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Living with materiality or confronting Asian diversity?
The case of iron-biofortified rice research in the Philippines[1]

Abstract

This paper draws on findings from a multi-sited study of international science policy processes in rice biofortification. It focuses on the ten year period between the discovery of a 'high-iron' elite line named IR68144-3B-2-2-3 and the publication, in 2005, of the findings of a bioefficacy study that proved crucial to securing the support necessary to scale up biofortifiation research as a global 'Challenge Program'. During this time, IR68144 took on many guises, defined and redefined in relation to different disciplinary, institutional and socio-cultural perspectives. This paper highlights the ways in which different actors responded to the material agency of IR68144; drawing implications for reflexive practice and context responsiveness in a research effort increasingly distant from its projected beneficiaries. The case of iron rice research shows that while attempts to shape rice (in whatever form) to suit a particular research or policy agenda may be successful within carefully tailored and time-bound settings; once these conditions are removed, the reality of rice, in all its complexity and heterogeneity, inevitably 'bites back'. Today, the centre of gravity of rice biofortification research is located in a more mobile 'global science' community. This paper shows how an instinctive appreciation of the materiality of rice, in interaction with humans – researchers and their subjects – and other material elements, was a key factor that differentiated the early research practice from that of a new generation of scientists attempting to achieve a set of global research targets.

Key words

Biofortification, agricultural research, rice science, micronutrients, nutrition, CGIAR

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Introduction

Biofortification, the enhancement of micronutrient levels of staple crops through biological processes, such as plant breeding and genetic engineering, has gained prominence in recent years as a potential solution to the problem of persistent micronutrient malnutrition or 'hidden hunger' on a global scale. In 2008, the Consultative Group on International Agricultural Research (CGIAR) generated an indicative list of 'best bets' or strategic areas of investment considered most likely to lead to 'sustainable poverty reduction' (von Braun et al. 2008). This list included 'scaling up biofortification'; with reference to its assessment by the 'Copenhagen Consensus 2008' as one of the 'top five solutions to global challenges'[2].

This paper traces a series of events that took place over the ten year period between 1995 and 2005, during which time foundations were laid for biofortification to become a future priority for the CGIAR. It focuses on research conducted during this time in the Philippines, involving scientists at the International Rice Research Institute (IRRI) and its national and international partners, which made a critical contribution to building the case for biofortification as a global project. In the course of this research, the materiality of a rice line selected for its grain iron density – variously as germplasm, seed, milled and un-milled grain and whole plant – manifested itself in ways that continually tested the ingenuity of the researchers. The results of this pioneering research (Haas et al. 2005), while encouraging, were nevertheless accompanied by a range of unresolved questions. By this time, however, iron rice research at IRRI had been absorbed, along with a range of other initiatives in different parts of the world, into a global 'Challenge Program' of the CGIAR called HarvestPlus.

This paper highlights some of the challenges involved in reconciling a globalised, goal driven research agenda and programme design with everyday science and development practice in particular locations. It traces the history of iron rice research through a series of stages: from modest beginnings at the margins of IRRI's rice breeding programme; to a more systematic research design which – for a brief period of time – achieved a national profile, capturing the attention of nutrition policymakers in the Philippines; and finally to its absorption within an ambitious global programme. It highlights how, at each stage, scientists and decision makers sought to emphasise certain aspects of the

[2] http://www.harvestplus.org/content/worlds-top-economists-say-biofortification-one-top-five-solutions-global-challenges (22 February 2010).

selected rice variety, while downplaying others; in such a way as to enable research objectives to be met. The key lessons to be learned from this case, however, concern the way in which a combination of institutional pressures and powerful imaginaries led key actors to a discount the obvious contingency of these project outcomes. In the event, they felt compelled to seize a window of opportunity to transform what had previously been a relatively modest project, struggling for funds and recognition at the margins of the CGIAR, into a large scale global initiative. In this context, situated successes based on specific materials employed within a very particular set of circumstances were generalised to apply to rice in general; generating conclusions that provided a platform for 'scaling up' activities - from particular groups of people in specific locations to 'populations as risk' around the world.

A serendipitous discovery

The idea of breeding micronutrient-dense staple crops is not a new one. In the 1970s, plant breeders at the CGIAR International Maize and Wheat Improvement Centre (CIMMYT) were making headway in developing high-lysine 'Quality Protein Maize'. However, these varieties proved to be low yielding and this, together with a shift in nutrition away from the 'protein paradigm', stalled the research at least for a time. This section explores how, two decades later, promoters were able to secure a foothold for biofortification research among an initially sceptical research community by summoning certain 'foundational myths' (Brooks 2010:125) embedded in the history and culture of the CGIAR system.

In the 1990s, it was an agricultural economist, Howarth Bouis[3], who took on the challenge of convincing CGIAR plant breeders to revive their efforts to develop nutrient-dense crop varieties. Initially unsuccessful, he teamed up with Ross Welch and Robin Graham who had been conducting research in a similar vein the United States and Australia.[4] Welch and Graham drew Bouis's attention to evidence from research on zinc-biofortified wheat in mineral deficient soils in Turkey (Cakmak 1996) which showed that nutritional and agronomic traits need not always be competitive as was the case in the early research on high-lysine maize. On the contrary, biofortification might offer a 'win win' proposition in which crops bred for increased uptake and utilisation of trace minerals, for example, zinc and iron, could be harnessed to improve crop productivity

[3] Howarth Bouis is based at the International Food Policy Research Institution (IFPRI), a policy research institution and member of the CGIAR system based in Washington DC.
[4] Interview, research scientist, Federal Plant, Soil and Nutrition Laboratory (PSNL), Cornell University, 19 January 2006.

and human nutrition simultaneously (Graham and Welch 1996). This notion of achieving synergies between plant and human nutrition were captured by the phrase ‘tailoring the plant to fit the soil’ (Bouis 1995a:18).

As research continued into the complex interactions between soils, crops and human bodies that might lead to improved nutrition and health, a concerted effort was made to gain the support of a critical constituency: CGIAR plant breeders. At this time, the plant breeders in the various breeding centres were reluctant to add more breeding objectives to what was already a demanding workload[5]. These reactions, combined with memories of the earlier experience with high-lysine maize made it difficult for Bouis and others promote the idea of biofortification research within the CGIAR. Furthermore, much still remained to be learned about these plant-soil-human nutrition dynamics and research thus far had therefore been fairly open-ended and exploratory. Even the idea of ‘tailoring the plant to fit the soil’, in the context of breeding for iron and zinc density implied a degree of site specificity and complexity that would have been unattractive to overstretched scientists.

To understand why this conceptualisation would have been so problematic it is instructive to consider how plant breeding came to be at the apex of what Anderson has called the ‘classic cluster’ of crop sciences that has dominated the organisation and practice of research and development within the CGIAR since the Green Revolution of the 1960s and 1970s (Anderson et al., 1991). Key to this hegemony has been a set of assumptions concerning the universality and scale neutrality of solutions embedded ‘in the seed’. In the case of biofortification research, the support of CGIAR plant breeders was secured by a crucial reframing of the task at hand from that of ‘tailoring the plant to fit the soil’ in diverse environments; to the more straightforward task of selection based on the ‘micronutrient content of the seed’(Graham and Welch 1996:55):

> The genetics of these traits is generally simple, making the task for breeders comparatively easy… The primary selection criterion is a simple and efficient one – the micronutrient content of the seed (Graham and Welch 1996:55).

Around this time, a group of IRRI plant breeders, led by Dharmawansa Senadhira, developing varieties for ‘problem soils’ found among their crosses an elite line named

[5] Interview, HarvestPlus project management team member, IFPRI, Washington DC, 31 January 1996.

IR68144-3B-2-2-3 (abbreviated to IR68144). The result of a cross between rice cultivars IR72 and *Zawa Bonday;* these materials were selected for their agronomic suitability for 'cold elevated areas' and aromatic quality. Senadhira became aware of Bouis's micronutrients project which had, by then, been allocated a modest five year budget (1994-1999) for a 'pre-breeding' feasibility study (Bouis et al., 1999). Since early indications suggested that IR68144 had a relatively high concentration of iron and zinc in the grain, Senadhira put it forward as a 'candidate' for the project.[6] Subsequent test results for IR68144 combined a high concentration of grain iron (21 parts per million) with promising agronomic performance (Gregorio et al. 2000).

Figure 1. Field planted with IR68144-3B-2-2-3, IRRI, Los Baños
Copyright: Michael Rubinstein, International Food Policy Research Institute, 2003 (reprinted with permission).

[Insert Figure 1 here]

While rich in a number of trace elements, it was the identity of IR68144 as a *high-iron* rice variety that captured the imagination of scientists, policy actors and donors alike. It also secured the collaboration of a team of nutritionists from the Institute of Human Nutrition and Food at the nearby University of the Philippines, Los Baños; led by Angelita Del Mundo, who had, for many years, been advocating the integration of nutritional concerns into rice research.[7] A seminar entitled 'Improving Human Nutrition through Agriculture', convened by IRRI at the conclusion of the five year micronutrients' project, provided an opportunity to showcase IR68144 as the embodiment of the 'win win' argument and as a golden opportunity to accelerate biofortification research:

> A high-iron trait can be combined with high yielding traits. *This has already been demonstrated by the serendipitous discovery* of an aromatic variety – a cross between a high yielding variety (IR72) and a tall, traditional variety (*Zawa Bonday*) from India – from which IRRI identified an improved line (IR68144-3B-2-2-3) with a high concentration of grain iron (about 21ppm in brown rice)…The yields are about 10% below those of IR72, but in partial compensation maturity is earlier. (Gregorio et al. 2000:383, emphasis added).

[6] Interview, plant breeder, IRRI, Los Baños, 9 June 2006.
[7] Interview, nutritionist, Institute of Human Nutrition and Food, University of the Philippines, Los Baños, 7 June 2006.

At this point the iron rice project underwent a transition from the rather open-ended, exploratory research from which IR68144 had emerged as a 'serendipitous discovery'. In subsequent years, IR68144 took on two identities: firstly as 'high-iron' rice grain to be used as the experimental material in a 'feeding trial' to test the bio-efficacy of iron in rice; and, secondly, as germplasm submitted to a varietal testing programme in anticipation of its commercial release as the Philippines' first nutritional rice variety.

The feeding trial: accommodating IR68144

Following the IRRI-convened seminar, an interdisciplinary team of scientists, including plant breeders from IRRI and national agricultural research institutions in the region and nutritionists from the Institute of Human Nutrition and Food at the University of the Philippines, Los Baños,, succeeded in securing funds from the Asian Development Bank (ADB) for a new phase of research, spanning four countries (Indonesia, Bangladesh, Vietnam and the Philippines).[8] A condition of the ADB support was the inclusion of a nutrition study, an outline of which had been presented by Del Mundo and her collaborators from Cornell and Pennsylvania State Universities at the seminar, which would assess the biological impact (or 'bioefficacy') of iron-biofortified rice through a 'feeding trial' to be carried out in ten convents in and around Metro Manila (Haas et al., 2000:442).

The feeding trial was a 'prospective, randomised, controlled, double blind, longitudinal (9 month) intervention trial involving 317 women. The study had two arms: low-iron rice and high-iron rice, which were the exclusive sources of rice consumed for 9 months' (Haas et al. 2005:2824). Prior to the feeding trial, IRRI-based researchers subjected the 'two arms' of the study – the IR68144 materials and the proposed control (a rice variety named PSBRc28) – to post harvest processes of milling, washing and cooking, measuring the retention of grain iron through these processes. In the event, the differential in iron content between the 'high iron' and 'low iron' varieties reduced dramatically, so that series of adjustments had to be made to engineer the iron differential required for the feeding trial. These included the selection of a new control (a commercially available variety in the Philippines called C4) with lower iron content; and a complex milling strategy which involved under-milling the IR68144 supplies and over-milling the control:

[8] www.adb.org/documents/prf/nutrition.asp (10 November 2005).

> In effect, the differential between IR68144 and PSBRc28 [the rice variety initially selected as the control] is largely based on milling and not genotype…. The differential may be achieved if a commercially produced rice such as C4 will be used opposite to IR68144 … treatments such as milling of IR68144 and washing of rice prior to cooking should be taken into consideration to maximize the differential [*sic*] (Gregorio et al. 2003, conclusions and recommendations).

In this way, different aspects of IR68144 were variously highlighted or downplayed; thus ensuring it met the specific requirements of 'high iron' materials for the purposes of the feeding trial, while other elements in the experimental design were adjusted accordingly. That these adjustments would be impossible to replicate in open market conditions should the materials be released as a commercial variety was a question that was put on hold, since the aim of the feeding trial was establish 'proof of concept'[9] for iron–biofortified rice. Meanwhile, these changes to the project design made additional demands on the research team and their research subjects. Under-milled rice cannot be stored for extended periods of time, so fresh supplies of the 'high iron' rice had to be delivered, in specific quantities, to each participating convent, on a fortnightly basis. Similarly, samples of left-over cooked (high iron and control) rice were to be extracted for regular testing, in order to monitor iron content and ensure its consistency from one delivery to the next (Haas et al. 2005).

To understand how these demands were accommodated it is important to recognise the uniquely Filipino mix of science, religion and familial relations that characterised the study. That convents were involved in this type of research activity, particularly given its more intrusive aspects (for example the regular weighing of food and the taking of blood to measure iron levels) was noteworthy. While there were pragmatic reasons for this choice of research setting, for example 'the high prevalence of iron deficiency, the considerable amount of rice consumed, the excellent cooperation of the subjects, and the structured routine' (Haas et al., 2000:442), the convent setting gave the project a special meaning for the 'research family' (as team members called themselves) who were all of the Catholic faith.[10] Del Mundo, in particular, 'had always dreamed of working

[9] Interview, nutritionist, Institute of Human Nutrition and Food, University of the Philippines, Los Baños,, 7 June 2006.

[10] This group included Dharmawansa Senadhira, Glen Gregorio, Cristina Sison and Dante Adorada at IRRI; Angelita Del Mundo, Angelina Felix and Melanie Narciso of the Institute of Human Nutrition and Food, University of the Philippines, Los Baños and Riza Abilgos-Ramos of

with religious sisters' in her research work (Del Mundo 2003:82). Similarly, convent leaders framed their participation in terms of 'humanitarian service', so the strictures of the feeding trial and the presence of research assistants with their measurement devices and techniques were readily integrated into the daily life of the convent.[11]

Within the closed world of the feeding trial, therefore, the differential between the 'high-iron' and 'low-iron' rice was engineered to meet the precise specification required for the study to take place. In this context, the research team was able to report that that the 'high iron' rice had a 'biologically significant effect'[12] on the iron status of research subjects, and to conclude that 'Iron-Biofortified Rice Improves the Iron Stores of Non-anaemic Filipino Women' (Haas et al. 2005:2823). Questions remained, however, about how the 'high iron' status of IR68144 might be sustained beyond the strictly-controlled environment of feeding trial. IR68144 materials had, by then, been submitted for varietal testing in the Philippines with the expectation that publication of the results of the feeding trial would coincide with the launch of the Philippines' first high iron rice variety.

Figure 2. Feeding trial participants and researchers at one of ten participating convents in Metro Manila
Source: Angelina Felix, Institute of Human Nutrition and Food, University of the Philippines, Los Baños (reprinted with permission).

[Insert figure 2 here]

A special variety

During the planning stages of the feeding trial, IR68144 was submitted for varietal testing for commercial release in the Philippines, on the strength of its initial performance (Gregorio et al. 2000). The national programme did not, at this time, have its own facilities for measuring grain iron content, so the figures which had been reported by IRRI scientists prior to the feeding trial were accepted at face value. The attention of the assessors focused instead on the agronomic performance of the material across several seasons and agro-ecological zones.[13] The following evaluation by the working group tasked with the assessment and categorisation of IR68144 highlights its 'novelty' value as a nutritional variety, despite its 'modest yield'. In light of these assessments, which

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PhilRice. Dr Senadhira passed away in1998 and, thereafter, Gregorio took the lead role in the breeding programme (Interviews, Institute of Human Nutrition and Food and IRRI, June 2006).

[11] Discussions with 'family members', while visiting participating convents, 21 December 2006.

[12] Interview, nutritionist, Institute of Human Nutrition and Food, University of the Philippines, Los Baños, 7 June 2006.

[13] Interview, member of the Rice Variety Improvement Group, Philippine Rice Research Institute (PhilRice) campus, Nueva Ecija, 17 January 2007.

show a marked contrast with earlier predictions (Gregorio et al., 2000), the material was approved, not, as originally intended, for irrigated and rainfed lowland conditions, but as a 'special variety'[14]; a category normally reserved for speciality aromatic, glutinous and upland rices not expected to meet the same yield requirements as lowland varieties. While its 'slight aroma'[15] was a consideration, its identity as the first nutritional variety (based on reported grain iron levels of 21ppm) appears to have been the deciding factor:

> IR68144-2B-2-2-3-2 is an aromatic line serendipitously discovered to contain high grain iron concentration. Based on the field performance tests, this line gave a modest yield in spite of its susceptibility to insects, pests and diseases…. Its novelty was appreciated by the members of the [rice technology working group][16] and was recommended to be named as MS13 in the category of Maligaya Special rices…. It may not be a truly impressive performance but its discovery catalysed the inclusion of nutrition as one of the breeding objectives (Padolina et al. 2003:11).

The final statement in this assessment - that the serendipitous discovery of IR68144 'catalysed the inclusion of nutrition as one of the breeding objectives' indicated the groundbreaking nature of the project and its output, MS13, and the high expectations at the time of the Philippines' first nutritional rice variety as a commercially viable product that would herald a new generation of 'conventionally' bred, biofortified crops. In the event these expectations were not fulfilled. With its release as an approved variety, MS13 became the responsibility of national institutions concerned with rice research and seed production in the Philippines. In years that followed, promotion and adoption of MS13 reflected its 'special' category, and was largely confined to areas around IRRI where scientists involved in the original research were at hand to provide ongoing support (for reasons that are discussed at more length in the next section).

Meanwhile, scientists at the Philippine Rice Research Institute (PhilRice) conducted further tests to better understand the 'high iron' character of IR68144/MS13. What they found confirmed earlier indications that the grain iron content varied significantly across different agro-ecological conditions and between seasons. These scientists went a step

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[14] 'Maligaya Special'. Maligaya village in Nueva Ecija province is the location of the national headquarters of the Philippine Rice Research Institute (PhilRice).
[15] Interview, plant breeder, IRRI, 9 June 2006.
[16] This working group reported to the Rice Variety Improvement Group, Philippine Rice Research Institute (PhilRice) campus, Nueva Ecija.(see note 12).

further in their analysis, however, going as far as to question whether genetic factors were indeed the primary determinant of grain iron content. According to their analysis such variability was surely an indication that it was environmental, not genetic factors that were the primary determinants of iron content:

> If the trait is genetic… there shouldn't be such variability… breeders should not only be looking at the content of the grain…[but at] at the ability of the plant to absorb iron… the root system… the absorbing capacity of the plant[17].

These questions went to the heart of the 'win win' argument for biofortification, through which plant breeders had initially been enrolled into the project: that sufficient genetic variation existed (Graham and Welch 1996; Bouis et al., 1999) and could be accessed through the 'simple and efficient' screening criterion of 'the micronutrient content of the seed' (Graham and Welch, 1996, 55). Notably, this argument had been instrumental in garnering wider support for a biofortification project that employed 'conventional' plant breeding, rather than transgenic techniques, particularly in light of the controversy generated by the high profile 'Golden Rice' project (Nash 2000). In this way, a boundary was drawn (Gieryn 1999) between support for biofortification and acceptance of GM technology which proved critical to the mobilisation of a wider constituency of support for biofortification as a a global effort (Brooks 2010, 2011).

In contrast, a conceptualisation of biofortification that stressed the importance of 'the absorbing capacity of the plant' as a whole, and in particular the role of the root system resonated with an earlier, more holistic, interpretation of biofortification as a matter of 'tailoring the plant to fit the soil' (Bouis 1995:18). Plant breeding for trace minerals, it seems, was not so simple after all. Interestingly, this insight came as no surprise to one of the plant breeders in the 'research family' at the centre of the research effort, who was the first to acknowledge the 'mysterious' character of IR68144:

> This rice is very mysterious. I don't know, even now I don't understand. Because there are seasons when the grains are big, and there are seasons when the grains are small. But once you plant the big grain, next season it will be small. It's really unusual, and sometimes you plant it and the iron is not that big either;

[17] Interview, research scientist, PhilRice, 7 June 2006.

that's the controversy. Sometimes it's really elevated. The first graph that I made: I cannot repeat it again. The effect of environment is very high.[18]

These reflections and observation by scientists in light of the performance of IR68144/MS13 as a rice plant*,* interacting with contrasting agro-ecological and seasonal conditions present a sharp contrast to accounts of its performance as the high-iron rice consumed by religious sisters within the bounded world of the feeding trial. Nevertheless, these contradictions were not exposed, and instead the high iron identity of IR68144/MS13 was accommodated within the parameters of a more forgiving certification category and sustained by the remaining members of the iron rice family who continued to support localised efforts to promote its cultivation, for example in small plots or 'rice gardens' reserved for family consumption, in locations where genotype by environment interactions had proved more favourable.[19]

Beyond this, MS13 was never promoted on a national scale, nor was it given prominence as a flagship product for the newly launched HarvestPlus 'Challenge Program'. Furthermore questions raised by the disproportional impact of environmental factors and post harvest practices on the outcome of a genetics-led research programme were neither seriously explored nor translated into new research questions. The following sections trace these attempts to 'scale up' biofortification and explore how and why certain lessons were drawn from this early research effort and taken forward to inform subsequent activities, while others were not.

Enriching rice: confronting Asian diversity?

When asked the most important lesson to be drawn from the very mixed success of IR68144/MS13, one participant in the varietal assessment process put it succinctly: 'national priorities *matter*'.[20] The release, in 2003, of MS13 coincided with two national initiatives then underway, which also centred on rice, the nation's most important crop. The first was the launch of a government subsidy programme to promote hybrid rice technology as a means to boost agricultural production (PhilRice, 2002, 20) and address national food security concerns. In the Philippines, the availability and affordability of rice is a constant theme in national politics, in which rice self sufficiency has historically been equated with national security (Castillo, 2006). The second was the passage of the Food

[18] Interview, plant breeder, IRRI, 4 December 2007.
[19] Interview, ANGAT-Laguna programme coordinators (ANGAT-Laguna, 2006).
[20] Interview, Rice Variety Improvement Group (RVIG) member, PhilRice campus, Nueva Ecija, 17 January 2007.

Fortification Act (Republican Act 8976) in 2000[21] which made the fortification of key staples with specific micronutrients, including rice with iron, mandatory. At this time, after several years of research, scientists the Food and Nutrition Research Institute were conducting final evaluations on their own iron-fortified rice'.[22]

Rice fortification has a long history in the Philippines which began with the Rice Enrichment Act of 1952 which made the fortification of rice with Vitamin B (then a public health priority due to the prevalence of Beri Beri at that time) mandatory.[23] By the 1990s, industrial fortification of a range of staple and non-staple food items had become a characteristic feature of nutrition policy and programming in the Philippines (Solon 2000; Florencio 2004). Rice fortification, however, has always been difficult to implement. There are a number of reasons for this. Traditionally consumed in its whole grain form, mixing and blending with a chemical fortificant is technically complicated and economically prohibitive. Furthermore, rice milling is a highly decentralised activity in the Philippines, making full scale implementation difficult to monitor.

Ultimately, rice is an inherently heterogeneous crop, shaped by diverse taste preferences and agronomic and food-related cultural beliefs and practices (Asia Rice Foundation 2004). For all these reasons it does not lend itself to the kind of streamlined processing and economies of scale that have attracted investment in industrial fortification of other food items such as salt and wheat flour. Therefore, while most food fortification initiatives in the Philippines are in the hands of public-private partnerships (Solon 2000), it was public sector institutions that were mandated with implementing the new regulations for the fortification of rice. In the event, it was a high profile 'food for school' programme, launched with Presidential backing, which provided the vehicle – and market – for the limited of stocks iron-fortified rice that had been produced for this purpose under the supervision of the National Food Authority.[24]

There are important lessons which could have been drawn from a more nuanced reading of the shifting interface between the high-iron rice project and national rice

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[21] The Food Fortification Act came into force in 2004.

[22] Interviews, nutritionists, Food and Nutrition Research Institute (FNRI), Metro Manila, 21 June 2006 and 23 January 2007.

[23] An account of the long history of rice fortification in the Philippines, co-authored by Drs. Rudolf Florentino and Ma. Regina Pedro, both formerly with the FNRI, can be found at: http://www.unu.edu/unupress/food/V192e/ch09.htm (18th March 2008).

[24] Interview, Iron-Fortified Rice (IFR) programme, National Food Authority (NFA), 25 January 2007.

politics in the Philippines. Members of the iron rice research family had been mindful of the governmental support for iron-enriched rice as well as the particular challenges faced by the iron-fortified rice programme; and saw their iron-*bio*fortified rice as providing a more sustainable alternative to '*artificially* enriching milled rice with iron' (Gregorio et al., 2000:382, emphasis added). But this perspective was a partial one, which neglected the broader political context. In the event, the high-iron project was but a short chapter in a more complex story of science, policy and politics surrounding, on the one hand, a national grand narrative of rice productivity and self-sufficiency which has endured since the Green Revolution era and, on the other hand, the appropriation of iron-fortified rice within a politicised campaign framed by the more emotive language of 'hunger mitigation'; propelled by regular coverage in the national media of hunger surveys conducted by groups like Social Weather Stations.[25] In this case, it was the quantity rather than the nutritional quality of food that was the main concern. It was in this context that IR68144/MS13, which unlike these other initiatives had no political support at this level, disappeared after a short appearance on the national stage.

Moving on: extracting lessons, setting targets

The results of the feeding trial were published in 2005, with the conclusion that 'consumption of biofortified rice, without any other changes in diet, is efficacious in improving iron stores of women with iron-poor diets in the developing world' (Haas et al. 2005:2823). This was an important milestone, which, in the event, coincided with the dispersal of the 'research family', as key members of this group moved on to pursue opportunities for study or career development.[26] In their place, a new 'international' group of research scientists had to pick up the threads of iron-biofortified rice research under what was now the 'rice crop component' of a CGIAR 'Challenge Program' called HarvestPlus.[27] Distancing themselves from the 'special variety' in the final stages of certification, the new team emphasised that, while the IR68144 materials were far from 'gold standard'[28], the results of the feeding trial represented a significant step forward in establishing 'proof of concept' for biofortification as an effective strategy for addressing micronutrient malnutrition.

[25] http://sws.org.ph (2 February 2007).
[26] Interviews, research scientists, Institute of Human Nutrition and Food, University of the Philippines, Los Baños and IRRI, June 2006.
[27] http://www.harvestplus.org/ (26 February 2010).
[28] Interview, HarvestPlus project management team member, IFPRI, Washington DC, 17 January 2006.

This paper has outlined ways in which, during the preparations for the feeding trial and on submission of the materials for varietal testing, a number of troubling questions had asserted themselves. In particular, preparations for the trial had revealed that much of the grain iron content was located in that part of the grain that is normally removed in the milling process (Gregorio et al. 2003); raising questions about how these benefits could be replicated outside the controlled conditions of the study. Even more problematic were observations pointing to the pivotal role of environmental factors in determining grain iron content, which called into question the wisdom of 'simple and efficient' selection based on 'the micronutrient content of the seed'. Might new ways be found to productively exploit these genotype by environment interactions rather than view them as problems to be minimised (cf. Simmonds, 1991)?

By this time, however, the HarvestPlus programme had been launched. Its design in incorporated a continued adherence to a genetics-led strategy, with the expectation that such a strategy would generate generic research outputs that could be 'scaled up' for maximum impact (CIAT and IFPRI, 2002). It was this framing of biofortification, as a strategy that offered 'impact at scale', that had secured the support of a newly instated CGIAR Science Council committed to a return to 'high impact' upstream research targeting problems of global significance (Science Council, 2006); as well as a major new donor, the Bill and Melinda Gates Foundation.[29] Biofortification, now a global project, was promoted in terms of a 'new paradigm' for agricultural research, in which agriculture would become 'an instrument of human health' (CIAT and IFPRI 2002, Graham 2002). Meanwhile, the Gates Foundation went on to launch its own parallel biofortification 'Grand Challenge' which, among other things, absorbed ongoing Golden Rice research into an equally ambitious programme.[30]

This 'scaling up' of biofortification research coincided with the departure of the research family and their replacement by a group of researchers more closely identified with a mobile, global research community than with local particularities and complexities. It was in this context that some of the more perplexing questions posed by the inconvenient behaviour of IR68144/MS13 were simplified, streamlined and ultimately sidelined. The next step would be to resume the search for rice germplasm with higher levels of grain iron content, in accordance with programme-wide targets that would now be set at a

[29] Interview, programme officer, Bill and Melinda Gates Foundation, 30th November 2005.
[30] http://www.goldenrice.org/Content5-GCGH/GCGH1.html (14 January 2011).

central location.[31] Genotype by environment interactions and uncertainties should indeed be studied, but these could be 'dealt with' through the conventional framework for multi-location field trials. Similarly, questions about the impact of post harvest practices were removed from the research agenda by a decision that in future, rice would be screened for iron in its white, polished form. A line was drawn between past efforts, in which selections had been performed with brown rice, and future research under HarvestPlus which would concentrate on the accurate isolation and measurement of the iron content in 'uncontaminated' white rice.[32] The strategy of 'simple and efficient' selection based on grain nutrient content was thus reinstated as an 'isolable problem' amenable to IRRI's normal *modus operandi* of genetics-led research (Anderson et al., 1991). Having streamlined the problem definition in this way, it was not long before scientists at IRRI were debating whether transgenic methods might be a surer and shorter route to achieving these globalised iron targets than 'conventional' plant breeding.[33]

A key idea linking these two phases of iron rice research was 'proof of concept'. This term functioned as a boundary term (Gieryn 1999) which lowered the bar sufficiently for the study to be defined as a success, while acknowledging the need for further research, thus bolstering the argument that support for biofortification research *should* continue (Brooks 2010). Within the narrow parameters of the study iron in the selected 'high iron rice' had indeed produced a 'biologically significant effect'[34] in human subjects. However, as earlier sections have demonstrated, the experimental conditions required for this success to occur were of a kind that would be difficult to replicate in uncontrolled 'real life' conditions, and probably even to repeat within in different study, conducted in a another place and at different time. IR68144/MS13 was a high iron rice variety primarily because the experiment within which it was employed was designed to make it so. Outside the boundaries of the study, however, characteristics that had been so carefully fine-tuned for experimental purposes soon resurfaced and interacted with local environmental conditions with unpredictable and 'mysterious' effects.

Conclusion: from 'proof of concept' to scaling up?

[31] Interviews, HarvestPlus project management team members, IFPRI, Washington, January 2006.
[32] Interviews, research scientists, IRRI, May and June 2006.
[33] Interviews, research scientists, IRRI, November and December 2006.
[34] Interview, nutritionist, Institute of Human Nutrition and Food, University of the Philippines, Los Baños,, 7 June 2006.

Today, international biofortification research is conducted, predominantly, under two global programmes, both with substantial support from the Bill and Melinda Gates Foundation. The first is HarvestPlus, initially a pilot 'Challenge Program' of the CGIAR, now in its second phase.[35] The second is one of a series of 'Grand Challenges in Global Health' launched by the Gates Foundation soon after the approval of HarvestPlus as a Challenge Program (Gates Foundation, 2005:13). The contrasts, commonalities and linkages between these two initiatives have been analysed in detail by Brooks (2010). A key characteristic of both programmes, however, is a renewed emphasis on the promise of 'silver bullet' solutions to solve a range of complex, intractable development challenges such as micronutrient malnutrition. In particular, a genetics-led approach to biofortification is built on an enduring set of assumptions about its potential to generate generic outputs that will be widely applicable and inherently scalable (Brooks et al., 2009).

As HarvestPlus entered its second phase, the emphasis shifted from 'proof of concept' research to 'scaling up biofortification', now identified as one of the CGIAR's 'best bets' for contributing to 'sustainable poverty reduction' (von Braun et al. 2008). The account given in this paper of the progress of iron rice research, through its early stages, suggest that expectations of a seamless transition from 'proof of concept' to 'scaling up' are unlikely to be realised. Rather, the progress of IR68144/MS13 has been an ongoing struggle, in which scientists have attempted, but never quite succeeded, to tame the material agency of seeds, plants and the environments within which they are planted and consumed (cf. Pickering 1995). This has been apparent at every stage: from the 'serendipitous discovery' and naming of IR68144 as 'high-iron' rice; to its accommodation within the contained framework of the feeding trial (but not within the national priorities and high politics of rice in the Philippines); and ultimately to its relegation as just one step along the road to achieving nutrient targets - now established at a remote, central location for the HarvestPlus programme - and as source material used by a new generation of scientists working to a new set of research goals.

Today's global biofortification research programmes assume a centralised, goal-driven research model; discouraging the development of more reflexive science practice which might otherwise reveal new and creative ways to exploit the materiality of rice, rather than see it as an obstacle to be overcome (cf. Simmonds, 1991). Nevertheless, this

[35] www.harvestplus.org/content/harvestplus-receives-funding-new-research-phase (4 May 2009).

process is neither irreversible nor complete. The experience of the iron-rice family offers a rich seam of unlearned lessons in this respect; and it is likely that other precursor projects to today's global biofortification efforts may well do the same. They point to the dangers of premature closure around singular pathways which preclude the exploration of unresolved uncertainties and potentially viable alternatives. More recent research on the enrichment of cereals with zinc (Cakmak 2008, Wissuwa et al. 2008) has re-opened the debate about the relative merits of genetic and agronomic approaches to biofortification; making this an opportune time to reflect on these lessons. As the case of iron-biofortied rice research shows, attempts to 'shape' rice (in whatever form) to suit a particular research or policy agenda can be successful within carefully tailored and time-bound settings, but once these conditions are removed the reality of rice inevitably 'bites back'. It is in the ambiguous space that exists between these grounded realities and the pressures of a funding environment demanding 'impact at scale' within ever shorter timeframes that boundary terms such as 'proof of concept' gain purchase. This paper has shown how use of such terms provide breathing space for decision makers, as they negotiate an uneasy 'consensus' that ultimately undermines the potential for good science *and* good development.

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