Breeding for Insect-Resistant Cotton across Imperial Networks, 1924-1950

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Abstract: This paper investigates the elevated expectations and dramatic downturns of the Empire Cotton Growing Corporation's African experimentation program. It follows the trials of U.4, an insect-resistant variety bred to withstand continental growing conditions, whose expansion through east and southern Africa was filled with promise but ended in disappointment. My argument has two strands. First, U.4 was a product of imperial connections. It was an amalgam of breeding knowledge accumulated in India, specialized training received in Trinidad, and specimens imported from across the empire. Transnational scientific networks were crucial to the Corporation's initial breeding successes. Second, the story that follows suggests that imperial scientific experts did not impose the Corporation's research goals monolithically across a wide range of African environments. Rather, Corporation scientists recognized the diversity of African environments and adapted their breeding programs to match local agro-ecological realities. I suggest that the ECGC breeding program is a story of expert knowledge that incorporated rather than undermined ecological specificity.

In 1928 the head of the Empire Cotton Growing Corporation (ECGC) declared that breeding efforts had produced a variety of cotton perfectly adapted to South African growing conditions. U.4, as it was known, was a small, compact variety that gave heavy yields despite a short stature and thin trunk. In its first year of field experiments the U.4 variety outperformed all other strains in drought resistance, freedom from shedding, and quickness in forming buds. Follow-up experiments revealed that U.4 out produced all of the other strains under cultivation by more than fifty per cent. Corporation breeders boasted: 'In no single instance, whether in good or bad conditions… has [U.4] failed to show up well.'[1]

Growers were similarly enthusiastic. South Africans heralded U.4 as the pivotal find that would help the Union turn the tide after consecutive disappointing growing seasons. One *Zululand Times* editorial heaped praise upon the Corporation's 'expert knowledge' for 'the discovery and development of means whereby [insect pests] might be effectively combated'.[2] The president of one cotton cooperative reassured his members worried about recent periods of drought and low prices:

> There is no need for despondency. It seems to me that the advent of the new U.4 strain, which ensures a bigger yield per acre, has come about at a most opportune time, and will

[1] F.R. Parnell, *Report on the Work of the Cotton Breeding Station, Barberton, Transvaal, for the Season 1928/29*, London, 1929.
[2] Editorial: expert knowledge, *Zululand Times*, 2 May 1929.

> prove the salvation of many cotton-growing friends. The yields to be expected this season promise to be very full ones, and with this greater production per acre the drop in prices will not be felt as severely as would otherwise have been the case.[3]

The promise of U.4's superiority extended throughout British Africa. The head of the ECGC expressed confidence that that the early success achieved in South Africa could be replicated throughout the continent.[4] Within a few years U.4 was being planted in more than a dozen African colonies, as far north as the Anglo-Egyptian Sudan and as far west as Nigeria. U.4 was lauded as the technological savior that could finally transform Africa into a major producer for British mills:

> The optimism of today, however, stands in a very different light as compared with the optimism that obtained with regards to cotton eight or ten years ago. In the latter period the optimism was based largely on hope and expectation. Today it is based on scientific knowledge and something that is actual.[5]

But efforts to capitalize on U.4's initial promise stalled a few years later. In South Africa, rains arrived late twice over the next five years, hampering cotton production. Further north, damage wrought by insect pests increased, eating into plants and profit margins. Only four years after U.4 was heralded as the industry's savior, South African cotton production plummeted by more than 80% from its zenith of 500 000 bales. By 1948 U.4 had been abandoned by growers and breeders throughout Africa.

This paper investigates the elevated expectations and dramatic downturns of the ECGC cotton experimentation program across Africa, with particular emphasis on its most significant discovery, U.4. My argument has two strands. First, the Corporation's research program was shaped significantly by its imperial connections. Specimens were imported from the Imperial Institute in Trinidad, knowledge was assimilated from previous experimental work in India, and successes achieved in South Africa were disseminated to other continental research centres and eventually used as the foundation of a new Africa-wide research station at Namulonge, Uganda. These transnational scientific networks were crucial to the Corporation's breeding successes.

This emphasis on the interconnectedness of the Corporation's breeding program fits well with Historical Geographer Alan Lester's recent call for 'networked accounts' of imperial history.[6] Lester argues eloquently for a new imperial history that destabilizes the static categories of core and periphery, which constrain the spatial imagination of empire as unidirectional and linear. Instead, he proposes that relationships between Britain and its colonies – and between the colonies themselves – are more usefully conceived of as networks, which allow multiple sites of scientific knowledge to be considered within the same analytical frame, without privileging one over the other.[7]

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[3] Address from G.M. Robinson, President of the central cooperative exchange, *Zululand Times*, 8 May 1930.

[4] S. Milligan, U.4 is a strain of great promise, *Reports from Experiment Stations 1927/28,* London, 1928, 32.

[5] Editorial: forging ahead, *Zululand Times*, 15 May 1930.

[6] A. Lester, British settler discourse and the circuits of empire, *History Workshop Journal* (2002) 24-48.

[7] A. Lester, Imperial circuits and networks: geographies of the British Empire, *History Compass* 4 (2006) 124-141. See similar calls in A. Lester, *Imperial Networks: Creating Identities in Nineteenth-Century South Africa and Britain* (London and New York, Routledge, 2001) , and D. Lambert, A. Lester (Eds), *Colonial Lives Across the British Empire: Imperial Careering in the Long Nineteenth Century*, Cambridge, 2006.

Focusing on these 'geographies of connection' reveals how multiple sites of imperial science were linked both materially and discursively. It underscores the key role of exchange in sustaining imperial power: specimens were shipped over thousands of kilometers to be tested in far away sites, publications amalgamated knowledge accumulated across various sites of inquiry, individuals lived and traveled through these colonial spaces and inevitably made connections between them. According to Tony Ballantyne, foregrounding the 'relational quality of the imperial past' requires a more 'mobile' approach that expands the analytical field from beyond the metropolitan core or colonial periphery.[8] This paper builds upon this call for a new spatial imagination of empire by tracing the flow of experts, specimens, and knowledge across these imperial networks.

The second strand of my argument relates to how Corporation breeders interacted with African environments. The story that follows suggests that imperial scientific experts did not impose the Corporation's research goals monolithically across a wide range of African environments; rather the Corporation's breeding program was intimately tied to regional priorities and concerns.

Historical scholarship tends to emphasize the coercive nature of colonial science. Accounts portray scientists as unwilling to engage with, or ignorant of, the complexities and diversity of African environments.[9] The knowledge that colonial experts accumulated in Europe did not match the ecological realities they encountered across Africa. But a recent review undertaken by Beinart, Brown and Gilfroyle suggests that this perspective might be exaggerated.[10] Not all colonial experts were ignorant of African environments. Helen Tilley's work on the African Research Survey reveals that this massive, top-down colonial venture remained sensitive to local conditions and environments. Tilley argues that scientists working on the Survey were aware of the 'extreme regional heterogeneity and complexity of Africa's environments'.[11] Monica M. van Beusekom's research on the French Office du Niger is another example where experts were attentive to African environments.[12] Daily interactions between projects officials and African farmers who brought their own place-specific knowledge reconfigured agricultural expertise and impacted the project's priorities.

The Empire Cotton Growing Corporation's breeding program was similarly characterized by a nuanced attention to African growing conditions. Corporation scientists recognized the diversity of African environments and adapted their breeding programs to match local agro-ecological realities. They called this the 'new place effect', which suggested that all cotton

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[8] T. Ballantyne, *Orientalism and Race: Aryanism in the British Empire*, (Basingstoke, Palgrave, 2002) , 3. See also H. Tilley, Ecologies of complexity: tropical environments, African Trypanosomiasis, and the science of disease control in British colonial Africa, 1900-1940, *Osiris* 19 (2004) 21-38, and S. Shapin, Placing the view from nowhere: historical and sociological problems in the location of science, *Transactions of the Institute of British Geographers* 23 (1998) 5-12.

[9] See for instance J. McCracken, Experts and expertise in colonial Malawi, *African Affairs* 81 (1982) 101-116, K. Showers, *Imperial Gullies: Soil Erosion and Conservation in Lesotho*, (Athens, Ohio University Press, 2005) , and J. Fairhead, M. Leach, *Misreading the African Landscape: Society and Ecology in a Forest-Savanna Mosaic*, (Cambridge and New York, Cambridge University Press, 1996) .

[10] W. Beinart, K. Brown, D. Gilfoyle, Experts and expertise in colonial Africa reconsidered: science and the interpretation of knowledge, *African Affairs* 108/432 (2009) 413-433.

[11] H. Tilley, African environments and environmental sciences: the African Research Survey, ecological paradigms and British colonial development, 1920-1940, in: W. Beinart, J. McGregor (Eds), *Social History and African Environments*, (Oxford, James Currey, 2003) 109-130.

[12] M. Van Beusekom, *Negotiating Development: African Farmers and Colonial Experts at the Office du Niger, 1920-1960*, (Portsmouth, NH, Heinemann, 2002) .

transferred between breeding stations would suffer unless strains were bred to match place-specific growing condition.[13] I suggest that the ECGC breeding program is a story of expert knowledge that incorporated rather than undermined ecological specificity.

The Empire Cotton Growing Corporation

The outbreak of World War One caused considerable anxiety for the British cotton industry. Britain's three main cotton suppliers – the United States, Egypt, and India – all curtailed production to grow more foodstuffs. American exports, the most important of the three due to their high quality fibres, dipped under 10 million bales in 1923, down from more than 15 million before the war.[14] In total, world cotton output dropped from just under 24 million bales in 1914 to 15 million bales in 1921.

British industry leaders scrambled to react to this precipitous decline. Many advocated expanding the imperial source of raw cotton, which would ensure a steady supply immune from foreign interruption. A Board of Trade committee commissioned to explore possible mechanisms of expansion concluded that insufficient investment in research and experimentation was the single most important obstacle to expanding empire supply.[15] They recommended the establishment of a new organization dedicated exclusively to scientific experimentation designed to increase production in promising colonies.[16]

In 1921 the Empire Cotton Growing Corporation was incorporated by Royal Charter to address this need.[17] The British Government provided one million pounds as a start-up capital grant. Continuing operating costs were to come from the industry itself. The Cotton Industry Act, passed by the British Parliament in 1923, imposed a levy of 6d. per standard bale on all cotton purchased by British spinners.[18] This levy, plus the interest on the initial capital, provided the ECGC with an annual income of approximately £130 000 during its first decade of operation.

The most pressing task for the nascent Corporation was to secure the specialized expertise necessary to propel such an ambitious scientific venture off the ground. Initially, a handful of experienced scientific officers were poached from the Indian Agricultural Services; however, the Corporation's governors realized that they needed a specialized curriculum to prepare scientists for the challenges they would encounter across the empire. So in 1926 the Corporation formalized links with the Imperial College of Tropical Agriculture at Trinidad (ICTA), which was chosen because it offered tropical growing conditions similar to those

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[13] J.B. Hutchinson, New place effect on cotton, *First Conference on Cotton Growing Problems,* London, 1930, 41.
[14] A brief review of the cotton situation, *African Sugar and Cotton Planter* 1 (Feb/March 1925) 7-8.
[15] The Empire Cotton Growing Corporation 1921-1950, *Empire Cotton Growing Review* 28 (1951) 1-30.
[16] The ECGC was originally envisaged as an offshoot of the British Cotton Growing Association (BCGA), which was established in 1904 by a conglomerate of British cotton interests to market and promote cultivation within the British colonies. After more than a decade of efforts to increase supplies the BCGA was inundated with requests for research and experimentation, an area in which it sorely lacked expertise. The ECGC was created to fill this void. For information on the BCGA see NA, GOV Vol. 699 Ref PS22/04, British Cotton Growing Association: Charter of Incorporation, 1904 and S. Onyeiwu, Deceived by African Cotton: The British Cotton Growing Association and the Demise of the Lancashire Textile Industry, *African Economic History* 28 (2000) 89-121.
[17] The Corporation was governed by an administrative council consisting of approximately eighty members drawn from the Board of Trade, the Foreign and Colonial Offices, various trade organizations and Chambers of Commerce connected with the cotton industry, as well as a few Members of Parliament.
[18] *The Economist* No. 4392, 29 October 1927, National Archives of South Africa (hereafter NA), Department of Commerce and Industries (hereafter RHN) Vol. 1127 Ref 111/5/2. See also G.B. Masefield, *A Short History of Agriculture in the British Colonies*, (Oxford, Clarendon Press, 1950)

trainees would encounter in the African colonies that were to be the main recipients of this accumulated knowledge.[19] Members of the ECGC's scientific staff were trained at Cambridge University for a year and then went to Trinidad where they completed courses in agriculture, chemistry, soil science, botany, genetics, entomology, mycology and bacteriology.[20] Between 1921 and 1952 over one hundred Corporation research officers received their training at Trinidad before dispersing to direct cotton-growing efforts throughout the empire.

South African Breeding Efforts

Corporation officials were convinced that Africa offered the greatest potential for expanding imperial production. Promising reviews of cotton's potential were arriving from all corners of the continent. In Nigeria public/private partnerships were increasing cultivation so rapidly that estimates of the colony's annual production capacity swelled to more than 7 million bales.[21] Cotton production was also expanding in Sudan, driven primarily by irrigation projects along the Blue Nile River. Started in 1906, these scattered irrigation projects would eventually culminate in the Gezira Scheme, which at its peak had over 420 000 hectares under irrigated cotton.[22] South Africa was also undergoing a surge in production with just under 70 000 hectares put under cotton in 1924. Prospects were particularly high in the South African lowveld, which was reaping disproportionate benefits from this explosion in cotton interest: production in Natal and Zululand jumped from under 4 million lbs in 1923 to 12 million lbs in 1926.[23] Corporation decision-makers were further excited by the South African government's 'full and hearty' commitment to cotton operations, as well as the established, centralized networks of experimentation and information dissemination that existed there.[24]

The first Corporation representative to visit Africa was G.E. Keatinge, former Director of Agriculture for Bombay, who arrived in South Africa in 1922 to assess the country's suitability as a base for a continent-wide expansion. Keatinge spent four months touring the Union's cotton growing regions and praised the fine soils, plentiful rainfall, and low incidence of hail and insect pests. He concluded that the Union's three major cotton growing regions – the Rustenburg district, the eastern Transvaal, and the Zululand lowveld – were capable of producing in excess of half a million bales annually; he mused that one million bales was not beyond the realm of possibility.[25] He attributed the nation's stagnating current output to a lack of trained scientific expertise: 'of pure line breeding under competent botanical supervision there has been none, and

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[19] The Empire Cotton Growing Corporation 1921-1950, 7.

[20] A. Aspinall, The Imperial College of Tropical Agriculture, Trinidad, *Empire Cotton Growing Review* 10 (1933) 165-172. The Corporation contributed £500 annually to the ICTA, and in return the College waived tuition fees for all Corporation trainees. The Empire Cotton Growing Corporation 1921-1950, 4.

[21] J.S. Hogendorn, The cotton campaign in northern Nigeria, 1902-1914: an example of a public/private planning failure in agriculture, in: A. Isaacman, R. Roberts (Eds), *Cotton, Colonialism, and Social History in Sub-Saharan Africa*, (Portsmouth, Heinemann, 1995) 50-70, 52.

[22] See V. Bernal, Cotton and colonial order in Sudan: a social history, with emphasis on the Gezira Scheme, in: A. Isaacman, R. Roberts (Eds), *Cotton, Colonialism, and Social History in Sub-Saharan Africa*, (Portsmouth, Heinemann, 1995) 96-118.

[23] See M.A. Schnurr, The boom and bust of Zululand cotton, 1910-1933, *Journal of Southern African Studies* (forthcoming).

[24] Report of the executive committee, to be submitted at the meeting of the administrative council on 13 January 1927, Agricultural Research Council – Institute for Industrial Crops at Rustenburg, South Africa (hereafter ARC-IIC), ECGC Files.

[25] G.E. Keatinge, Cotton growing in South Africa, *Reports from Experiment Stations* (1922), 49.

this is probably the most insistent need of the cotton industry in South Africa at the present time'.[26]

Keatinge's tour convinced him that the single greatest obstacle to successful cultivation in South Africa was damage wrought by the jassid insect. Jassid (*Empoasca facialis*) is a small-winged leaf-hopper that breeds on the underside of plant leaves and sucks sap from the veins, causing them to dry out and shrivel up.[27] All of the strains under cultivation in southern Africa were vulnerable to jassid damage. Serious outbreaks were being reported throughout Swaziland, Southern Rhodesia, the eastern Transvaal, and Zululand.[28] There were so many insects on the plants that one Zululand farmer remarked the entire colour of his field was changed from a 'lovely green colour to a rusty red'.[29] The South African Inspector of Lands who toured the Union's cotton-growing districts in 1924 reported that jassids had overrun all the fields he visited and were present at every stage of growth.[30] He estimated that one-third of that year's crop had been destroyed by pests; the crop was so scarce and scattered that it was hardly worth picking. Local experts were convinced that eliminating jassid damage would allow the enterprise to thrive. 'Once this difficulty [insect pests] is overcome,' wrote one official, 'there will hardly be a limit to the development of cotton growing in South Africa'.[31]

Existing methods of jassid control were woefully inadequate. Experiments using Bordeaux mixture (diluted copper sulfate and hydrated lime) were a complete failure.[32] Other trials with spraying dusts and copper solutions were more promising, but high costs made widespread dissemination impractical. The Union's Chief Entomologist believed that the only real hope lay in breeding jassid-resistant cotton varieties, a process that would take years and require significant capital investment.[33]

Keatinge came away convinced that breeding for jassid resistance was the most effective strategy for boosting the continent's cotton production. He recommended that the Corporation establish an experiment station in the eastern Transvaal to support the South African cotton industry, charged with growing commercially pure varieties under careful observation, testing these varieties against each other, and making the most successful widely available to commercial growers across Africa.[34] The Union government responded enthusiastically to this proposal: they would welcome any assistance the Corporation was willing to provide.[35] The details were finalized within one year. The Union's Department of Agriculture agreed to provide

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[26] G.E. Keatinge, Cotton growing in South Africa, 24.

[27] The jassid is endemic to south-eastern Africa, where it feeds primarily on sweet potato, groundnut, beans, and cowpea. Cotton plans are most vulnerable to jassid attacks later in the growing season (February/March) when most of the earliest bolls are mature but still not ready to be picked. For more see E.O. Pearson, *The Insect Pests of Cotton in Tropical Africa*, (London, Empire Cotton Growing Corporation, 1958) .

[28] *Zululand Times*, 16 July 1925 and *Zululand Times*, 24 March 1927.

[29] President's report, Hluhluwe farmers' association, annual general meeting 1926, *Zululand Times*, 10 June 1926.

[30] F.F. Beaumont, Inspector of Lands to Secretary to the Land Board, 15 March 1925, NA, Secretary for Agriculture (hereafter LBD) Vol. 4044 Ref QC15.

[31] Annual report for 1925/26, *Farming in South Africa* I (1926) 325. See also E.H.T. Powell, Cotton growing in Natal and Zululand", *Farming in South Africa* I (1926) 185.

[32] The battle against the boll, *African Sugar and Cotton Planter* 2 (Feb 1926).

[33] Chief Entomologist to Secretary of Agriculture, 14 April 1925, NA, LBD Vol. 4044 Ref: QC15, and Chief, Division of Entomology to Mr. Evans, 13 April 1925, NA, LBD Vol. 4044 Ref: QC15.

[34] G.E. Keatinge, Note on cotton growing in the Transvaal east of the Drakensberg Mountains, submitted to the Union Government, Dec 29 1922, *Reports from Experiment Stations* 1 (1923) 54-61.

[35] D. Reitz, South African Minister of Lands, Response to Keatinge, 8 February 1923, *Reports from Experiment Stations* I (1923) 66/67.

a start-up grant of £900, and offered an operational and transportation allowance to all ECGC officers based in South Africa.[36] For their part, the Corporation committed to providing two supervisors and three South African assistants who had recently finished their one-year training at the Imperial College.[37] They also promised to fund the bulk of the annual operating expenses, predicted to be just under £4 000 per year. In 1924 the ECGC established a research station at Barberton in the eastern Transvaal, with over 150 acres available to field trials. This would become the nexus for the Corporation's efforts into insect-resistant breeding.

The ECGC's African breeding program was coordinated by Sean Milligan, a Scot who had spent thirty years farming and studying agriculture in Britain before joining the Indian Agricultural Department in 1905. During his tenure as Deputy Director of Agriculture in the Punjab, Milligan oversaw the widespread dissemination of imported American varieties and the expansion of irrigation projects. He was subsequently appointed Bengal's Director of Agriculture, before being recruited by the ECGC in 1924 to head their African operations.[38] Based in South Africa, Milligan occupied himself primarily with outreach, leaving the task of formulating and directing Barberton's research agenda in the hands of F. R. Parnell. Parnell was a veteran cotton breeder who had made his reputation with the Indian Agricultural Department before he took charge of the Barberton breeding station in 1924.

The South African Division of Entomology had compiled a scattered record of observation and experimentation during the 1920s which had yielded some useful observations on jassid behaviour: first, that jassid incidence was usually correlated with higher precipitation levels; and second, that the leaf-hoppers bred on the underside of the leaf and wrought their deadly sap-sucking damage from there. Parnell integrated these observations with knowledge from his Indian cotton breeding experience. There, breeding efforts aimed at jassid-resistance had focused on the link between a cotton plant's hairiness – the length and density of hairs on the underside of the leaf – and its resistance to jassid. Experiments in the Punjab had revealed a close inverse correlation between the degree of hairiness and the number of eggs laid. Parnell hypothesized that the hairs tickled the ovipositor of the female, causing her to shy away from laying her eggs on the leaf vein. His first series of trials at Barberton set out to compare the density and length of hairs on the underside of the leaf with jassid incidence. Weekly tests measured jassid counts on sections of thirty leaves of different varieties. By the end of the first season, Parnell had confirmed that both hair density and length affected the plant's susceptibility to jassid attacks.[39]

Parnell then searched for existing hairy varieties to assess their level of jassid resistance. His Corporation colleagues sent seed with varying degrees of hairiness from all over the empire, from Tanganyika, Nyasaland, Uganda, India, Australia, and America.[40] Varieties with smooth undersides imported from America, including Acala, Delfos, and Express, were all wiped out by jassid, which was absent in the United States. Hairier varieties, such as the Ugandan, proved

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[36] P.A. Bowmaker, General correspondence, Chief, Division of Plant Industry to Secretary for Agriculture, 11 March 1930, NA, Department of Irrigation (hereafter LPS) Vol. 3 Ref BHE35.

[37] Report of the Executive Committee, to be submitted at the meeting of the Administrative Council on 19 October 1927, ARC-IIC, ECGC Files.

[38] For more on Milligan's background see *The South African Cotton Growers' Journal* (February 1925) 13.

[39] F.R. Parnell, The breeding of jassid-resistant cottons: report for the season 1924/25, *Empire Cotton Growing Review* II (1925) 7. See also F.R. Parnell, *Report on the Work of the Cotton Breeding Station, Barberton, Transvaal, for the Season 1926/27,* London, 1927.

[40] F.R. Parnell, Cotton Plant Breeder, Barberton, general, 1924, NA, Department of Entomology (hereafter CEN), Vol. 683 Ref: E7005.

most resistant. These initial trials confirmed Parnell's hypothesis that cotton plants with smooth, non-hairy leaves were especially vulnerable to jassid destruction.

The most resistant imported variety was a selection known as Cambodia, sent by a Corporation scientist in Madras. Parnell had encountered Cambodia during his Indian breeding work: it produced large bolls with good quality lint – over 1.125 inch in staple – and its jassid-resistance had been established unequivocally. But it was a very large plant, as much as eight or nine feet high, and almost as wide across with stems that were quite delicate. Parnell worried that this would make it very susceptible to the violent storms that occurred regularly across the lowveld. Experiments confirmed just that, as all the Cambodia planted at Barberton was destroyed by hailstorms. Trials with Cambodia were abandoned the next year due to its weakness in resisting these adverse weather conditions. This failure convinced Parnell that any jassid-resistant strain would also have to be resilient to eastern South Africa's other ecological variables, especially high winds and erratic precipitation levels, for it to achieve wide-scale success. He decided to re-orient breeding efforts away from acclimatization of foreign varieties: the breeding of jassid-resistance would begin with strains that were already well adapted to local growing conditions.

Parnell initiated a program of single-plant selection in which a large population was planted and the best performers for the desired trait, in this case jassid resistance, were retained, while the rest were discarded. The progeny of these selected plants were then re-grown in isolation and screened again for the desired trait. This process was repeated until a uniform plant population was obtained that demonstrated consistent performance. Initial trials focused exclusively on hardy varieties with sturdy stalks that had proved resilient during previous season's violent storms, such as Zululand Hybrid, the region's most popular strain, an American import named Improved Bancroft, and Ugandan varieties. By the end of the 1926/27 growing season Parnell's investment in single-plant selection began to show encouraging results. Two strains emerged as the most promising. The first, A.12, was a selection of Zululand Hybrid made by a local grower, a strong, tough type, very hairy with lots of bolls. The second, U.4, was the progeny of a single plant selected at Barberton by Parnell in early 1925 from Ugandan cotton. U.4 was a small compact variety that gave heavy yields despite its small stature: it averaged only 4.3 grams per boll compared with Zululand Hybrid at 5.5 grams and Improved Bancroft at 6.6 grams, but its overall yield per plant was higher than both.[41] Both A.12 and U.4 thrived in the 1926/27 growing season, the second of consecutive drought years. Both yielded an average of 750 lbs per acre each, and suffered little or no jassid damage.

In 1927/28, U.4 yields surpassed those of A.12 and it emerged as the most promising jassid-resistant variety. Yield tests at Barberton recorded an average yield 50% better than that of Zululand Hybrid, and 100% better than non-resistant varieties of Improved Bancroft and Uganda (the U.4 parent).[42] Moreover, U.4 out-yielded A.12 across a range of different soil and climatic conditions by an average of 40%. In spite of late rains and prevailing drought conditions, the 1 200 acres planted with U.4 yielded returns of between 1 000 and 1 500 lbs per acre, with yields of up to 2 000 lbs per acre reported in a few places with favourable growing conditions. The U.4 variety also outperformed A.12 in jassid-resistance, drought resistance,

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[41] F.R. Parnell, The origin and development of U.4, *Empire Cotton Growing Review* 7 (1930) 177-182.

[42] F.R. Parnell, *Report on the Work of the Cotton Breeding Station, Barberton, Transvaal, for the Season 1927/28,* London, 1928.

prolific flowering capacity, quickness in forming buds and setting fruit, freedom from shedding, and ginning percentage.[43]

In the eyes of ECGC personnel, one more growing season was needed to confirm U.4's supremacy. Yields in 1928/29 stayed between 1 400 and 1 750 lbs per acre of seed cotton, compared with only 711 lbs for A.12 and 303 lbs for Improved Bancroft. The most encouraging news came from farmers off the station who planted about 1 000 acres of U.4 and reported favourable returns and strong jassid resistance. They also suggested that U.4's small bolls seemed better able to withstand dry conditions and were more resistant to bollworm attacks than the larger bolls produced by other strains. The season's experiments convinced Parnell that U.4 was the jassid-resistant variety that he had been searching for.[44] Corporation breeding efforts were reoriented to focus exclusively on its improvement and propagation. By 1930 breeders had produced over three hundred tons of seed, which allowed Union farmers to put more than 30 000 acres under U.4.

<u>U.4 in East and Southern Africa</u>

Corporation officials were anxious to verify whether the strong performances and rave reviews that U.4 generated within the Union could be replicated in other African environments. Parnell was confident that U.4 could thrive throughout the continent, however he warned that re-selections could only be successful if they were adapted to local growing conditions. He was emphatic that U.4's success in the South African lowveld was due not only to its jassid resistance but also to its repeated selection for other traits that allowed it to thrive within local conditions, such as early fruiting, a higher number of smaller bolls rather than fewer-but-bigger bolls, and hardier stalks able to withstand strong winds. He termed this holistic search for place-specific breeding 'safeness' – the ability of the cotton plant to adapt to variability in local growing conditions – and it became a key feature of the Corporation's dissemination efforts. This was no simple transplantation. Rather, U.4 seed was dispatched in bulk to be adapted by Corporation breeders to the varied growing conditions experienced throughout Africa.

U.4 enjoyed almost immediate success in the Corporation's two southernmost breeding satellites, at Bremesdorp in Swaziland and Gatooma in Southern Rhodesia. U.4 was first attempted at the Corporation station in Swaziland during the 1926/27 growing season and underwhelmed breeders there with a crop that was 'weak, a poor sample, rather diseased'.[45] The following season, though, produced dramatic results. Jassid attacks were severe from January through March, destroying all other strains grown at the station but leaving U.4 relatively untouched. U.4's output nearly doubled those of all other strains planted, plus it boasted the longest lint length and the highest ginning percentage. In the growing seasons that followed breeders began selecting for U.4 varieties that flowered earlier in the season, reasoning that this would make them less vulnerable to the cotton stainer bug, Swaziland's second most pernicious insect pest, which generally attacked the crop late in the season.[46] By 1930 Swazi breeders succeeded in breeding for an early maturing strain of U.4 that translated into a net increase of

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[43] Ginning percentage is the proportion of lint relative to seed.
[44] F.R. Parnell, *Report on the Work of the Cotton Breeding Station, Barberton, Transvaal, for the Season 1928/29,* London, 1929.
[45] Swaziland, *Reports from Experiment Stations 1926/27,* London, 1927, 95.
[46] Cotton stainer bugs (*Dysdercus spp.*) feed on the cotton boll impairing their growth. Their name derives from the fact that many species transmit micro-organisms that stain the cotton boll yellow. E.O. Pearson, *Insect Pests in Tropical Africa*, 256-290.

76% (in weight) of lint exported. They lauded U.4's 'complete superiority' over all other strains.[47] By 1930 it was the only variety of cotton being distributed to Swazi growers.

The arrival of U.4 at the Gatooma station in Southern Rhodesia had a similar impact. Corporation officials there had been lamenting the damage wrought by jassids for years, complaining that these pests were the single most important limiting factor to cotton growing.[48] Gatooma breeders were particularly hopeful about U.4's potential because attacks there seemed similar to those experienced at Barberton: 'the symptoms of a bad attack exhibited at Gatooma agreed with the description given by Parnell'.[49]

U.4's impact was immediate. In the first year it was planted U.4 proved almost completely resistant to jassids in the face of a particularly severe infestation. It also withstood partial drought, which were common to the area. U.4 weathered these adverse conditions better than any other strain. Breeders were effusive:

> the general quality [was] extremely high; single-plant yields are very good; the lint lengths are excellent; ginning percentages and lint indices are high, and the seed cotton is uniform. All the selections are highly jassid-resistant; most of them are also early maturing. They are drought-resistant, and if some of them behave well under conditions of heavier rainfall some very excellent strains should be resolved.[50]

The following season breeders undertook 140 single-plant selections to seek out U.4 strains best suited to southern Rhodesia's growing conditions. Breeders at Gatooma were particularly concerned about the damage wrought by American bollworm, a moth whose larvae are laid on the upper surface of the leaves and then burrow into flower buds or young bolls for food.[51] Previous seasons revealed that damage was less severe earlier in the growing season when the maize crop was mature (bollworm preferred maize to cotton and left the bolls relatively undisturbed). So breeders focused on selecting for early maturing U.4 that would bloom in conjunction with maize to minimize damage from American bollworm.[52] As in Swaziland, U.4 soon became the dominant variety distributed to farmers. More than 10 000 acres were put under U.4 each year in the early 1930s.[53]

U.4 garnered less enthusiastic reviews when it was transplanted to environments further north. Trials planted at the Corporation station in Northern Rhodesia were so severely decimated by both bollworm and stainer bugs that further selections were impossible. Bollworm attacks caused shedding of as much as 50% of squares in some cases, which led to average yields per plant of only 36 grams of cotton compared to 142 obtained the year before.[54] Breeders in Nyasaland encountered similar disappointments. U.4 failed to outperform the local variety, Nyasaland Upland, which proved more resistant to the cocktail of insect pests that caused havoc there, especially Red, Spiny, and American bollworm.[55]

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[47] Swaziland, *Reports from Experiment Stations 1928/29,* London, 1929, 91.
[48] Southern Rhodesia, *Reports from Experiment Stations 1926/27,* London, 1927, 131.
[49] Southern Rhodesia, *Reports from Experiment Stations 1926/27,* London, 1927, 118/119.
[50] Southern Rhodesia, *Reports from Experiment Stations 1927/28,* London, 1928, 109.
[51] Cotton bollworm (*Heliothis armigera*) feeds on other African staples such as maize, sorghum, tobacco, tomato and beans, but proves especially devastating for cotton stands. It is endemic throughout Sub-Saharan Africa. See Pearson, *The Insect Pests of Cotton in Tropical Africa*, 142-160.
[52] Southern Rhodesia, *Reports from Experiment Stations 1933/34,* London, 1934, 57.
[53] Southern Rhodesia, *Reports from Experiment Stations 1927/28*, London, 1928, 126.
[54] Northern Rhodesia, *Reports from Experiment* Stations 1927/28, London, 1928, 169.
[55] Nyasaland, *Reports from Experiment Stations 1928/29*, London, 1929, 199.

Negative reviews became the norm in other faraway locales such as Nigeria and Anglo-Egyptian Sudan, where U.4 was planted for one or two growing and then discarded.[56] Initial reports were more positive in Uganda, whose breeders received U.4 for the first time in the 1929/30 growing season. While jassid was only a minor pest in the region, breeders were impressed by U.4's yields on poor soils, its drought tolerance, and, most crucially, its resistance to Blackarm disease, a bacterial blight endemic to the region that causes leaf spots and boll rot. U.4 outperformed all other varieties in its first year of planting: the mean yield per plot of U.4 was 19.8 lbs, while the next highest was only 11 lbs.[57] The quality of lint produced, though, was a concern: U.4 produced lint that was short, harsh and damaged. Breeders set about selecting for strains to improve these characteristics but achieved little success over the next few growing seasons. U.4 derivatives continued to yield large quantities of low quality lint, leaving breeders frustrated and pessimistic over the potential of future trials.[58]

U.4's disappointing performance across east Africa convinced Corporation officials that reselections had reached their practical limit.[59] The focus shifted instead to crossing U.4 selections with a range of other varieties in the hopes that the resultant hybrids might be better adapted to east African growing conditions. In 1930 Dr. Harland, the Corporation's head breeder at the Imperial Institute at Trinidad, arrived in Africa to tour the continent's cotton growing regions and assess how the Trinidad station could best support the Corporation's fledgling African efforts. He was impressed by U.4's success in southern Africa, but surmised that diminishing returns further north were due to growing conditions that were significantly distinct from those in which U.4 was originally bred to succeed. He dismissed the possibility that simple transplantation of bulk seed using selection by phenotypic variation would allow U.4 to thrive in such unfamiliar environments. Instead, he brought U.4 seed back with him to Trinidad to backcross with others strains collected by Corporation breeders throughout the empire.[60]

The first of Harland's backcrossed hybrids arrived back in Africa in 1933. Most performed poorly and were discarded outright: many were completely defoliated by jassid, while others bloomed late and were destroyed by stainers or bollworm. The most successful was the (U.4 x Cambodia) x U.4 backcrosses, which sought to combine Cambodia's hairiness, sturdiness, and strong lint with U.4's proven jassid resilience. The early crosses were reduced in size and resembled the U.4 parent in habit and growth. But after only a few growing seasons at Barberton progeny demonstrated a combination of ginning percentage and hairiness far superior to either parent.[61] The mean average for the best performers of the U.4 x Cambodia crosses were 575 lbs per acre compared with 450 lbs per acre for the best U.4 performers.

But this initial optimism was short-lived. Breeders began to complain about weak jassid resistance, late blooming habits, unsturdy trunks, and short, harsh lint. Stations that continued

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[56] Jassids were not present in either colony so it is not surprising that U.4 was so easily discarded. Reports also suggest that U.4 was transplanted to non-British colonies, including Portuguese East Africa, Angola, and the southern part of the Belgian Congo. None of these transplantations succeeded. *Empire Cotton Growing Corporation, 1921-1950*, 26.

[57] Uganda, *Reports from Experiment Stations 1929/30*, London, 1930, 274.

[58] Uganda, *Reports from Experiment Stations 1933/34*, London, 1934, 99.

[59] *Empire Cotton Growing Corporation, 1921-1950*, 26.

[60] Harland backcrossed U.4 with a wide variety of strains originating from all across the empire including India, Jamaica, Gambia, Egypt, Uganda, and the United States.

[61] F.R. Parnell, *Report on the Work of the Cotton Breeding Station, Barberton, Transvaal, for the Season 1942/43,* London, 1943, 20.

replanting Harland's backcrosses found that the plants became smaller and more compact over time. There were some instances of success – backcrosses in Nyasaland and Southern Rhodesia fared particularly well in the first few growing seasons – but most stations abandoned these hybrids within a few years of their introduction.[62]

Consolidating Expertise at Namulonge, Uganda

By the late 1930s enthusiasm for U.4 and its hybrid offspring had begun to wane. Disappointment was rife in east Africa: having already discarded pure bred U.4 substrains, breeders in Northern Rhodesia, Nyasaland and Uganda had become equally pessimistic over the prospects of Harland's U.4 backcrosses. Observations in Northern Rhodesia confirmed that jassid damage was minimal compared with that wrought by bollworms and locusts: these two combined to limit production of one U.4 crop to 16 lbs of cotton per acre, the lowest yields ever recorded in the colony.[63] Cotton experimentation there was discontinued two years later. Bollworms and stainers continued to plague breeders in Nyasaland, who finally closed down the substation in 1944, admitting defeat: 'U.4 evidently suits South African conditions better than those of Nyasaland'.[64] Breeders in Uganda discarded U.4 in 1938, also citing mediocre yields and poor lint.

U.4 wasn't faring much better further south. Farmers in Southern Rhodesia and Swaziland began to report faltering jassid resistance, while breeders complained about low ginning percentages and poor quality lint.[65] U.4 was even performing poorly in South Africa, where growers also began to complain about declining jassid resistance. South African cotton production dipped accordingly: from 773 000 lbs in 1940, to under 500 000 lbs in 1941, to 130 000 lbs in 1942, and down to 36 000 lbs in 1945.[66]

Economics played an important role in U.4's declining prospects. Cotton prices experienced a lull during the 1930s, ranging from a high of 7.49 d. per lb in 1930 to a low of 4.93d. per lb in 1938.[67] Producing the crop and delivering it to market cost the average farmer a minimum of 4 and ½ d. per lb., leaving little incentive to continue production once prices dipped below 6d. as cotton ceased to profitable in comparison with other crops.[68] In 1942 Parnell reflected that:

> For some years before the war started, it was becoming more and more clear that South Africa could not possibly develop into an important producing country with cotton prices at their then low-level. We know that considerable areas are suitable for the crop and that good yields of good quality cotton can be obtained: unfortunately other economic factors

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[62] See *Reports from Experiment Stations 1934/35,* London, 1935 and *Reports from Experiment Stations 1937/38,* London, 1938.

[63] Northern Rhodesia, *Reports from Experiment* Stations *1933/34,* London, 1934, 75.

[64] Nyasaland, *Reports from Experiment Stations 1943/44,* London, 1944, and Nyasaland*, Reports from Experiment Stations, 1944/45,* London, 1945, 135.

[65] See *Reports from Experiment Stations 1939/40*, London, 1940, 148.

[66] *Official Yearbook of the Union* 1941/42, Pretoria, 1942, 381.

[67] B.R. Mitchell, *British Historical Statistics*, (Cambridge, Cambridge University Press, 1988) , 760.

[68] Southern Rhodesia, *Reports from Experiment Stations 1938/39*, London, 1939 and Southern Rhodesia, *Reports from Experiment Stations 1939/40*, London, 1940, 40.

intervene, making the costs of production high in comparison with those of some larger producing countries.[69]

The onset of World War Two offered a brief reprieve as the wartime price of cotton rose to over 8 d. per lb in 1943. But rising American output flooded the market and caused prices to crash within a few years.[70] Increasing American production was a major force behind cotton's diminishing fortunes in Africa. Production had been rising steadily throughout the first part of the twentieth century, due largely to expansion west of the 98th and 100th meridians into western Texas, Oklahoma, Arizona, New Mexico, and California, where greater irrigation capacity allowed for plantations much larger than were possible in the southern states.[71] Rapid adoption of mechanized tractors, planters, cultivators, strippers and dusters in the 1920s and 30s further boosted production efforts.[72] President Roosevelt's New Deal programs shifted the focus toward intensive rather than extensive cultivation by emphasizing programs and improved methods that increased yields on existing lands, accelerating the transition from smaller farms to larger ones.[73] By 1940 the United States was producing in excess of twelve million bales of cotton annually with more than eleven million bales still in warehouses from previous years, overwhelming international demand and stymieing global prices .[74]

In contrast with the sluggish increase in cotton prices, the prices of other commodities boomed. In South Africa, for instance, the price of maize increased by 106% between 1938 and 1945; citrus increased by 65% during the same period, and field crops such as potatoes and beans rose by 138%.[75] At the same time experimental costs were rising: annual ECGC expenditures for experimental work at Barberton ballooned to just under £7000 by 1940, which was over 30% higher than predicted.[76] Parnell recognized that the current economic outlook offered 'no hope of the present type of cotton being produced on a large scale'.[77]

This combination of U.4's declining prospects and swelling American production forced Corporation officials to rethink their African breeding program. In 1942 the Corporation's Scientific Advisory Committee undertook a review of their African operations and recommended consolidating existing breeding stations into one central research station surrounded by a handful of nearby satellite stations, all clustered in the region with the greatest growing potential.[78] A

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[69] F.R. Parnell to Pieter Koch, 31 January 1942, Barberton Cotton Experiment Station, General, 1942-43, NA, Department of Agricultural Extension and Education, (hereafter LON) Vol. 358 Ref A290.
[70] F.M. de Toit, Cotton Culture, *Farming in South Africa* 15(January 1940) 4.
[71] C.L. Saffell, When did King Cotton move his throne (and has it moved back)?, *Agricultural History* 74 (2000) 293-308.
[72] G.C. Fite, Recent progress in the mechanization of cotton production in the United States, *Agricultural History* 24 (1950) 19-28.
[73] T. Saloutos, New Deal agricultural policy: an evaluation, *The Journal of American History* 61 (1974) 394-416 and W.C. Whatley, Labor for the picking: the New Deal in the South, *The Journal of Economic History* 43 (1983) 905-926.
[74] F.M. de Toit, Cotton culture, *Farming in South Africa* 15(January 1940) 4.
[75] J.M. Tinley, *South African Food and Agriculture in World War II*, (Stanford, Stanford University Press, 1954) , 89-100.
[76] Empire Cotton Growing Corporation and British Cotton Growing Corporation, 25 January 1950, NA, HLK Vol. 67 Ref 51/2.
[77] F.R. Parnell, *Report on the Work of the Cotton Breeding Station, Barberton, Transvaal, for the Season 1942/43,* London, 1943, 17.
[78] *Report of Administrative Council of the Corporation Submitted to the Twenty-First Annual General Meeting on 2 June 1942,* London, 1943, 2.

number of factors precipitated this change. Most crucially, Parnell and other officials began to advocate for larger scale production schemes. In the early 1940s a general enthusiasm for large-scale, mechanized, high input agricultural schemes prevailed among colonial scientific officers.[79] Corporation scientists mused over the possibility that a cotton scheme could be highly mechanized on a huge scale: 'the most direct method of increasing production is by planting a bigger acreage'.[80] Such a venture required consolidating resources currently scattered across disparate continental breeding centres as well as the experimental station at Trinidad.[81] Practical considerations accelerated this transition: many breeders volunteered to serve in World War Two, leaving the Corporation without the human resources to staff multiple research centres.

This new consolidated station was to be located in east Africa, considered to be the region with the greatest growing potential. While production in southern Africa had been declining since the late 1930s, Uganda and Sudan had emerged as the continent's two largest producers with annual crops exceeding 300 000 bales each.[82] Tours of Tanganyika and Kenya convinced officials that both were well suited to large-scale production.[83] Parnell was nominated as the new station's Director and set about searching for a suitable site. He settled on 1600 acres located at Namulonge, Uganda, approximately 18 kilometres north of Kampala. The plot consisted of slight hills with swamps in the connecting valleys, with at least 500 acres fit for experimental work.[84] Experiments got underway in 1949 and focused primarily on improving varieties, as well as the application of inorganic manures and insecticides. Jassids, which were considered only a minor pest in east Africa, were given little attention. The Corporation's Chief Entomologist concluded that the jassid 'presents no obstacle to cotton growing'.[85] All further work into the selection of U.4 and its substrains was abandoned.

Conclusion

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[79] J.M. Hodge, *Triumph of the Expert: Agrarian Doctrines of Development and the Legacies of British Colonialism*, (Athens, Ohio University Press, 2007) .

[80] F.R. Parnell, Possibilities of increased cotton production in east Africa, *Empire Cotton Growing Review* 24 (1947) 159. See also E. Teale, Undeveloped land in east Africa, with special reference to Tanganyika. *Empire Cotton Growing Review* 24 (1947) 12.

[81] *The Empire Cotton Growing Corporation 1921-1950*, 8. Many Corporation scientists argued that the fundamental work undertaken at Trinidad would benefit from closer contact with the most applied work taking place in Africa.

[82] W. Nowell. *Review of the Work of Experiment Stations 1936/37*, London, 1937, 3. See also *Report of Administrative Council of the Corporation Submitted to the Twenty-Sixth Annual General Meeting on 3 June 1947,* London, 1948. In contrast, South African production had dropped to 340 bales by this point.

[83] *Report of Administrative Council of the Corporation Submitted to the Twenty-Sixth Annual General Meeting on 3 June 1947,* London, 1948.

[84] *Report of Administrative Council of the Corporation Submitted to the Twenty-Fifth Annual General Meeting on 25 June 1946,* London, 1947, 2. Construction for the research station cost more than £200 000. £100 000 came from the Colonial Development and Welfare Act, £80 000 from the Corporation and £25 000 from the cotton industry itself. Operating costs were financed primarily by the Corporation and the governments of the colonies that were expected to benefit from its establishment, including Uganda, Tanganyika, Kenya and Nyasaland. See *Report of Administrative Council of the Corporation Submitted to the Twenty-Seventh Annual General Meeting on 6 July 1948,* London, 1949, 2.

[85] E.O. Pearson, Insect pests as a factor affecting large-scale cotton growing in Africa", *Empire Cotton Growing Review* 24 (1947) 246.

By 1950 the Corporation had consolidated most of its African operations at Namulonge, with 13 European scientists and a total staff of more than 250.[86] This spatial reorganization of knowledge marked a significant transformation in the Corporation's African breeding program. The web of scattered breeding stations that facilitated the expansion of U.4 was a system of extensive breeding designed to synch this agricultural innovation with the particularities of local growing conditions. Namulonge, in contrast, consolidated expertise and specimens with the goal of expanding large-scale ventures in a region considered to have little ecological differentiation. The Corporation's new era of scientific experimentation was focused on improving yields per acre in the most promising sites in east Africa, exemplifying a 'strong technocratic turn in official thinking'.[87] This transformation reflects the broader shift or 'conversion' that Historian Joseph Hodge narrates in the realm of British agricultural development more generally. A commitment to expanding networks of knowledge in the 1920s and 30s morphed into a more centralized, large-scale doctrine of agrarian development, that was only possible as funds became widely available following World War Two.[88]

In this paper I have argued that U.4 was a product of imperial networks. It was an amalgam of breeding knowledge accumulated in India, specialized training dispensed in Trinidad, and specimens imported from sites across the empire. Its expansion outward from Barberton was buoyed by multiple research visits and detailed correspondence. When mass selection stalled, backcrosses undertaken at the Imperial Institute at Trinidad temporarily boosted efforts in Nyasaland and Southern Rhodesia. This traffic of specimens, breeders, and knowledge was crucial to U.4's development and its (short-lived) success.

Employing a network approach places the focus of analysis squarely on the flow of specimens, ideas and individuals connecting these different colonial settings to one another, revealing that U.4 was not a product of any one particular place but rather emerged out of the links between them. The story of U.4 underscores the relational quality of imperial scientific endeavours, or, in the words of Helen Tilley, 'the transnational and geographically interdependent nature of knowledge production'.[89] This empirical account supports calls by Frederic Cooper and Ann Stoler to broaden colonial historiography in order to avoid 'nationally bound' perspectives that 'have blinded us to those circuits of knowledge and communication that took other routes than those shaped by the metropole-colony axis alone'.[90] Within this approach the geographical imagination of empire is transformed from one that is linear, neat, and static, to one that is layered, interrelated, and much messier.

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[86] Thirty-two of the Corporation's forty-four scientific officers were stationed in east Africa. See Table 6.3 The distribution of ECGC scientific officers, 1928-1962 in J. Hutchinson, D.F. Ruston, The Empire Cotton Growing Corporation and the organization of research on raw cotton, in: J. Cockcroft (Ed.) *The Organization of Research Establishments*, Cambridge, 1965, 142.

[87] S. Clarke, A technocratic imperial state? the Colonial Office and scientific research, 1940-1960, *Twentieth Centry British History* 18 (2007) 453-480, 479.

[88] J.M. Hodge, *Triumph of the Expert: Agrarian Doctrines of Development and the Legacies of British Colonialism*, (Athens, Ohio University Press, 2007) . See also S. Berry, *No Condition is Permanent: The Social Dynamics of Agrarian Change in Sub-Saharan Africa*, (Madison, University of Wisconsin Press, 1993) , 47.

[89] H. Tilley, Ecologies of complexity: tropical environments, African Trypanosomiasis, and the science of disease control in British colonial Africa, 1900-1940, *Osiris* 19 (2004) 21-38, 38.

[90] A.L. Stoler, F. Cooper, Between metropole and colony: rethinking a research agenda, in: F. Cooper, A.L. Stoler (Eds), *Tensions of empire: colonial cultures in a bourgeois world*, (Berkeley, CA and London, UK, University of California Press, 1997) 1-58, 28. See also A. Lester, Imperial circuits and networks: geographies of the British Empire, *History Compass* 4 (2006) 124-141.

U.4's transplantation throughout east and southern Africa also sheds important insight into the relationship between colonial experts and African environments. Bred to succeed within the particular growing conditions of the South African lowveld, U.4's transplantation to breeding stations across Africa is one instance where colonial experts were cognizant of the diversity and heterogeneity of African environments. Corporation breeders did not simply plop down U.4 and hope that it would work under these varied conditions. Rather, they set out reselecting for traits that would allow substrains to thrive within each locale's particular growing conditions. This meant selecting for early maturing strains in Swaziland and Southern Rhodesia to mitigate against damage caused by the stainer bug and the American bollworm, respectively. Reselections in Uganda focused on U.4's resistance to Blackarm disease, while breeders in Nyasaland were largely unsuccessful in targeting their efforts on strains that could resist the cocktail of pests that prevailed there. Corporation scientists recognized that for U.4 to succeed it needed to be molded to local growing conditions: as one review of the African experimental program concluded 'cotton must be fitted into local agriculture in such a way as to become a homogeneous part of it'.[91] Parnell's guiding principle of safeness – integrating U.4 within local growing conditions – epitomized this recognition of place-specific variation.

The story of U.4 suggests that colonial experts did not always view Africa as a single, undifferentiated whole. This process of technological transfer was nuanced and site-specific. Breeders paid attention to place-specific constraints and allowed local ecological complexities to influence the character and direction of the scientific intervention. This case supports David Livingstone's contention that 'the 'where?' of scientific activity matters a good deal'.[92] The scientific program that produced U.4 was contingent upon place, not a triumph over it.

Taken together, these insights help to explain the incongruity between U.4's elevated expectations and dramatic disappointments. The emphasis on imperial networks underlines the contingent and somewhat unstable nature of imperial science, while the focus on the locally sensitive approach employed by Corporation officials serves as a reminder that colonial-era agricultural failures cannot always be explained away as the poor environmental understanding of imperial scientific experts. U.4's breeding program was the product of a scientific emphasis on jassid resistance, a financial commitment to expanding cotton as a commodity crop, and a political vision of widespread cultivation throughout the continent. When these priorities shifted in the early 1940s – due to changing research agendas, the Corporation reorienting its focus towards intensive, large-scale production, and a surge in American output – the web of relations sustaining U.4 was reconfigured. As these networks collapsed, so too did U.4.

[91] J.C. Willis, *Review of the Work of Experiment Stations 1934/35*, London, 1935, 3

[92] D. Livingstone, *Putting Science in its Place: Geographies of Scientific Knowledge*, (Chicago and London, University of Chicago Press, 2003) , 3. See also S. Naylor, Introduction: Historical Geographies of science - places, contexts, cartographies, *British Journal of Historical Studies* 38 (2005) 1-12.