sometimes they had prior familiarity with indigo plantations on account of family and social ties with indigo planters already working in India, though at other times that connection was lacking. In either case they learnt the nitty-gritty of planting and manufacturing by apprenticeship with senior planters on the job. There was no substitute to the wisdom of the 'old hands' in the transfer of relevant skills from one batch of planters to another. The entrepreneurs also moved between factories across the districts in India thus disseminating in another place what they learnt in one location.

The European indigo planters positively improved upon the pre-existing indigenous methods of cultivation in India. At the end of the nineteenth century, John Augustus Voelcker, the agricultural chemist who had been invited by the colonial government to make recommendations for the improvement of Indian agriculture, cited the indigo plantation as an example of where better techniques of cultivation were used in terms of selection of seeds, and the use of implements and fertilizers: 'The cultivation of indigo has been very greatly improved by the European planter, and the native growers have to some extent followed the example set them'. [22]In his analysis Voelcker showed a keen awareness of the land structure of plantations and the different methods of cultivation by the planters and the peasants who were contracted by the former to grow indigo. On the small and dispersed landholdings owned by Indians, the European planters were scarcely in a position to control day-today operations and bring about innovations. But in the cases where planters were owners of holdings, and they were large in size, they viably used improved implements like the 'Hindoostan plough' and seed drills. Voelcker was generally impressed with planters' cultivation methods and underscored 'how great … [was] the care exercised in tilling the soil, in obtaining a fine even surface, in preventing any loss of moisture, and in breaking up any crust that forms after the rain has fallen'.[23] He attested a 'heavy application of manure', generally *seet*, the refuse from indigo production, which was known to provide enhancement in yield. Artificial manures had also been tried, but they had not provided any benefits commensurate to cost.[24] All of these show that the Bihar planter had a fair knowledge of influences of climate, soil, rainfall, and manures to their agriculture, which he purposefully made use of.[25]

The chemical process involved in manufacturing underwent very little modification in the first three quarters of the nineteenth century. The world of modern science had little to offer in terms of improving the basic knowledge of indigo chemistry. Wilfred Vernon Farrar has explained that organic chemistry, which began its career with a quest to understand the nature of compounds in the living matter was forced to change course due to the very complex chemical composition of plant substances that were difficult to separate in a pure state. Organic chemistry turned to simpler versions of these compounds that were found in coal gas and coal tar,[26] while those who stayed the course to study natural product chemistry found the path particularly tortuous. Long before, in 1808 the French chemist Michel Eugene Chevreul proposed that 'indigo-white' was the colouring principle in the indigo leaves. Chevreul's theoretical paradigm reigned supreme for the next several decades. Indigo science gained some empirical precision shortly after the mid century. In 1855 the Manchester based chemist, Edward Schunck was able to isolate a glucoside, named it *indican*, which he proposed to be the precursor of blue. Schunck did not achieve any further success in clarifying the properties of the glucoside given its chemically unstable nature. No further advance could be made on the natural product until 1900 when the Dutch chemists working with natural indigo isolated a precursor different than what Schunck had found earlier. [27]

The pace of inventive activity on the Bihar plantations had actually picked up around the mid century. The push towards improving production processes by the planters in these decades may have come from economic impulses originating in the agriculture. Pouchepadass has noted the rising trend in wages on the plantations and in procurement price for indigo between the 1860s and 1890s. [28] Under the circumstances adopting technology to cut costs would have emerged as a clear option. James Inglis, an important Bihar planter confirms that ‘amazing and rapid improvements’ were being introduced to the mechanical side of manufacturing in the 1860s and 70s. [29] In his detailed exposition of the process of production for indigo in late nineteenth century colonial India, J. Bridges Lee, an innovator himself, marked out several mechanical improvements that had been devised to replace ‘old methods’. All the important factories had adopted the use of steam to improve operations such as pumping water into the steeping vat, turning the beating wheel in the oxidizing vat, and lifting the steeped liquor into the boiler through an ejector. The use of beating wheels with steam power allowed savings on the ‘costly’ coolie labour. In addition, Lee informs us that heating with a steam jet had replaced direct heating in the boiler, which ensured that no product was burnt, as happened previously. It had also become common to use new mechanical contrivances like the drainer in the oxidizing vat that helped ensure ‘the system of regular, continuous, and uninterrupted working’. Lee had registered three specific patents for putting calibrated pressure on leaves in the steeping vat, for a ‘slow bath method of oxidation’, and for turning out indigo slabs all of which declaredly helped in the task of fine tuning manufacturing and improving yield. [30] It is not unlikely that these patents would have found buyers in the general environment that favoured adoption of several process innovations in the indigo districts.

The latter half of the nineteenth century was also punctuated by deliberate efforts in colonial India to use the knowledge of chemical principles to amend processes of fermentation and oxidation in the manufacturing cycle. In Germany the famous chemist Justus von Liebig turned his attention to aspects of plant growth and metabolism in the 1840s. His contributions at Giessen University formed the embryo for the consequent development of the field of agricultural chemistry that had a primary impact worldwide in terms of the application of chemistry for improving crop yield. [31]But more generally Liebig's influence also brought about an improved understanding of the chemistry of agricultural commodities. Indeed Liebig had personally motivated and encouraged his student Edward Schunck to take up research on the chemistry of natural pigments including indigo.[32] Knowledge of the action of chemical reagents on indigo seems to have become widespread in India in the last quarter of the nineteenth century. That the addition of chemicals in the vats to regulate the output of dye was gaining currency is reflected in the comment of senior planter W.M. Reid who, as one of the 'old hands', expressed reservations against these new trends of 'doctoring' in dye production. [33]One particular agent who made a distinct contribution to the application of chemical principles to indigo manufacturing in Bihar was Eugene Schrottky who claimed to be a former student of Liebig.[34] In the 1870s and 1880s Schrottky registered in Bengal seven patents on relevant chemical and mechanical processes (Table 1) and sold them to the Bengal Indigo Manufacturing Company, one of the largest indigo companies in Bihar. At least five other prominent indigo factories purchased the right to use these patents.[35]

Table 1
Eugene Schrottky's patents registered in Calcutta

Date of registration	Short description of the patent
Sep 20, 1877	Use of yeast from fermenting vats and other precipitates in the manufacture of indigo
April 5, 1879	Use of yeast from previous fermentation, of borax, and other alkaloids in the manufacture of indigo
Aug 16, 1881	Use of oxidizing salts in the manufacture of indigo
June 13, 1882	Use of saltpeter, nitrates, and sulfates in the manufacture of indigo
May 7, 1884	Re-steeping of the indigo plant and the use of a perforated base for the fermenting vat in the manufacture of indigo
March 9, 1886	Improvements in the re-steeping process and the yeast process in the manufacture of indigo
Aug 12, 1887	Use of carbolic acid and antiseptics in combination with saltpeter in the manufacture of indigo

Source: Board of Trade Papers, Public Record Office, Kew [36]

The picture on indigo manufacturing in Bihar presented by John Augustus Voelcker is variegated and requires careful analysis. Voelcker advised that not 'rule of thumb', i.e., common sense and experience, but rather 'strictly scientific' principles should guide manufacturing by the planters. For instance, he noted the lack of unanimity among the planters with regard to the methods for packing of the steeping vats, the type of water to be used, and duration of steeping.[37] Voelcker counselled that precision on all of these would continue to evade the planting community until 'details of each step [was] … thoroughly understood'. He disapproved of the readiness shown by the planters in severally trying out measures suggested by many of the 'adventuring so-called "chemist"' on the plantation, as he obviously did not have much faith in the ingenuity of these measures or in their chance of success. Instead Voelcker invited the entrepreneurs to come together and pool their resources in order 'to have the whole subject carefully worked out by a man of eminent scientific standing'.

It is possible to make sense of the claims and counter-claims of experts and lay experts in light of the 'discontinuous' nature of natural pigment science in the last quarter of the nineteenth century.[38] John August Voelcker's counsel on 'correct' chemical processes joins the cacophony of a multitude of opinions on Bihar's plantations. As a matter of fact Voelcker's own understanding of the glucoside *indican* in indigo leaves as a soluble substance, or his belief that the fermentation stage was ineffectual are woefully inaccurate in light of natural pigment chemistry, as we know now.[39] Indigo planter James Inglis in Bihar was not off the mark when he bemoaned the absence of clear facts at the time: 'The whole manufacture, so far as chemistry is concerned, is yet crude and ill-digested', he noted in exasperation.[40] Not that Inglis in a colonial outpost was disadvantageously placed with regard to scientific information. Those principles were not understood precisely in the field of contemporary chemistry. While it is likely that a few 'charlatans' made false claims of scientific ingenuity in a situation where nobody could offer a conclusive opinion, other suggested measures were apparently meritorious.[41] The planters tried out multiple adaptations suggested to them by those who tinkered the mechanics of production and made use of the available knowledge of agricultural chemistry to offer a chance of yield enhancement. At the same time, Voelcker's call to seek clarification of 'details of each step' failed to evoke a response. It seems reasonable to assume that the reality of inadequately understood science had reduced the attractiveness of Voelcker's proposal for a full-fledged scientific program. Voelcker's submission appeared overly ambitious to the planters, especially in a situation where they were not experiencing any pressure from the market.

3) Synthetic Indigo and the Scientific Response in the Colonial-Imperial Nexus

Synthetic indigo was the product of persistent research and development within the industrial set up of Western Europe. The synthetic dye industry arose in mid-nineteenth century Britain, aiming to displace natural colours with artificial colours drawn from coal-tar hydrocarbons. In the earlier period British and French companies dominated the production of synthetic dyes. But from the 1870s most important advances were made in Germany.[42] The exceptional German leadership position in dyestuffs has been explained on account of pioneering science-based industrial chemistry that was uniquely exemplified by collaboration between academic and industrial chemists, investment-intensive research in industrial laboratories, a modern patent law, and possession of very sophisticated theoretical and empirical skill base in organic chemistry. Sufficient motivation existed to channel scientific resources to solving the riddle of indigo synthesis. Carsten Reinhardt and Anthony Travis provide us with some perspective on the immense worth of the natural dye by drawing our attention to the fact that between 1880 and 1896 the average annual value of the world's output of the plant-derived indigo stood at 80 million marks, which was equal to the turnover of all European coal-tar dye factories put together. [43]

Industrial research on indigo began specifically with the works by Adolf Baeyer at the Gewerbeinstitut in Germany in 1865 that led to the discovery that indole was the mother substance of indigo. But at this point no other source of indole could be found than the indigo plant itself. On the positive side, however, Baeyer proposed a constitutional formula for indigo that helped subsequent works in its synthesis. Heinrich Caro, an industrial chemist at BASF took the initiative to forge collaboration with Baeyer. Benefiting from this new partnership Baeyer managed to synthesize indigo utilizing different pathways in 1878 and 1880. This initial success ignited further industrial interest and led to a tripartite agreement for research and development between Baeyer, and BASF and Hoechst. The second Baeyer pathway, starting from toluene, was scaled up by BASF to introduce an intermediate into the market in 1880 that allowed depositing of indigo on printed cloth after reduction with another chemical. But the product did not catch the fancy of printers partly due to the fact that it was twice the price of natural indigo. The solution towards smashing the monopoly of natural indigo lay in finding a cheap and abundantly available starting material. While the modern structure of indigo was understood by 1883 the problem of finding a pathway that could be profitably used in industrial production remained. Finally, in 1890, Carl Heumann at Zurich Polytechtechnic in Switzerland established the critical pathway starting from naphthalene, derived from coal tar. BASF and Hoechst immediately purchased the rights to its use. A further seven years of development in the industrial laboratories and pilot plants led to the launching of synthetic indigo on the market by BASF in July 1897; and Hoechst followed soon after.

The colonial, natural blue had faced challenges from other hydrocarbon-derived synthetic substitutes before, but synthetic indigo in 1897 truly threatened its dominance in the market place. A number of synthetic substitutes over the past decades had aimed to capture the indigo market. Among these were the alizarin blues and a few azo dyes of German make. However, they had largely failed in making inroads into the consumer demand for indigo on account of the fastness that the latter afforded. But synthetic indigo began to rapidly eat into the German and then the important British, French, and

Table 2
Export of indigo from Calcutta, 1895-96 to 1905-06

Year	Weight in cwt (112 Pounds=1 hundredweight or cwt)
1895-96	111,714
1896-97	109,001
1897-98	71,364
1898-1899	81,779
1899-1900	59,078
1900-1901	71,637
1901-1902	55,038
1902-1903	29,403
1903-1904	29,858
1904-1905	30,029
1905-1906	19,062

Source: Review of the Trade of India in 1905-06 [44]

American markets for the agricultural product. The total export from the Calcutta port that primarily shipped indigo from Bihar plummeted. While some of the annual fluctuations in export figures reflect the impact of weather conditions on agricultural output, the long-term trend clearly demonstrates a decline in the natural indigo industry in the wake of shrinking consumer demand. The export of natural indigo fell within a decade to less than a fifth of the total in 1895-96 (Table 2).

The synthetic indigo triggered a scientific response of a different level to improve the agricultural product in the colonial and imperial worlds. It provided urgency to the efforts of those who stood behind natural indigo for protecting its slice of the market, and a direction to those efforts. The signal from the market was unmistakable: natural indigo had to be improved on an urgent basis or it would perish. The competition also set the direction of improvement along reduction of cost and enhancement of purity. Planters bore the primary responsibility to save their product, though they received the support of the imperial and colonial governments. The former was concerned at the prospect of losing their grip on the blue dye trade to Germany. The colonial government acted out of its interest in stopping the impending collapse of a flourishing industry.

The planters considered the use of science, in particular the new research from the field of chemistry. Synthetic indigo's success in the marketplace was commonly attributed to the efforts made by academic and industrial chemists in Germany. Could the planters also use chemistry successfully to improve their product? Issues like these were routinely debated at the meetings called by the Bihar Indigo Planters' Association (BIPA), the primary trade organization of the planters. Their weekly newspaper - the *Indian Planters' Gazette and Sporting News* - rapidly disseminated information coming from England on the matter. The indigo planters and traders did not typically remain ensconced in the colonial outpost, but rather maintained close connection with the trade and scientific circles in their home country. These connections proved crucial in sensitizing them to the emerging promise offered by chemistry in Europe. Each year several from among the community vacationed in England once the manufacturing season ended in February or March. Some were from the Yorkshire region, the heart of the dyeing and printing industries. Others took the time to visit the textile districts and met with those involved with the trade — dyers, printers, the sellers of dyes and drugs, and colourists. Many also attended public meetings of such trade and professional associations as the Society of Dyers and Colourists at Bradford, the Society of Chemical Industry at Manchester, and the Royal Society of Arts in London, sometimes to keep them informed in order to safeguard commercial interest and at other times out of sheer curiosity. They were exposed to debates on the state of research on indigo, all of which had emerged in the field of chemistry.

The planters launched a search for an appropriate scientist for their laboratory to be set up in India. In September 1898 the planters had subscribed to a company in London called the Indigo Defence Association (IDA). One of the stated functions of the company was to collect and disseminate commercial and scientific information to help bolster the export of Indian indigo.[45] The IDA assumed the responsibility of finding a suitable candidate for the task at hand. Its representatives in London selected Christopher Rawson, a trade chemist who was well known for his credentials within the dye and textile industry in England. As a consulting chemist he had been involved with the English end of the indigo trade. Indigo imported from India was of variable constitution and colour potency. The sellers and buyers of the blue dye in British markets routinely engaged chemists to settle its price. Rawson offered his expertise for testing colour percentages. He was well versed in all aspects of indigo’s chemistry and knew well the preferences of the dyers and printers in Yorkshire. It was hoped that he would bring this understanding to the task of indigo improvement. Accepting the invitation of the IDA, Rawson headed for India to lead the laboratory established by BIPA. Meanwhile, a group of indigo traders based in Calcutta had come together to form the Indigo Improvements Syndicate, or IIS. They took the initiative to hire another English agricultural chemist, E. A. Hancock, who reached India in 1899.[46]

The Imperial Institute in London, while not responsible for the commencement of chemical experiments in India, soon after sent an important scientific report that affirmed the appropriateness of the chemical approach. Historian of metropolitan science, Michael Worboys, has noted the credentials of the Imperial Institute during this period as a ‘natural products research laboratory’ for the whole Empire. The Scientific and Technical Department at Imperial Institute came into existence in 1895 and became increasingly involved in investigating the commercial potential of plants, plant-products, and minerals of the ‘Empire’. [47]The traders at the Indigo Improvements Syndicate in Calcutta asked for the favour of Britain’s Board of Trade in early 1900 asking its counsel towards clarifying the exact nature of competition with synthetic indigo and also how best to organize the scientific efforts in India. Given the strengths of Imperial in carrying out such investigations, the Board of Trade solicited the opinion of experts there on planter’s query. Renowned chemist, Wyndham R Dunstan headed the Science and Technology Department here. His report, submitted in May 1890, summed up the recommendation from the experts in England. Dunstan called for an all out scientific attack to improve plant indigo. He suggested measures to improve farming, to devise better extraction processes, and to make the final product more suitable for use by the consumers in all of which chemistry had a foreseeable role to play. The planters were persuaded by Dunstan’s suggestions and thanked him for the useful report.[48] The metropolitan government was also convinced by Dunstan’s logic, which is apparent from the fact that the office of Secretary of State in London forwarded his report to the central government in India and through them to the provincial government in Bengal recommending action.

The adoption of chemical approach also found a sympathetic reception among the Bengal administrators who, it must be pointed out, were somewhat slow in getting directly involved with indigo experiments. But provincial bureaucrats in Bengal were not oblivious to the new threat posed to the regional dye industry by German synthetic indigo. They considered various ways in which the government could provide assistance to the imperilled industry. In this early stage they set up a Sugar Committee with a brief to explore the possibility of growing sugarcane on the indigo tracts. But they also considered the possibility of providing state subsidy for initiating chemical experiments on indigo. In a letter to the Lieutenant Governor of Bengal, dated Aug 13, 1900, F A Slacke, the Revenue Secretary, the highest agricultural official in the province, thought that much good could be done to the cause of protecting the natural indigo industry, "if the Government could find the money for the employment for three years of two really good chemists". [49]

4) From Vat to Crop in the Field: Colonial Science to the Aid of the Natural Dye, 1898-1905

The planters put in place a robust scientific program to enhance the yield and purity of the natural dye. The effort was spearheaded by the establishment of five chemical laboratories and experiment stations in Bihar at Muzaffarpur (1898), Mosheri (1899), Dalsigserai (1899), Piprah (1902), and Sirsiah (1904). Some of the best experts on natural product chemistry, botany, and agronomy trained in England and Germany arrived in India to work at these stations. The planters combined in order to pool their resources in this endeavour and utilized their political capital in the colony to secure public funding for these experiments. If the science sponsored by the planters did not solve their problem in the market place, it was because the task of improving natural indigo was too difficult. In the end, it would seem that science failed the planters.

Colonial science launched into Bihar served the interests of a number of colonial groups: the indigo planters, Western scientists, and the administrators. These groups were united in their goal to save natural indigo, but their rationale for joining the fight against the synthetic indigo was fundamentally different. The financial interests of the planter-businessmen, the professional interests of the many scientists from the metropolis who published in reputed journals, presented research findings at scientific societies, and hoped to work in Britain in the future, and the stakes of local administrators were disparate. On account of their distinct purpose these actors favoured different scientific routes. The scientists too opted for a variety of approaches based on their training and their perception of the problem at hand. An emphasis on the multivalent nature of the enterprise enables capturing the complexity of colonial science in its valiant effort to save the natural dye industry.

The early phase of indigo experiments in colonial India was dominated by chemical approaches. At BIPA's laboratories, Christopher Rawson, the dye chemist from Yorkshire, applied himself to the goal of making post-harvest extractive processes more effective. Rawson was guided in his work by the dominant perspective of Edward Schunck on the chemistry of indigo. Following Schunck's conclusions in believing that the precursor of blue was an unstable compound that was prone to quickly disintegrate into wasteful substances, he asked the planters to start the oxidation process as soon as possible after fermentation. Rawson devised a new 'ammonia gas process' that involved oxidizing the steeped liquor with ammonia instead of air and conducted an experiment on refinement by heating the finished product with slaked lime at or near boiling point. But his new methods and processes did not pass beyond the experimental stage. They remained confined to the laboratory and were not scaled up for possible implementation by the planters.[50]

The experts secured a better understanding of the place of fermentation in manufacturing, but did not make any advance in terms of gaining a control over its internal processes. Both J. Bridges Lee and John Voelcker had earlier advised the discarding of the fermentation stage altogether. Rawson, however, affirmed his belief in the utility of fermentation by requesting to hire a bacteriologist with expertise in the behaviour of microbes and enzymes to work on it. But the new bacteriologist brought from England, Cyril Bergtheil, faced insurmountable impediments in gaining any further understanding of the nature of the underlying changes in fermentation. Finally he only managed to make a few suggestions to the planters about varying external conditions like the temperature and the state of acidity and alkalinity to obtain optimal yield.[51]

At the Dalsingserai indigo factory, the focus of attack was the crop, not the manufacturing cycle. In the chemical laboratory belonging to IIS here, the agricultural chemist E. A. Hancock focused on the soil and the effects of manures on its productivity. Outside the formal research program, the owner of the indigo estate at Dalsingserai, Bernard Coventry pioneered a third approach to indigo improvement. Coventry was not a chemist, nor even a scientist, but was rather identified by contemporaries as a 'practical agriculturist'. As an experienced and adept planter Coventry was able to differentiate between good and bad plant types. In the estate adjacent to the chemical laboratory he started categorizing indigo plants originating in different regions because he wished to segregate and propagate the higher yielding strains. [52]

So far colonial science clearly had not made much headway in achieving results that could be translated into steps to secure market for the natural dye. The chemists had failed in pushing the frontiers of knowledge in indigo chemistry. Despite their best efforts they were not able to improve upon the understanding of the glucoside *indican.* Bergtheil failed to isolate *indican* despite the fact that he was aware of the works of Dutch chemists Henri ter Meulen and S. Hoogerwerf published in Amsterdam in 1900 in which they had described a procedure for isolating the crystalline *indican*. Bergtheil was also unable to isolate a pure extract of the indigo enzyme. The measures that the two chemists suggested for fine-tuning manufacturing were either too complicated for implementation on an industrial scale, or offered marginal increase of yield. Planters needed drastic, not incremental, improvements to survive the competition of synthetic indigo. Writing several years later, D.J. Reid, an important planter, confirmed that Rawson and Bergtheil 'did not succeed in obtaining any important results'. Officials were speaking openly about the impatience of planters with the inapplicability of results from Rawson's experiments.[53] Coventry's agricultural trials towards the selection of more potent plants had also not yet delivered any useful insights or a concrete result. Since the indigo crop took an entire year to mature and flower the process of improvements in stock on the basis of observable characteristics was going to be a long drawn out one.

Meanwhile the colonial state became an active agent in the organization of indigo experiments and trials by providing its financial resources. At the end of 1900 planters' organizations BIPA and IIS, writing simultaneously to the provincial and central governments in India, and to the Secretary of State in London, requested that the government subsidize their indigo experiments. German competition was threatening an important industry. Under the circumstances, the planters argued, they were entitled to governmental support. They pointed to existing precedents in colonial India and in the settlements in Australia where the Crown's government had come forward to support the troubled tea and sugarcane industries. A general consensus prevailed among the different arms of the imperial and colonial government that planters deserved state support, and at the end of due consultation the administrators in Bengal communicated their favourable decision to the planters. The quantum of Bengal's financial support for indigo experiments continued to increase, and by 1903 the state became the sole sponsor of natural indigo science in colonial India. [54] Government's funding provided the administrators an opportunity to influence the program for indigo experiments as it was being laid out. The assessment by the officials at the centre and in the province as to what type of experiments would benefit the industry on the one hand and their general outlook on investment in science and their long-term policy of agricultural development in the colony were going to have a bearing on the nature of initiatives on indigo.

Support for the botanical line of investigation to improve yield gradually became more pronounced. As early as 1901, an important central government functionary, George Watt, the Reporter on Economic Products to the Government of India, implored bringing an additional focus on the plant in the field. In Watt's opinion indigo research in India had until then overly emphasized chemical experiments while ignoring the plant itself. As a trained botanist, who had been a professor of botany at Calcutta University between 1873 and 1884, he could easily see the lopsidedness of the research program. He said: ‘It is, in my opinion, a disgrace to the industry that so little should be known of the botany and agriculture of a plant upon which so much capital has been invested’. [55] Watt’s verdict that the plant itself needed additional attention very quickly descended on to the government departments, and became the guiding principle for all administrators in the short-term. The key aspect of the plant-centred program was the improvement of the local strain, *I. tinctoria* by introducing germplasm from other parts of the country and, importantly, from the Natal province in South Africa, from where current strains of indigo plant had originated. The central government arranged for the visit of the indigo planter H.A. Baily to Natal in July 1902 to procure *I. arrecta* seeds.[56] The Bengal officials funded the trip of an indigo scientist and the curator of the Calcutta Herbarium to south-eastern Punjab and the North-Western Provinces in India to explore and collect different strains of the plant.[57] The experiment station at Dalsingserai became the lead centre where efforts were concentrated in the attempt to improve the stock of local plant varieties.

Research on indigo from 1903 to 1905 was organized at Dalsingserai and Sirsiah stations. It is difficult to miss a weakening in enthusiasm among the central government officials for the indigo experiments. During the period they prominently pursued their favourite project to start colonial India’s first and leading agricultural research institute at Pusa in Bengal. This central station was to undertake a comprehensive research, education, and outreach programs covering all crops including indigo. The officials actually refused to provide support to the Dalsingserai station for exclusively pursuing indigo experiments, instead proposing to absorb the existing experiments there into the forthcoming central institute. [58] Such an approach from the centre came in the wake of the declining economic importance of the colonial industry to the imperial economy. The scope of indigo export to from India had come down to one-fourth of the peak level in 1895-96. However, despite its reduced size the industry was still important enough at the regional level. Thus the Bengal administrators remained the staunchest supporters of the indigo experiments. When the owners of the Dalsingserai estate expressed their inability to spare their factory lands for the continuation of experiments and trials after 1903, the Bengal officials came forward to arrange the site for a new indigo station at Sirsiah.

Within this overall context of the diminishment of the natural indigo industry in India, work on indigo improvement largely turned towards the plant. Key advance was made at Dalsingserai in terms of success with a new, higher-yielding, foreign variety of indigo procured from abroad – Java indigo. By the middle of 1903 the experimenters at Dalsingserai, prominently Coventry and a new botanist, H.M. Leake, were confirming that Java indigo (*I. arrecta*) was capable of consistently giving a 50% higher yield than the native variety (*I. tinctoria*). Some work remained towards fully acclimatizing the foreign variety to the local climate and soil. However, the researchers were energetically pursuing those goals, and felt reasonably confident of achieving them. This was the most drastic improvement in yield ever promised since the challenge of synthetic indigo first arose. The news of Java's promise stirred up euphoria among the planters in Bengal who urged all experts to focus exclusively their efforts on acclimatizing and improving the new plant variety. Coventry, Leake, and from 1905 onwards, Bergtheil at Sirsiah, did precisely that. Bergtheil, by now holding the influential post of the Imperial Bacteriologist in the colonial administration, had become a convert to selection and hybridization experiments in the field, saying, 'This is a most important aspect of … work, and perhaps the direction in which the chief hope of permanent assistance to the industry lies'.[59]

There was one exception to this general trend in the conduct of indigo experiments along agricultural lines. William P. Bloxam, a chemist at Dalsingserai, continued to work on improving the chemistry of indigo manufacturing between 1903 and 1905.[60] Bloxam also believed that the chemists' primary task was to maximize the percentage of recoverable colour. But, having reviewed the works of his predecessors, he concluded that the appropriate approach to the problem lay in first establishing the total colour that could be obtained from any specimen of green indigo leaf. Then, in order to record at which stage in manufacturing the losses in recovery were taking place, one needed to check accurately the output of dye at different stages in the manufacture of indigo. His analytical explorations did not stop there. Bloxam's strategy towards deriving the theoretical values of recoverable and recovered colour in turn encouraged him to analyze the accuracy of tests being used to measure colour percentages. He later submitted in his report that the 'potassium permanganate' test then used to measure colour percentages in India and England was "altogether useless and misleading".

The colonial patrons terminated Bloxam's contract in India, forcing him to secure re-employment in the metropolis where he went on to complete his line of investigation. Bloxam submitted to Bengal in 1904 that he was on the verge of a major scientific finding that would not only enable natural indigo to win its battle against the synthetics but also bring prestige to the colonial officials as sponsors of first-rate scientific work. On these grounds he requested the officials for an extension of his tenure at the Indian indigo laboratories, but failed. The planters in Bengal were also clearly dissatisfied with Bloxam's experiments. They saw Bloxam's pursuit of accuracy as a goal distant from their immediate objective of yield improvement and cost reduction in the market. The common intransigence of Bengal officials and planters led to Bloxam's exit from India. Meanwhile the metropolitan chemists like William Ramsay interceded on Bloxam's behalf.[61] They praised the quality of Bloxam's work and argued that he merited support because his research had potential benefits for the future. The British imperial government saw wisdom in inviting Bloxam to the University of Leeds where he could pursue and explore his characteristically advanced questions. Clearly, the metropolitan government had confidence in Bloxam's line of query and thought that if pursued in a metropolitan setting, it had the potential to reverse the fortunes of colonial indigo and win back for imperial Britain its prior dominance in the blue dye trade. The banishment of Bloxam from India puts into relief the disparity in the conditions between the metropolis and the colony for undertaking complex scientific experiments. It is not that Bloxam's experiments at Dalsingserai were unworthy of support. Rather, the colony was an unsuitable place for science of that nature. Bloxam's science was purged from the colony because it did not promise to make natural indigo profitable in the short-term, but more importantly because it could not be completed under the resource-poor colonial conditions.

5) Emerging Tensions between Colonial and Imperial Science, 1905-1908

The bid to scientifically improve indigo were made, increasingly, in a context of a drop in consumer demand in the metropolis, divestment by the indigo manufacturers in India, and a change in the cultivation pattern on the Bihar plantations. The export of plant indigo declined sharply in the decade after 1897 because of the loss of cotton printing market, the single largest component of the dyeing and printing market. Most cotton printers in the West quickly switched to synthetic indigo showing their strong preference for the purity of the artificial colorant. Natural indigo would never win back this segment of ‘purity-conscious’ consumers. The colourist John Lightfoot of Broad Oak, the leading print works in the Yorkshire region, reminisced, ‘It was not until August 17th, 1897 [that] we had our first sample cask of BASF artificial indigo. The price was 1/7 [1s. and 7d.]. On March 1st 1900 is the last mention of natural indigo and after that until the war in 1914 to 1918 we used nothing else either for dyeing or printing but BASF or M L&B’s indigo’. [62] Other printers in the region and elsewhere likewise deserted the natural blue. The attenuated consumer demand for natural indigo up to World War I was constituted by niche sectors like woollen dyeing where the natural dye was preferred due to technical reasons. In other market segments dyers were known to mix a small amount of Bengal indigo with synthetic indigo in order to improve fastness or in order to get the typical coppery red tinge imparted only by the natural product. Besides fashion and taste, nostalgia for the ‘real’ dye kept a few consumers faithfully attached to the garments dyed with natural indigo. Intervening in the market, the British national government also provided minimal protection by decreeing that naval uniforms be dyed with the natural product.[63] This regulation remained in place until 1908.

The loss of consumers in the West caused financial loss to the indigo manufacturers in colonial India and made them withdraw their capital from the industry. Gilanders, Arbuthnot and Co., a major managing agent for the indigo factories in Bihar, incurred a severe financial loss on their indigo operations following the introduction of synthetic indigo. [64] Since the mid nineteenth century the company had financed scores of indigo factories and were the proprietors of several of them. As the threat of synthetic colorants refused to go away the company 'decided to clear out of indigo altogether'. They sold off their interests in one indigo factory after another. In 1906, they put up for

Table 3
Quantity and value of indigo exported from India, 1906-1913

Year	Export from Calcutta	Total export from India	Average price / cwt in London in £-s-d	Total value of export in £
1906-07	19,309	35,102	20-6-0	467,000
1907-08	16,627	32,490	20-1-4	425,000
1908-09	17,698	24,946	20-10-8	327,000
1909-10	11,221	18,061	20-1-4	234,500
1910-11	10,985	16,939	20-15-4	223,500
1911-12	14,556	19,213	20-2-1	251,200
1912-13	9,229	11,857	17-10-0	146,730

Source: Review of the Trade of India in 1911-12 & 1912-13 [65]

sale their last indigo factory for as little as one tenth of its actual value representing a trend of massive divestment by the indigo manufacturing interests. [66]Planters' land holding rights were surrendered to the Indian landed interests from whom they were acquired in the first place. Many of the planters went back to England or re-located themselves elsewhere in the Empire. The economic historian of colonial India, Amiya Kumar Bagchi has also drawn our attention to the process of large-scale conversion of European indigo factories into sugar factories during these years.[67] The recalibration of demand and supply levels for indigo is reflected in the overall trade figures (Table 3).

The Bihar planter was no longer the archetypal ‘indigo planter’ of the previous years who produced exclusively for the indigo market. A good number of the remaining planters had begun raising multiple crops on their plantations. The chance of winning back the bulk printing market in the West was negligible. Despite the best efforts by the planters to keep costs down the price of natural indigo on an average was 35% higher than that of synthetic indigo on a unit-to-unit basis in the pre-World War years,[68] and there were buyers available at that price. Under the circumstances the planter tried to produce indigo as cheaply as possible for what remained of the market. The need for scientific expertise remained as any lowering of cost would possibly bring more buyers. At the same time in order to keep his plantation profitable as well as to distribute risks in face of volatility of indigo market the planter combined the cultivation of indigo with sugar, tobacco, flax, and other crops. Writing the history of the Bihar Planters’ Association, its Secretary T.R. Filgate admitted that ‘the planter of to-day is more of a general farmer than a specialist in indigo only’. Even the Bihar Indigo Planters’ Association dropped the word ‘indigo’ from its name in 1905, to be henceforth called the Bihar Planters’ Association. The organization was also restructured to have separate standing committees for ‘indigo’, ‘sugar’, and ‘other crops’ in order to reflect the current reality where the planters had stake in several crops and his sole dependence on natural indigo was a thing of the past.[69]

Meanwhile the nature of indigo agriculture on the Bihar plains changed with the growing cultivation of the Java variety of indigo plant (*I. arrecta*). In many ways the introduction of Java indigo into Bihar was a crowning achievement for the colonial efforts undertaken in the shadow of the synthetic’s competition. The seeds obtained from south-east Asia and South Africa were painstakingly acclimatized at Dalsingserai and then at Sirsiah. Cultivation of the new variety by the planters started in 1904 and it immediately caught their fancy as yields from the foreign variety were clearly above those from the native variety on Bihar’s agricultural tracts. According to one note the new species gave yields as high as 12 to14 *seers* an acre compared to the average yield of 8 *seers* an acre by the *sumatrana* variety (1 *bigha* = 0.87 acre; 1 acre = 0.4 hectare). [70]As a result the expansion of Java indigo was remarkable. At one of the major indigo factories in Belsand, planter D.J. Reid increasingly turned to the Java variety in the years from 1905 to 1908 and consistently obtained appreciably higher yields on his estate. Indeed many planters in colonial India believed that Java indigo was going to be their weapon in reclaiming their market. [71]

Increased cultivation of Java indigo brought a renewed demand on the experts in colonial India to expend all their efforts towards acclimatizing the new strain and establishing appropriate cultivation practices for it. The experts at Sisrsiah, led by Cyril Bergtheil, responded well to this call. One area of effort at Sirsiah was directed at perfecting best farming practices for the Java plant. Secondly, Bergtheil actively collaborated with a fellow jute expert, R. S. Finlow, and an Indian plant expert, D. L. Dey, on the problem of hard seed coat that was known to interfere with the process of germination of Java plant in the Indian conditions. Bergtheil and his associates suggested treating Java seeds with concentrated sulphuric acid, as opposed to scarifying (physical scratching), which was the usual practice until then. In subsequent papers Bergtheil explained that the hard seed coat arose from the depositing of extra cellulose. Bergtheil suggested immersing the seeds in sulphuric acid for some time, washing, and then drying, a combination of steps that was easier and required less labour than scarifying. He established that after treatment with sulphuric acid the germination rate for the *I. arrecta* variety went up from 3% to 95%.[72]

Additional scientific efforts were channelled towards selecting better varieties of the Java and s*umatrana* plant. For some time the planters and their experts at Sirsiah had weighed the possibility of bringing a new botanist to the station who could contribute to improving the stock of plants. It is likely that the renewed drive towards selection came out of the ‘rediscovery’ of Mendelian genetics by the European scientists in 1900 that had raised expectancy worldwide about the increase of yield from plants through controlled breeding. [73] Planters requested the government officials to search for an appropriate scientific expert at home. In fact when there was some delay on part of the officials, the planters took the initiative to find out a botanist, Alexander Turnbull, who joined Sirsiah in the summer of 1906.[74]

In contrast to the scientific efforts centred on the plant in India, Bloxam's experiments in the metropolis concentrated on resolving complex analytical questions relating to the manufacturing cycle of the natural dye. Bloxam's work at the University of Leeds between 1905 and 1907 marked an excellent advance in the knowledge of indigo chemistry. The chemist followed the threads of experiments he had previously conducted at Dalsingserai in India. In the metropolitan setting, he had far superior access to scientific information. Furthermore, Bloxam actually obtained samples of plant extract, *indican*, and indigo enzyme from scientists in the Netherlands, all of which aided his analytical work. Bloxam put his energy towards devising more accurate tests for measuring the output of colour at different stages of manufacture in order to settle the question of efficiency of the indigo manufacturing process in India. Bloxam's tetra-sulphonate method, which promised a higher level of accuracy in indigo testing, was first proposed at the meeting of the Society of Chemical Industry in August 1906. In January 1907 Bloxam proposed an alternative 'isatin method' for accurately and reliably estimating the colour-yielding ability of indigo leaf. [75]

Armed with accurate tests Bloxam declared that a huge loss of colour was taking place during the manufacture of dye in India. His study indicated that the amount of colour-giving glucoside in the natural indigo leaf was 0.6% by weight and not 0.3% as believed earlier. [76]His precise tests also showed that the indigo cakes manufactured by common Indian operations had a low colour percentage of 60.3% to 61.9%. Earlier the scientists in India had believed that the current manufacturing processes were effectively taking out most of the colour present in the plant. Now Bloxam's results questioned that certitude.

The results of Bloxam's experiments completed at the University of Leeds were considered meritorious achievements of imperial science. Detailed exposition of his experiments and their results found their way into the most prestigious science journals in the metropolis. The reputable Nature magazine also celebrated these scientific findings. Citing the study as credible evidence, the natural dye protagonist A.G. Perkin asked indigo scientists in the colony to re-focus their attention to manufacturing. [77]

But despite the evident usefulness of Bloxam's results and their celebration in the metropolis, the indigo experiments in colonial India continued to have a primarily agricultural orientation. A combination of factors conspired to keep Bloxam's findings in shadow. On 20 February 1909 Raphael Meldola, a prominent British chemist, was invited to offer his opinion on the matter of continuation of Bloxam's experiments to the Indian Government Advisory Committee of the Royal Society in London. While Meldola agreed that the results of Bloxam's experiments were worthwhile and that it clearly seemed that the natural indigo industry had a glimmer of hope, he did not favour the continuation of any more analytical work of the type Bloxam was pursuing. Referring to Bloxam's results Meldola elaborated that the end of the matter was not reached when the most perfect of analytical processes had been devised. Meldola put the onus of responsibility on the planters, stating that it was for the planters now to get to the bottom of the matter while investigating at which point and to what extent potential colour was being lost. The business community also had to determine, Meldola argued, if it was possible to plug the holes in the manufacturing processes and recover the extra *indican* whose existence the new tests had predicted. It was one thing to prove analytically in the laboratory that the indigo plant could yield more colour and quite another to recover that extra colour on a manufacturing scale by using available capital and technology. [78] That did not happen.

In a way Bloxam was also trying to turn back the clock for indigo science in colonial India. The scientists in India had moved on to agricultural and botanical lines of investigation after 1905. The high yield of the new Java variety of plant provided hope for results from such experiments. Now Bloxam was imploring the scientists in India to return to chemical experiments without suggesting a concrete way of recovering the extra *indican*. That was the context in which Bloxam's findings faced resistance in India.

The policymakers in colonial India did not put their weight behind the research possibilities opened up by Bloxam's findings. The administrators were hearing conflicting voices. Imperial bacteriologist in India, Cyril Bergtheil, refuted the findings of Bloxam. The administrators believed the interpretation provided to them by their own bacteriologist. They repeatedly stressed the point that Bergtheil was 'the man on the spot', and therefore would know better. The administrators found a majority of planters solidly united in demanding agricultural experiments in the field rather than chemical experiments in the laboratories. The bureaucrats decided to go with the reasoning of the planters whose welfare was the rationale for the government's funding of indigo experiments. In England, the officials at India House refused to renew Bloxam's contract. Bloxam was deeply distressed over the fact that planters in India did not implement his conclusions. [79]

6) Declining Patronage of Science in the Pre-War Years

Sometime during the period from 1907 to 1909 the British national government changed its policy towards the supply of synthetic and natural indigo into the metropolis. Since 1897 the German companies had continuously expanded their production of synthetic blue and captured additional markets in the West. Before the turn of the century BASF and Hoechst moved beyond Germany and set up manufacturing base for artificial indigo in France. In 1908 CIBA in Switzerland joined the ranks of BASF and Indigo GmbH as the world's third major supplier of synthetic indigo. The British dye manufacturers had long demanded the reforming of the patent laws in order to prevent the German dye companies from carrying out 'blocking patents'. It was argued that through patenting manoeuvres the Germans had stifled all national effort at manufacturing synthetic indigo. Responding to the demand from indigenous industrial groups the government undertook regulatory steps to rectify the situation. Consequently a new Patent Act came into effect in Britain in 1908 that mandated the German companies to work their British patents in the country or face revocation. These regulations only led to the German MLB (Hoechst) setting up a factory at Ellesmere Port in England. Production at this foreign-owned facility started in 1908 and its output of synthetic indigo rose from 9 tons in 1908 to 293 tons in 1913, [80]whereas the attempts to indigenously produce synthetic indigo failed. Meanwhile the national government's support to indigo planters seems to have run its course. In 1908 the government withdrew its earlier regulation that had made the use of natural indigo mandatory for dyeing naval uniforms. The government was acceding to the naval department's request to allow the use of cheaper synthetic indigo to cut costs. But the step also reflected the conviction of the metropolitan government that the planters had been afforded support for a sufficiently long time.

In India, the support of the central state to indigo industry came in the form of patronage of scientific experiments at the Pusa Institute. The imperial government's program for agricultural research and development in the colony had matured by now. The Imperial Agricultural Institute at Pusa had a full complement of experts on agricultural chemistry, mycology, entomology, agri-horticulture, and economic botany. While the primary responsibility for indigo research was deferred to the experts at BIPA's Sirsiah station, the central government scientists at Pusa continued to provide input on indigo experiments whenever needed.

The provincial Bihar government remained the primary supporter of indigo experiments during the period even though the scale of its financial commitment was reduced. The backing by the local administrators to indigo was in keeping with the reduced importance of the colonial product in the wider imperial-colonial world and its new stature as a local industry. The Bengal officials firstly bargained with the centre that Cyril Bergtheil, now colonial India's Imperial Bacteriologist, be relieved from his duties at Pusa to lead the planters' indigo laboratory at Sirsiah. Secondly, they committed public funds for the next five years towards the conduct of indigo experiments. At the same time they persuaded the planters to pledge resources for the ensuing scientific work at Sirsiah.[81]

The Java variety of indigo took centre stage in the subsequent program of scientific improvement by the botanists at Sirsiah and Pusa. As a variety that had shown initial promise it appeared to be the right candidate for their attention. A new botanist at Sirsiah, F.R. Parnell applied his knowledge of plant physiology to investigate the basis of formation of *indican*. He utilized ‘sand cultures’ to monitor the plant’s metabolism and to gain an understanding of processes leading to the deposition of the glucoside. Parnell also supervised a second round of selection trials at Sirsiah. He discovered firstly that indigo plants normally cross-fertilized, and then identified the insect vectors that aided pollination among the plants. But aside from these early discoveries no concrete results were obtained through the botanical program for improvement.

The remaining scientific efforts could not measure up to the task of resolving a new problem that beset indigo agriculture in Bihar. Java indigo in Bihar suffered from a major incidence of wilt in 1909 leading to a large-scale crop failure. Thus the new high-yield foreign variety had seemingly hit a roadblock even before its full potential could be realized in Bihar. The severity of wilt accelerated in the following years reaching a crisis proportion. Wilt received the undivided attention of experts at Sirsiah and Pusa but to no avail. Meanwhile the destruction of crops was widespread. In addition, wilt affected the production of Java seeds causing widespread shortage, and forcing the planters to revert to growing the *sumatrana* variety. [82] Under the circumstances the planters were completely despondent and asked that the Sirsiah Station be closed down from March 31, 1913. [83]

As on the earlier occasion, colonial science failed the planters again in the pre-War years. The scientific improvement of indigo to beat market competition in the colony had always proved to be difficult. Reduced patronage during this period added to the normal constraints of working under colonial conditions. The breeding program for indigo did not get a fair chance to prove its efficacy. The success of breeding program for sugarcane in the West Indies, for example, was based on generous commitment of funds and personnel consistently as well as comprehensive state support on a long-term basis.[84] In the absence of early success on the biological front no such support was made available to the natural dye. The experts suspended their work on breeding to focus on solving the problem of wilt. But the new disease continued to confound the experts at Sirsiah and later at the Imperial Agricultural Institute in Pusa without being resolved in the end.

7) Concluding Remarks

The sponsorship of research to improve the natural dye transpired in response to many forces in imperial Britain and colonial India. The priorities of the interest groups across disparate nodes were overlapping but non-identical. It is true that the colonial administrators, scientists, and planters belonged to the same political 'class' even if their acts were not always in harmony. Many of them also belonged to the same social group. For instance, the planters had social and personal ties with each other and with members of the Indian Civil Services under the Raj that extended within their networks back in the home country. But there were also countervailing interests at work that generated conflicts between them. Many factors complicated the synergies between the process of governmental decision-making and the requirements of indigo business in colonial India. It is indeed in calling everyone simply a 'colonialist' that the Colonial Studies literature on the history of science in South Asia misses an opportunity to capture the complexity of factors at work. For instance, such formulations do not account for the difficulty that the planters encountered in persuading the administrators to subsidize their indigo experiments. Nor do they capture the spirit of public policy measures leading to the establishment of the Pusa station where a comprehensive agricultural research, education, and outreach program was inaugurated in 1905. If one were to focus on the colonial actors in India, it is apparent that the science of indigo improvement in colonial India evolved on account of the economic, political, and professional self-interest of many actors: planters wanting to maximize profits and maintain the viability of their industry in the face of a new technological challenge; colonial administrators intent on finding a balance between support to the indigo industry and overall agricultural development; professional scientists keen to explore challenging issues in the chemistry of indigo production, in fermentation, and in the breeding of plants. The indigo science resulting at these colonial stations truly reflected these underlying tensions and their fundamental unity.

Among the forces that patronized the science of indigo improvement it is the planters who have borne the brunt of blame for the apparent ‘failure’ of natural indigo against synthetic indigo. Most of these criticisms came from metropolitan scientists or the interests associated with the dye trade in Britain. Thus, writing in 1900, F.M. Perkin, son of the prominent mauve inventor William Perkin, begrudged what he considered the reluctance of the planters in using science to improve production as against massive investment by their German competitors: ‘Will Indian manufacturers [i.e. the British planters in the colony] never lay out capital in scientific investigation? Will they *never* realise that money so laid out is almost certain in the near future to bring in a rich return?’ Some other opinions utilized inappropriate frameworks for drawing comparison. Disregarding the reality of an agricultural, plantation-based production system they critiqued ‘paltry’ investment by the planters as against investment to the tune of hundreds of thousands of marks by the manufacturers of synthetic indigo in Germany. Still other commentators were oblivious of the intricacies of the scientific program undertaken to improve indigo in India.[85] The barrage of attack followed again in 1908-09 after the publication of Bloxam’s report criticizing the planters for their neglect of what was seen as important scientific evidence emerging from the metropolis. [86]Such was the force of this rhetoric that the head of planters organization, T.R. Filgate meekly admitted that while the planters could be held guilty of inadequate attention to science in pre-1897 era, they had certainly done their best since then. Filgate was probably referring to the fact that no laboratories were set up and no chemists or biologists hired by the planters’ organization, BIPA prior to the advent of synthetic indigo. But even if laboratories were not set up, the evidence assembled in this study illustrates the open mindedness of planters to the use of scientific and technological principles in agriculture and manufacturing. Filgate defended the position of planters in not resuming manufacturing experiments based on Bloxam's conclusions of 1908. Most importantly, he also pointed out that the application of scientific methods in combination with the planting of the new variety of indigo had enabled the planters to produce natural indigo 'at half its former cost'. [87]But apparently even that was not sufficient to beat the competition of synthetic indigo.

Going against the rhetoric of above metropolis-based criticisms this paper has depicted the agricultural classes as persistent in their patronage of science. The earlier historiography had denied an agency to the planters who were mostly represented either as 'colonial exploiters' or as 'profiteers' who looked for short-term gains while operating a backward, agricultural system of production. On the contrary, this paper has argued that the planters' decisions regarding deployment of scientific principles and sponsorship of laboratory research appear perfectly rational on a consideration of their problems and priorities. Faced with the challenge of German dye the planters mobilized financial and political resources to rack up the best science available at the time. To their credit they survived the German challenge for a while, and kept all round optimism alive about the prospects of the natural dye. In the end even their best efforts failed to save the natural indigo industry. However synthetic indigo was victorious despite the deployment of science by the planters. They were certainly not anti-science or innately conservative, as the current historiography would lead us to believe.[88]

[1] M. Wilson, *Reminiscences of Behar*, Calcutta, 1908, 105.

[2] Wilson, op. cit. (1), 123, 125, 135, 149, 180-82, 192, 197, 211.

[3] In the earlier period, Europeans of all nationalities set up plantations on the indigo tracts. But as the industry picked up momentum the mercantile state and the British planters effectively kept out other Europeans whom they called 'interlopers'.

[4] B. Chowdhury, *Growth of Commercial Agriculture in Bengal, 1757-1900*, Calcutta, 1964.

[5] B. B. Kling, *The Blue Mutiny: The Indigo Disturbances in Bengal, 1859-1862*, Philadelphia, 1966.

[6] Wilson provides a list of the names of planters who joined the Bihar plantations from 1820 to 1905, although the list is not comprehensive, cf. Wilson, op. cit. (2), 15-18. It should also be mentioned that other regions in the subcontinent, in particular Madras, Punjab, and the North Western Provinces also produced and exported the dye. But 'Bengal indigo', manufactured under the supervision of Europeans, far exceeded them in importance. It was the best quality colour that was exported out of India and far exceeded other varieties in terms of value. Synthetic indigo displaced Bengal indigo whereas small, insignificant quantities of other varieties continued to be exported to cater to lower ends of the Western market and the local market.

[7] Government of Bengal, Revenue (Agriculture), October 1900, File 2-1/3, Nos. 3-32, No. 10. These files of the colonial government in the province are located at the Bihar State Archives in Patna (India). Henceforth, these files are simply referred to as 'Bihar State Archives, Agriculture'.

[8] W.W. Hunter, *A Statistical Account of Bengal, Volume XIII, Tirhut and Champaran*, London, 1877, 163.

[9] A review of the engagement of Calcutta based British financial interests with colonial indigo manufacturing appears in S. Chapman, *Merchant Enterprise in Britain: From the Industrial Revolution to World War I*, Cambridge, 1992, 107-128. In the earlier part of the nineteenth century they together provided credit to the tune of £1.2-2 million to the indigo planters (on 112). More detailed discussion of the bankers and agency houses for the first half of the nineteenth century can be found in A. Tripathi, *Trade and Finance in Bengal Presidency, 1793-1833*, Calcutta, 1956; S. B. Singh, *European Agency Houses in*

Bengal, 1793-1833, Calcutta, 1966. A brief reference also appears in A. K. Bagchi, *Private Investment in India, 1900-1939*, Cambridge, 1972, 161-162.

[10] Wilson provides details of the rich social life of the planters in his book, including their food and wine, sprawling houses and servants, recreation at clubs, their parties and hunting expeditions. cf. Wilson, op. cit. (1), 112, 114-120, 123, 144-148, 157-159, 144-148, 175-179, 185-189. John Beames provides specific information on the education of sons and daughters of rich planters at reputed public schools on hills and elsewhere in India. cf. J. Beames, *Memoirs of a Bengal Civilian*, London, 1961, 148-149. Another planter, James Inglis has described in his two books hunting and other sports that the planters indulged in. cf. J. Inglis, *Sports and Work on the Nepaul Frontier Or Twelve Years Sporting Reminiscences of An Indigo Planter*, London, 1878; *Tent Life in Tigerland, Being Reminiscences of a Pioneer Planter in an Indian Frontier District*, London, 1888. In short, while it is true that the indigo work in tropical climate was arduous, the European planters were seemingly coping well. Overcoming their nostalgia for home they were invested in a quality life they were leading locally, and were willing to defend it.

[11] The calculation of loss to Indians as a result of the decline of the natural indigo industry is a tricky business considering that for much of the nineteenth century most Indians were opposed to European planters and their plantations. Along those lines, this paper considers the disadvantages of ruination of natural dye industry at the end of the nineteenth century to 'colonial economy' rather than to 'Indian economy'. The industry's creation of employment for Indians needs to be assessed carefully. cf. I. Ray, 'The indigo industry in colonial Bengal: A re-examination', *The Indian Economic and Social History Review* (2004) 41: 2, 199-224. Ray contends that before 1830 the industry provided employment to a total of 1.36 million people. But after that period the industry brought an overall financial loss to Indians in addition to inviting violence and associated social and financial costs (on 224). For the earlier part of the nineteenth century it may be fair to say that the industry created gainful employment for Indians. But after the first quarter of the nineteenth century Indians were generally 'forced' to cultivate indigo on their best land; the native growers would have preferred to put their best agricultural plots to other crops that were more remunerative. In the late nineteenth century the opposition to indigo had clearly nationalist overtones. Indian indigo growers couched their opposition to planters as 'peasants', but increasingly as 'Indians'.

[12] The socio-economic factors behind peasants' discontent are described in J. Pouchepadass, *Champaran and Gandhi: Planters, Peasants and Gandhian Politics*, Delhi, 1999, 107-115, 122-127; the peasant rebellions erupted later, 144-166.

[13] Chowdhury, op. cit. (4); Kling, op. cit. (5); P. K. Shukla, *Indigo and the Raj: Peasant Protests in Bihar, 1780-1917*, Delhi, 1993; Pouchepadass, op. cit. (12).

[14] For a representative sample of such an account, see D. Kumar, *Science and the Raj, 1857-1905*, Delhi, 1995, see especially the section on plantation research, 152-8; see also D. Kumar, 'Science in agriculture: A study in Victorian India', *Asian Agri-History* (1997), 1: 2, 77-103, on 87-92.

[15] P. Reed, 'The British chemical industry and the indigo trade', *British Journal for the History of Science* (1992), 25, 113-25, on 116. It is worth underscoring that the generally triumphalist narratives of the victory of synthetic dyes over natural dyes creates an inclination to put forth interpretations in which the planters and plantations are depicted as standing in the way of the forward march of science and technology.

[16] Most such proclamations are value judgements, certainly not valid empirically nor useful to the task of interpretation and concept formation.

[17] A. L. Stoler, 'Rethinking colonial categories: European communities and the boundaries of rule', *Comparative Study of Society and History* (1989), 13: 1, 134-161; A. L. Stoler and F. Cooper, 'Between Metropole and Colony: Rethinking a Research Agenda', in F. Cooper and A. L. Stoler (ed), *Tensions of Empire: Colonial Cultures in a Bourgeois World*, Berkeley, 1997, 1-56, especially see a synopsis on 4.

[18] Stoler cites two articles by David Arnold as notable exceptions to this trend. D. Arnold, 'European orphans and vagrants in India in the nineteenth century', *The Journal of Imperial and Commonwealth History* (1979), VII: 2, 104-127; 'White colonization and labour in nineteenth century India', *The Journal of Imperial and Commonwealth History* (1983), XI: 2, 133-158.

[19] Chowdhury, op. cit. (4), 80-124, especially see his summation on 123-124; Pouchepadass, op. cit. (12), see 49-58 for a description of manufacturing labour, 127-136 for his analysis of appropriation of surplus from the peasantry, and 65-66 for a summation of his critique of the primitive characteristic of cultivation and manufacturing.

[20] P. P. Courtenay, *Plantation Agriculture*, London, 1965, 1-49.

[21] W.M. Reid, *The Culture and Manufacture of Indigo with a Description of a Planter's Life and Resources*, Calcutta, 1887, 130.

[22] J. A. Voelcker, *Report on the Improvement of Indian Agriculture*, Delhi, 1986, first published, 1893, 222, 236, 257-266, quote on 257.

[23] Voelcker, op. cit. (22), p. 257.

[24] Voelcker, op. cit. (22), p. 259.

[25] Voelcker was not appreciative of everything. He was critical of the type of efforts the planters had made towards ascertaining the best sowing methods or selecting the best combination of manures. It was not sufficient that the planters had tried one plan or the other in a particular year and then on not finding it advantageous given it up. Voelcker sought exactitude in recommending that the trials be conducted on small experimental plots side by side and a definite conclusion be arrived at. But his criticism in this regard was directed at the agriculturist classes in general who in his opinion did not diligently follow through agricultural experiments and their results, and found the dereliction of indigo planters comparable to that of 'the average good English farmer'. cf. Voelcker, op. cit. (22), 261.

[26] W. V. Farrar, 'Edward Schunck, F.R.S. a Pioneer of natural-product chemistry', *Notes and Records of the Royals Society of London*, (Jan., 1977), 31: 2, 273-296, on, 273, in *Chemistry and the Chemical Industry in the Nineteenth Century: the Henrys of Manchester and Other Studies*, (ed. R. L. Hills and W.H. Brock), Aldershot, Brookfield, 1997.

[27] In 1883, Adolf Baeyer in Munich elucidated the modern chemical structure of indigo, but, given the context of industrial secrecy around the finding, this information had no immediate impact on the study of the natural product. This is described later. For the review of developments in the chemistry of natural indigo, see Arthur George Perkin and A. E. Everest, *The Natural Organic Colouring Matters*, London, 1918, p. 480; Farrar, op. cit. (26), 282-85.

[28] Pouchepadass, op. cit. (12), 49-60, Table D (not paginated).

[29] Inglis, op. cit. (10), 37.

[30] J. B. Lee, *Indigo Manufacture*, Lahore, privately published, January 1892, 25, 55, 57, 71, 99, 102-103, 106, 115-116, 134. A copy of the book is available at the Hagley Museum and Library in Wilmington (USA).

[31] Liebig's pupils and followers were instrumental in spreading the impact of Liebig's principles in Europe and the United States. cf. W. H.Brock, *Justus von Liebig: the Chemical Gatekeeper*, Cambridge, 1997.

[32] Farrar, op. cit. (26), 275-76.

[33] Reid, op. cit. (21), 1.

[34] It has not been possible to independently confirm whether Schrottky was a student of Liebig. He was popular among many planters, and had previously taught at a college in Bombay. He claimed a long interest in the chemistry of indigo.

[35] "The First Schedule," Incorporation papers of the Bengal Indigo Manufacturing Company, Public Record Office Kew (England), Board of Trade Papers, BT 31/4628/30398/100052; "The Second Schedule," Incorporation papers of the Bengal Indigo Manufacturing Company, Public Record Office, Kew (England), Board of Trade Papers, BT 31/4628/30398/100052. Henceforth referred to as 'Public Record Office'.

[36] Public Record Office, BT 31/4628/30398/100052.

[37] Voelcker, op. cit. (22), 261-265.

[38] The large body of research in the field of sociology of scientific knowledge inspires the notion of 'discontinuous science' used here.

[39] Voelcker, op. cit. (22), 264.

[40] Inglis, op. cit. (10), 37.

[41] J. B. Lee joins J. A. Voelcker in warning the planters to be wary of the 'charlatans.' cf. Lee, op. cit. (30), 55, 47.

[42] The best depiction and analysis of this historical process appears in A. Travis, *The Rainbow Makers: The Origins of the Synthetic Dyestuffs Industry in Western Europe*, Bethlehem, 1993; and C. Reinhardt and A. Travis, *Heinrich Caro and the Creation of Modern Chemical Industry*, Dordrecht, 2000.

[43] C. Reinhardt and A. Travis, op. cit. (42), 187-188.

[44] *Government of India: Review of the Trade of India in 1906-06*, by Frederick Noel Patton, Director General of Commercial Intelligence, Calcutta, 1906, 36.

[45] Incorporation papers of Indigo Defence Association Limited, Public Record Office, BT 31/8154/58924/100052.

[46] Little information is available on E. A. Hancock's training. But we can infer from Hancock's reports that he was an agricultural chemist. Hancock's work in India mostly comprised testing soils and assessing the impact of addition of manures on soil chemistry and plant growth.

[47] M. Worboys, 'The Imperial Institute: The State and the Development of Natural Resources of the Colonial Empire, 1887-1923', in *Imperialism and the Natural World* (ed. J.M. Mackenzie), Manchester, 1990, 164-186, on 170-171.

[48] For Dunstan's report see Bihar State Archives, Agriculture, October 1900, File 2-I/3 3-32, Nos. 11-12; Letter from Begg, Dunlop and Company in London to W. R. Dunstan, dated June 25, 1900, Public Record Office, AY4/2047/100168.

[49] For Slacke's letter see Bihar State Archives, Agriculture, Notes and Orders, File 2I/3, Nos. 3-32, October 1900.

[50] "Mr. Rawson's Report No. 1," 14 July 1898; "Mr. Rawson's Report No. 2," 19 August 1898; "Mr. Rawson's Report No. 3," 26 September 1898; Rawson's report to the Indigo Defence Association Limited, 31 July 1899, 1; Rawson's Report to the Indigo Defence Association Limited, 6 February 1900 (referring to experiments of the previous year), 3, Bihar State Archives, Agriculture, File 2I/3, March 1900; Rawson's letter to BIPA, 16 August 1900, 1, Bihar State Archives, Agriculture, File 2I/3, March 1900; 'Notes on Experimental Work done at Peeprah during the Morhan Mahai 1902 by Christopher Rawson, dated 11 August 1902', 4-5, Bihar State Archives, Agriculture, August 1903, File 2I/7.

[51] 'Private and Confidential', Rawson's letter to the Bihar Indigo Planters Association, 4 October 1900, Bihar State Archives, Agriculture, File 2I/3, March 1901; 'Bacteriologist's Note I' by Cyril Bergtheil, 9 August 1902, Bihar State Archives, Agriculture, 2, December 1903, File 2-I/7 3; Cyril Bergtheil, 'The Fermentation of the Indigo –plant', *Transactions, Journal of the Chemical Society* (1904), LXXXV, 870–92. Much of the theoretical advance in studying fermentation with regard to indigo manufacturing was made in the Dutch metropolis. Perkin and Everest, op. cit. (17), 487-88.

[52] E. A. Hancock, Note on the Work of the Indigo Improvements Syndicate at Dalsingserai. Bihar State Archives, Agriculture, May 1901, File 2-I/3 1-7, Nos. 3(b)-3(c).

[53] See Inspector General of Agriculture, J. Mollison's notes cited in Bihar State Archives, Agriculture, December 1903, File 2I/8 3, Notes and Orders, p. 2; D.J. Reid, 'Indigo in Bihar in *Bengal and Assam Behar*

and Orissa: their History, People, Commerce, and Industrial Resources, compiled by S. Playne, (ed. A. Wright), London, 1917, 255-268, on 258.

[54] Letter from E Macnaghten, BIPA to Revenue Secretary, Government of Bengal, 7 August 1900; Response of E Lister, Revenue Under-Secretary, Government of Bengal to the General Secretary, BIPA, 8 October 1900, Bihar State Archives, Agriculture, October 1900, File 2 I/3 3-32, Nos. 13, 28; Notes and Orders, Bihar State Archives, Agriculture, May 1901, File 2 I/3 1-7; IIS's letter to the Government of Bengal, 31 January 1901, Bihar State Archives, Agriculture, May 1901, File 2-I/3 1-7, Nos. 1-2 & 3(a); Revenue Secretary F. A. Slacke's letter to the Secretary, BIPA, 27 March 1901, Bihar State Archives, Agriculture, May 1901, File 2 I/3 1-7, No. 4; Notes and Orders, Bihar State Archives, Agriculture, May 1901, File 2 I/3 1-7.

[55] G. W. Watt's letter to Secretary, BIPA, demi-official, dated, Jan 31, 1901, Notes and Orders, Bihar State Archives, Agriculture, May 1901, File, 2I/3, 1-7, Nos. 1-8.

[56] 'Natal Indigo Seeds', Bihar State Archives, Agriculture, December 1902, File 2I/6, 9-25, Nos. 1 – 19.

[57] Letter of L. E. B. Cobden-Ramsay, Revenue Under Secretary, Bengal, to Commissioner of Patna Division, 15 September 1902; letter of Superintendent, Royal Botanic Garden to Revenue Secretary, Bengal, containing the report of Captain Cage, Bihar State Archives, Agriculture, November 1902, File, 2I/11 1-5, Nos. 63-67.

[58] See central government official, Sir Denzil Ibbetson's letter to Lt Governor of Bengal, J. A. Bourdillon, dated March 10, 1903, Bihar State Archives, Agriculture, December 1903, File, 2I/8 3, Notes and Orders.

[59] Cyril Bergtheil, 'An account of the scientific investigations which have been and are being conducted in India', *Indian Planters' Gazette and Sporting News* (23 December 1905), 771-2. The holdings of this journal are located at the National Agricultural Library, Beltsville (USA).

[60] A detailed description of the work completed by Coventry, Leake, and Bloxam at Dalsingserai are available in the form of a report: W. P. Bloxam and H. M. Leake, with the assistance of R. S. Finlow, *An Account of the Research Work in Indigo, Carried Out at the Dalsingh Serai Research Station from 1903 to March 1904*, Calcutta, 1905.

[61] Letter from William Ramsay to the Under-Secretary of State for India, India House, 6 November 1904, entitled, 'Employment by the India Office of Mr. W. P. Bloxam for the purpose of carrying on further

researches regarding the methods of production of natural indigo', Government of India, Proceedings of the Department of Revenue and Agriculture for May 1905, No. 25, Serial No. 1, India Office Records, the British Library, London, (subsequently, 'Proc. Rev. & Agr.'), P/7069; Letter from A. Goldby, Under-Secretary of State for India, to Sir William Ramsay, No. R&S 2662, 11 November 1904, No. 25, Serial No. 1, May 1905, India Office Records, Government of India, Proc. Rev. & Agr., P/7069.

[62] Thomas E. Lightfoot, History of Broad Oak, unpublished typescript, 1926; located in Acrington Library, Great Britain. I am thankful to Dr Philip A. Sykas at Manchester Metropolitan University for passing along this information to me.

[63] A note in *Nature*, dated November 29, 1900 reports that 'The Government… has ordered that all blue cloth supplied to the Army and navy Departments shall be dyed with *natural* indigo.' *Nature* (November 29, 1900), 63: 1622, 112. It must be added here, that decisions regarding use of dyes were taken at the departmental level. In the end, it was only the navy that decreed the use of natural indigo, a regulation that remained in place until 1907. cf. *Selections from Despatches Addressed to the Several Governments in India by the Secretary of State in Council*, 50th Series, Part II, 1st July-31st December 1907, 379, 381-82. India Office Library, London, V/6/358.

[64] J. S. Gladstone, *History of the Gilanders, Arbuthnot & Co. and Ogilvy, Gilanders & Co.*, London, 1910, 30-31, 92-93.

[65] *Government of India: Review of the Trade of India in 1911-12,* by Frederick Noel Patton, Director General of Commercial Intelligence, Calcutta, 1912, 57; *Government of India: Review of the Trade of India in 1912-13*, by Frederick Noel Patton, Director General of Commercial Intelligence, Calcutta, 1913, 45.

[66] Gladstone, op. cit. (64), 93.

[67] Bagchi, op. cit. (9), 362-365.

[68] Reid, op. cit. (53), 258.

[69] T.R. Filgate, 'The Behar Planters' Association, Ltd,' in *Bengal and Assam Behar and Orissa: their History, People, Commerce, and Industrial Resources*, compiled by S. Playne, (ed. A. Wright), London, 1917, 268-271, on 271.

[70] Reid, op. cit. (53), 257.

[71] D J Reid, 'Ten years' practical experience of Java indigo in Bihar', *Agricultural Journal of India* (1917), 12: 1, 1-26, on 19-20.

[72] Cyril Bergtheil and D. L. Day, 'On the Cause of 'Hardness' in the Seeds of *Indigofera arrecta*', *Annals of Botany* (1907), 21: 81, 57-60; R. S. Finlow and C. J. Bergtheil, 'A Method for Producing Immediate Germination of 'Hardcoated' Seeds', *Journal of the Asiatic Society of Bengal* (1908), 3: 10, 77.

[73] Robert Olby, *Origins of Mendelism,* 2nd edition, Chicago, 1985.

[74] Letter of R W Carlyle, Revenue Secretary, Bengal, dated, December 3, 1906, to Revenue Secretary, Government of India. Bihar State Archives, Agriculture, May 1907, File 2I/2 5-6, No. 1.

[75] W. P. Bloxam, 'The Analysis of Indigo', *Journal of the Society of Chemical Industry* (15 August 1906), 25, 735-44; I. Q. Richardson, S. H. Wood, and W. P. Bloxam, 'Analysis of Indigo – Part II', *Journal of the Society of Chemical Industry* (15 January 1907), 26, 4-7; A. G. Perkin and W. P. Bloxam, 'Indican Part I', *Transactions, Journal of the Chemical Society* (1907), 91, 1715-28; R. Gaunt, F. Thomas and W. P. Bloxam, 'Analysis of indigo (Part III) and of the Dried Leaves of Indigofera Arecta and Indigofera Sumatrana', *Journal of the Society of Chemical Industry* (30 November 1907), 26, 1174-1185, on 1178-9, 1182.

[76] William P. Bloxam, *Report to the Government of India Containing an Account of the Research Work on Indigo Performed in the University of Leeds, 1905-1907*, London, 1908, 107; Modern estimates put the weight of *indican* in indigo leaves at an average 0.8%. Bloxam's findings were generally in the right direction in pointing out the availability of extra color in the leaf. cf. Travis, op. cit. (42), fn. 28, on 297.

[77] *Nature* (September 20, 1906), 74: 1925, 526; 'The Indigo Question', *Nature* (October 15, 1908), 78: 2033, 604-05.

[78] 'Memorandum by Professor R Meldola, FRS, upon the Present Position of the Indigo Question – To the Indian Government Advisory Committee of the Royal Society', Proceedings of the Indian Government Advisory Committee of the Royal Society for 1909, CMB/59. These records are located at the archives of the Royal Society, London.

[79] Bloxam's obituary notice by A. G. Perkin, 'William Popplewell Bloxam', *Journal of the Chemical Society* (1914), 105, 1195-1200.

[80] Travis, op. cit. (42), 223-227; Reed, op. cit. (15), 116-120.

[81] For sanction of Rs. 32,500 to the planters, see "Order – By the Government of Bengal, Revenue Department," Bihar State Archives, Agr., October 1909, File 2-I/3 1-7 ¾, Board's file 114 of 1909, No. 10; for reference to BIPA's commitment regarding the payment of Rs.10,000 per annum, see the letter of Director of Agriculture, Bengal, W R Gourlay's to Revenue Secretary, Bengal, dated March 31, 1909, Bihar State Archives, Agriculture., October 1909, File 2-I/3 1-7 ¾, Board's file, 114 of 1909, No. 5.

[82] For the aggravating problem of wilt, see Reid, op. cit. (71), 9-18; for wilt causing widespread shortage of Java seeds, Reid, op. cit. (53), 256.

[83] Second Annual Report of the Agricultural Department, Bihar and Orissa, 1913, p., 5, Government of Bihar and Orissa, Revenue Department, Bihar State Archives, Agriculture, File no. 1A/189 of 1913, Nos. 29-32.

[84] Richard Drayton has pointed to the success of sugarcane-breeding program in the British West Indies in the 1880s. The colonial botanical stations helped improve the plant strain and agriculture, all of which in combination with other factors enabled the West Indian sugar to survive the competition of beet sugar. Geo-political interest ensured massive investment of imperial resources subsequently in order to preserve the West Indian sugar factories. cf. R. Drayton, *Nature's Government: Science, Imperial Britain and the 'Improvement' of the World*, New Haven and London, , 2000, 252-253, 257-261.

[85] For F.M. Perkin's quote, see *Nature* (November 1, 1900), 63: 1618, 9 (italics appear in the original); see also, *Nature* (November 29, 1900), 63: 1622, 112.

[86] See the comments of chemists Raphael Meldola and A.G. Perkin in *Nature* cited above (op. cit. 77).

[87] T.R. Filgate, "Research Work on Natural Indigo", *Nature* (October 1, 1908), 78: 2031, 540.

[88] It should be added here that, not uncommonly, the charge of the innate conservatism of planters appears in different guises across different historiographies. Using a variety of rationale, scholars have faulted the agricultural classes for their lack of scientific and technological credentials, either in the knowledge of those principles or in their implementation. For example, T.J. Barron is scathing in his criticism of coffee planters' preference for profit before science in his study of nineteenth century coffee plantations in Ceylon: 'Where science and profit-making appeared to conflict, the planter almost invariably preferred… the latter.' A planter here is held guilty for his disinclination to pursue science for its own sake. cf. T.J.

Barron, 'Science and the Nineteenth Century Coffee Planters', *The Journal of Imperial and Commonwealth History* (October 1987), XVI: 1, 5-23, especially, 6-8, quote on 7.