Agric Hum Values (2017) 34:87–102
DOI 10.1007/s10460-016-9696-1

Disembedding grain: Golden Rice, the Green Revolution, and heirloom seeds in the Philippines

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Accepted: 30 March 2016 / Published online: 16 April 2016

Abstract "Golden Rice" has played a key role in arguments over genetically modified (GM) crops for many years. It is routinely depicted as a generic GM vitamin tablet in a generic plant bound for the global South. But the release of Golden Rice is on the horizon only in the Philippines, a country with a storied history and complicated present, and contested future for rice production and consumption. The present paper corrects this blinkered view of Golden Rice through an analysis of three distinctive "rice worlds" of the Philippines: Green Revolution rice developed at the International Rice Research Institute (IRRI) in the 1960s, Golden Rice currently being bred at IRRI, and a scheme to promote and export traditional "heirloom" landrace rice. More than mere seed types, these rices are at the centers of separate "rice worlds" with distinctive concepts of what the crop should be and how it should be produced. In contrast to the common productivist framework for comparing types of rice, this paper compares the rice worlds on the basis of geographical embeddedness, or the extent to which local agroecological context is valorized or nullified in the crop's construction. The Green Revolution spread generic, disembedded high-input seeds to replace locally adapted landraces as well as peasant attitudes and practices associated with them. The disembeddedness of Golden Rice that boosts its value as a public relations vehicle has also been the main impediment in it reaching farmers' fields, as it has proved difficult to breed into varieties that grow well specifically in the Philippines. Finally, and somewhat ironically, IRRI has recently undertaken research and promotion of heirloom seeds in collaboration with the export scheme.

Keywords Rice · Seeds · Genetically modified crops · Golden Rice · Green Revolution · Landraces · Breeding · Heirloom crops

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Introduction

It is now over a decade into the spread of genetically modified (GM) crops into parts of the Global South.[1] While it is common to hear this described as a single process—see, for instance, ISAAA (2014)—it is becoming clear that different GM crops in different countries lead to very different outcomes. In India, despite some high-profile articles that take the performance of GM cotton as indicative of "yield effects of genetically modified crops in developing countries" (Qaim and Zilberman 2003, p. 900), the effects of GM cotton have been largely a function of India's particular problems with agricultural deskilling (Stone 2011a), and the fate of GM eggplant (brinjal, aubergine) was partly determined by India's Ayurveda establishment (Kudlu and Stone 2013). Adoption and impacts of GM cotton in Burkina Faso and South Africa are strongly shaped by specific economic relationships between growers and gins (Dowd-Uribe 2014; Witt et al. 2006). Generalities

[1] Most terms for the technology are contested, but genetically modified here simply refers to incorporation of recombinant DNA. GMO refers to a genetically modified organism.

that ignore the ways that GM crops are "embedded historically, institutionally, politically and materially" (Dowd-Uribe et al. 2014, p. 146) leave us with superficial understandings of the technology.

The question of embedment is particularly relevant in the case of GM "Golden Rice." Golden Rice is unusual as it is conceived as a medical food, with a biosynthetic pathway engineered to produce beta-carotene in the endosperm (rather than only in the bran, as in most rice). Beta-carotene is a vitamin A precursor, and the hope was that this would mitigate vitamin A deficiency (VAD), which in extreme cases can cause blindness or death among poorly fed children.

The battles over Golden Rice have been fiery even by the usual standards of GMO contestation. Industry executives, molecular biologists, and media professionals charge that children are being left blind or "murdered" by Golden Rice critics, who in turn hold that the technology is an overrated and misguided techno-fix and a "Trojan Horse" to open the floodgates of GM crops into the Global South (Brooks 2010, pp. 76–83; RAFI 2000). In this fight the two sides are oddly complicit in decontextualizing and disembedding Golden Rice, as if it were a generic GM vitamin tablet in a generic plant bound for the generic Global South. It is not. It is *rice*—the most widely consumed and arguably the most culturally freighted crop in the world (e.g., Ohnuki-Tierney 1993; Shiva 2000–1). And it is not headed for the generic Global South or even for generic Asia, but specifically for the Republic of the Philippines. Indeed, it started as an idea from the Philippines (Enserink 2008) and it is being bred and tested in a research institution in the Philippines, to be approved by the Philippine Bureau of Plant Industry, to be sold in Philippine markets to Philippine growers, and potentially fed to Filipino children.[2] Most discussions of Golden Rice mention this Philippine context only in passing, if at all, focusing instead on generic issues such as VAD and biotechnology acceptance.

This is remarkable because the Philippines is hardly just a country with vitamin A-deficient children. The country is in many ways unique with respect to rice, with a storied history, complicated present, and contested future for the crop. The Philippines is where Green Revolution rice was born and introduced, intended to replace locally adapted landrace rice with input-intensive "scientific" grains. The Philippines remains home to the world's preeminent rice breeding institute—the International Rice Research Institute (IRRI)—that is leading the breeding and testing of Golden Rice.[3] Complicating the Philippine rice scene is that coincident with the testing of Golden Rice has been the launch of a project promoting the cultivation and export of heirloom landrace rice grown on the ancient terraces of the Cordillera mountains of northern Luzon—the same type of seeds the Green Revolution sought to replace.[4] Further complications in the Philippines context for Golden Rice are on the public health front: the country has managed to slash its childhood VAD levels with conventional nutrition programs just as Golden Rice is being touted as the cure to an otherwise intractable problem.

Our first aim here is to re-embed Golden Rice in cultural, historic, agronomic, economic, and public-health contexts specific to the Philippines. To do this we examine, compare, and analyze interactions among Green Revolution rice, Golden Rice, and, to a lesser extent, heirloom rice. We show that, more than simply categories of seeds, these are concepts at the center of highly consequential institutional and ideological bundles. Therefore, a secondary aim of the paper is to develop a theoretical perspective on Green Revolution rice, Golden Rice, and heirloom rice as reflecting distinct "rice worlds." This term encompasses biological characteristics of seeds, agro-ecologies of rice landscapes, processing and marketing, key institutions, visions of what rice should be, and how it should be produced. In particular we explore two attributes that distinguish these rice worlds. The first is where they stand in relation to *productivism*, which is the philosophy that output is to be prioritized at the expense of other agricultural virtues. Green Revolution rice, in many ways, epitomized productivism, but heirloom rice is defiantly nonproductivist. Meanwhile Golden Rice, promoted for its medical rather than its agronomic properties, has failed to reach Philippine farmers because it has yet to meet standards of productivity. The second attribute is *embeddedness*, defined as the extent to which local agro-ecological context is valorized or nullified in the crop's construction. With Green Revolution and Golden Rice, disembeddedness and placelessness are prized, although for different reasons. Meanwhile, heirloom rice is marketed explicitly on its embeddedness in the Cordilleran landscapes, and the institutions at the center of this rice world were founded explicitly with the aim of impacting Cordilleran communities.

As the world debates the fate and likely impact of Golden Rice, this rich context of rice in the Philippines is thus of practical and theoretical importance for the light it can shed on the very different ideological and institutional

[2] Breeders and researchers in Viet Nam, India, and Bangladesh are also working with Golden Rice, but release is not on the horizon in any of these countries.

[3] IRRI (see Fig. 2) collaborates with PhilRice—the Philippine Rice Research Institute—in the Golden Rice development and testing.

[4] The rice sector in the Philippines is unusual in other respects outside the scope of this paper. Despite being a major rice producer, it is also one of the world's largest importers of rice. It is also home to particularly advanced participatory breeding schemes for rice (Sievers-Glotzbach 2014).

entailments that have been attached to one of the world's most important crops.

Rice worlds, productivism, and embeddedness

Various scholars, including Alfred Schutz and Jürgen Habermas, have used the concept of *lifeworld* to describe human communication in general, but (Schurman and Munro 2010, p. xvii) narrow the concept to modes of thought that "come into being through a process of ongoing activity and social interaction among groups of people. Lifeworlds naturalize a certain broad vision of the world and guide interpretations of specific phenomena. We narrow this concept to apply it to the materiality of a specific crop—thus, "rice worlds"—and broaden it to encompass not only shared meanings and ideas, but also the institutions that promote and benefit from those meanings.

Productivism, which joins the belief in production for production's sake (Niblio 1995, p. 22) with the assumption that farmers should be rewarded for maximizing output (Evans et al. 2002, p. 314), is a key axis of variability in rice worlds. Productivism provides the basis for the commonly used scale in which increases in potential crop yield equate to stages of technological and economic progress. This is not only a mindset but a policy propagated after the Second World War as US-based and Bretton Woods institutions forced many countries to adopt methods of national income accounting that ignored nonproductivist metrics such as income inequality, local versus foreign ownership, and various aspects of sustainability (Niblio 1995, pp. 22–28). An illustration of the productivist framework applied to rice comes from breeder Swapan Datta (2004), who compares 10 types of real or envisioned plant types on yield potential (Fig. 1). The scale progresses from heirlooms ("landraces") to Green Revolution plants ("semidwarfs, IR8, IR72") to the "transgenic hybrids" that were expected by 2010, to other improvements expected to lead to a yield of 16 tons/hectare (ha) in 2015.

While progress in yield potential is commonly made to appear the obvious and inevitable goal of rice improvement, it is problematic in many ways. Note first that the progression relies on a rigged scale of measurement. Yield potential is quite different from the yield actually achieved in farmers' fields (Laborte et al. 2012; Lobell et al. 2009; Richards 1997), and moreover, these yield figures ignore other components of multispecies production systems that declined with the Green Revolution (Bray 1994). High yield is hardly the only attribute valued by farmers (Soleri et al. 2008); consequently some new crop types have low adoption rates despite being classified as progress on the scale of potential yield.[5]

The scale is also based on a progression in which forms of crop improvement are rendered obsolete by newer, more productive technologies. In fact, impressive advances in yield potential continue to be made with conventional breeding (often combined with modern genomics). For example, elite cultivars developed in China are currently producing 12–14 tons/ha. (Cheung 2014; Peng et al. 2008).[6]

But the larger problem is that this ordering obscures the meanings and institutional entailments of different rice worlds by imposing a unidimensional scale. Our approach for analyzing the three rice worlds and their articulations is a framework based on geographical *embeddedness*, defined here as the extent to which local agro-ecological context is valorized or nullified in the crop's construction. We argue that global industrial agriculture has been built on a "systemic placelessness" typified by crop breeding based on an underlying modernist philosophy that nullifies place. This disembeddedness was central to the Green Revolution's creation and deployment, as seeds with a mongrel ancestry were bred in an institute designed to enact a modernist future and ignore local context; they were then deployed with the intent of marginalizing locally adapted landraces and the farming practices associated with them. Golden Rice is even more profoundly disembedded and placeless: an invention of European biologists who used primarily American funding to insert DNA from scattered locations across the biological kingdoms to alter Green Revolution rice in order to treat malnourished children of Asia, partly to help fight a global public relations war. Yet to ever be planted by farmers, Golden Rice must become geographically embedded, specifically by being made productive in seeds adapted to the growing conditions of the Philippines lowlands, and this is precisely where it has foundered. Meanwhile, seeds of the small but surging heirloom sector, which are adapted to specific conditions and cultivation practices of terraces in Ifugao, Mountain, and Kalinga provinces, are being marketed explicitly on place—the narrow environments to which they are adapted and the geographically specific forms of wet-rice terrace cultivation that are practiced there (Fig. 2).

[5] For example, NERICA varieties, much heralded by breeders, have not been taken up with enthusiasm (Kijima et al. 2011).

[6] Note too that none of the improvements anticipated in 2004 have come to pass. The "New Plant Type," portrayed as a stage of progress already achieved, was incapable of out-yielding the best *indica* rice varieties (Peng et al. 2008); no transgenic rice varieties have yet been approved for commercial planting; and C4 rice (a proposed plant transformed to have a radically more efficient photosynthetic process) is a speculative product still far from potential release (Normile 2006; von Caemmerer et al. 2012). Datta expected that by 2015 breeders would be designing new crop varieties from scratch, but this remains a distant prospect (Cheung 2014; Long et al. 2015).

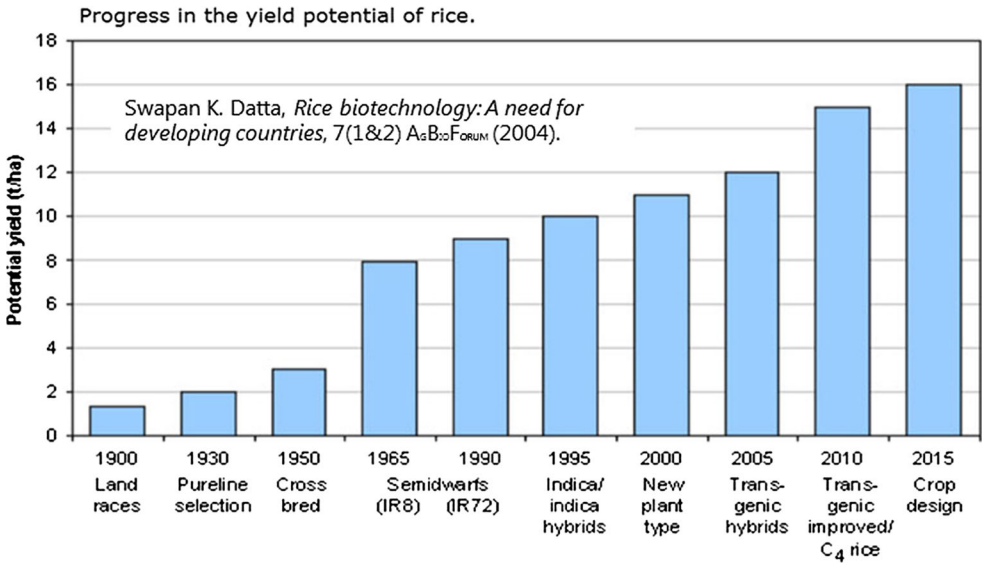


Fig. 1 Rice types ranked on potential yield, from Datta (2004)

Much discussed and also criticized as vague and undertheorized, embeddedness has taken on various meanings in a literature spanning several disciplines (Bowen 2011; Montgomery 1998; Murdoch et al. 2000). Analysis of this literature is beyond the scope of this article, but we recognize two basic and conceptually separable referents. The first concerns how economic behavior is shaped and constrained by social relations (Granovetter 1985; Polanyi et al. 1957) and labor processes (Kloppenburg 1991). This socio-economic embeddedness is particularly central to "locavore" alternative food systems, with their emphasis on trust and transparency (DuPuis and Goodman 2005; Harris 2010; Winter 2003). As Bowen puts it, "locally embedded, alternative food systems are set in opposition to the distanced, socially disembedded food relations associated with global industrial agriculture" (2011, p. 326). This perspective on locavorism and embedding has problems that we return to in the discussion of heirloom rice, but it is not our primary focus. We are using "embedding" in a second sense that refers to physical geography and ecology—the interactions between people and their surroundings and the ways in and extent to which technologies and practices are adapted to the agroecology of specific places. As "quality" in rice seed and food is constructed, this ecological embedment may be seen as an asset or liability (Morris and Kirwan 2011), as dramatized by the clash of Filipino rice worlds.

Green Revolution rice

The "Green Revolution" refers to assemblages of wheat and rice plants professionally bred and released primarily in Asia in the 1960s, where they were promoted along with agricultural chemicals.[7] For wheat, the key figure was plant-pathologist-turned-breeder Norman Borlaug, who ran a Rockefeller-sponsored breeding program in Mexico starting in 1944. His wheats were adopted in Mexico in the 1950s and in Asia (most famously India) in the late 1960s and early 1970s. The legacy of this program included the international maize and wheat breeding institute in Mexico (CIMMYT), which continues to develop wheat and maize varieties. In the case of rice, the institute preceded the revolution: IRRI was founded in 1960 and released its first "Green Revolution" rice, named IR-8, in the Philippines in 1966.[8] The two branches of the Green Revolution shared a crop design adapted to input-intensive cultivation: plants that responded well to fertilizer and irrigation, had short ("semi-dwarf") stalks, and matured quickly to allow multicropping.[9]

Both branches were also built on disembeddedness. Borlaug's wheats were not bred in India, where they had their major impact; the key germplasm originated in Japan, was brought to the United States, and then to Mexico, where Borlaug's "shuttle breeding" strategy—raising alternate generations of plants in the southern highlands

[7] Some use "Green Revolution" for all "modern varieties" in developing countries (Evenson and Gollin 2003), although there were many differences between the 1960s revolution and later breeding (see Evenson 2004).

[8] CIMMYT and IRRI are two of the network of 14 breeding and agricultural research centers comprising the Consultative Group on International Agricultural Research (CGIAR).

[9] Also known as "early" varieties, this mainly meant photoperiod-insensitive plants that could be used for more than one cropping cycle per year.

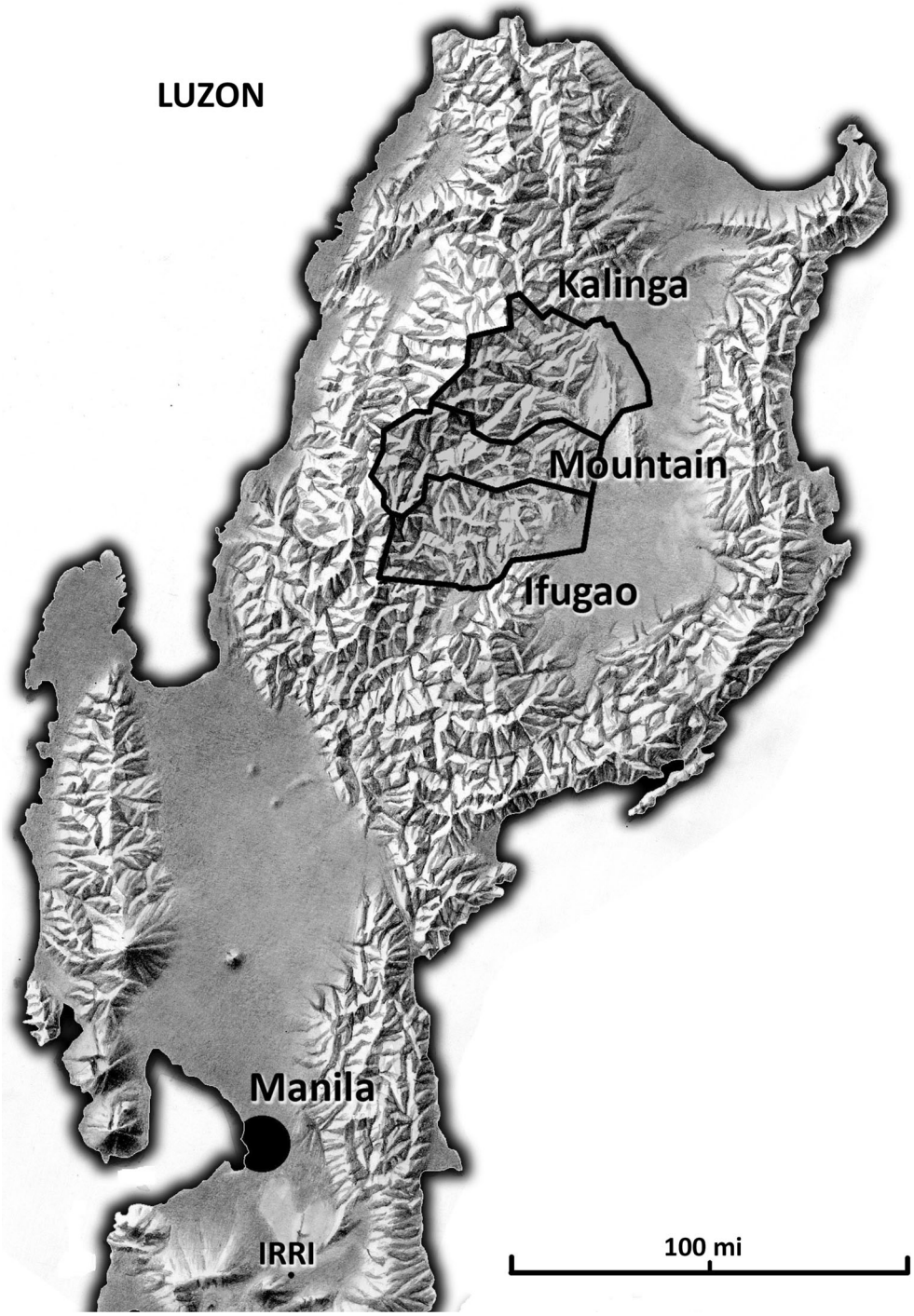


Fig. 2 Central and Northern Luzon, Republic of the Philippines, with IRRI (in Los Baños) and the Cordillera provinces where the heirloom export scheme operates

and the northern desert—further canceled out the effects of place.[10] They are routinely described as inherently higher-yielding as if this trait were independent of place, even though different crop traits have different effects depending on the growing environment.

The Green Revolution in rice has been just as disembedded as its wheat counterpart, beginning with the breeding institution itself. IRRI's founding director was American horticulturalist Robert Chandler, and its campus was designed by two Filipino architects Chandler judged to be competent to deliver on the modernist vision he shared

[10] At the time, the explicit treatment of locally adapted seeds and practices as problems to be overcome was challenged by few, the exception being geographer Carl Sauer (Richards 2004, p. 266; Wright 1984).

with the sponsors at the Ford and Rockefeller foundations. Supervising the design was Ralph Walker, an American modernist whose firm was known for military installations and suburban corporate research campuses. The institute looks, as historian Nick Cullather put it, "like an Ohio consolidated high school perched on a volcano" (2010, p. 165). Making concessions to neither climate nor local conventions, the aluminum and glass structures were intended to convey "the power and richness of American life" (Cullather 2010, p. 163). But while the institution was denying its local context, it was just as adamantly asserting a temporal reference: the new campus was intended to embody and perform the future and to modernize the values and personalities of Filipino scientists and farmers. After its opening in 1962, buses from Manila brought "a thousand tourists a week to Los Baños for a glimpse of the future…and a sense of time-travel" (Cullather 2010, p. 166).

The rice seeds nurtured in this facility had provenances even more diverse than the Green Revolution wheats. The original germplasm was taken from Taiwan, which became a hub of rice breeding because so many different streams of genetic material crossed there: wetland tropical *indica* varieties from China, mountain dryland varieties probably from the Philippines, and subtropical *japonica* varieties from Japan. Japanese colonial breeders here focused on short-stalked, fertilizer-responsive, photoperiod-insensitive varieties (Richards 1997), and IRRI breeders continued this strategy. The East Asian mixtures were then crossed with an Indonesian strain to produce the truly placeless IR-8, which was cast as the star in a drama of modernization (Evenson and Gollin 1997). IRRI compared IR-8 to the Model T Ford: "a rugged variety that could go almost anywhere" (IRRI 1977).

The IRRI breeders consciously chose a "cosmopolitan" breeding strategy rather than one built on local varieties (Harwood 2015; Richards 1997, p. 206). They were guided by the concept of the rice plant *ideotype*: a conceptual model of an ideal plant with physiological and morphological characteristics that theory predicted would yield well under ideal conditions (Donald 1968). Local farming environments would be amended and standardized to suit these high-performing cultivars. Seeds would be densely planted and amply supplied with water and fertilizer in meticulously weeded, pest-controlled fields. Ideotype breeding thus epitomizes a theory-driven, disembedded approach to crop improvement.[11] Unsurprisingly, farmers rarely achieved the expected ideal environments, and the truth was that yields for the early-generation rices were "highly unstable and subject to a declining trend" (Otsuka et al. 1994, p. 284). Later generations performed better after being crossbred with locally adapted varieties, and the ideotype approach continues to inform breeding strategies at IRRI. It provided models for the proposed New Plant Type in the 1990s and C4 rice in the 2000s (see Fig. 1 and fn. 6).

The ideotype breeding strategy fit neatly with the postwar modernist belief in a "single, convergent, and international modernity" (Cullather 2010, p. 84), but a more specific motivation concerned the rice plant as a rhetorical object. Disembedded rice optimized for ideal field conditions could be used to demonstrate spectacular results. Norman Borlaug advised rice breeders that their ideotypes had be "spectacularly demonstrated" in order to convince farmers (Borlaug 1972; Richards 1997, p. 207).[12] Of course this required that conditions be tightly controlled, but controlling field conditions was the stock-in-trade of breeding institutions like IRRI. In line with this spectacular philosophy, the high yields achieved on carefully controlled experimental plots at IRRI were reported with such exaggerated enthusiasm in the Philippine press that even IRRI officials complained (Cullather 2003).

Farmers were not the only audience for agricultural spectacle (Maat and Glover 2012). High yields in idealized rice plots were valuable to Chandler and IRRI managers, who wanted "sufficient splash to justify Ford's and Rockefeller's massive investment" (Cullather 2004, p. 238). They also benefited Philippine President Ferdinand Marcos, who had been elected on a platform of improving rice, and US President Lyndon Johnson, who visited IRRI in October 1966 to promote images of a humanitarian mission to contrast the escalating war in Viet Nam.

When IR-8 was released with great fanfare in 1966, the Philippine press heralded its yield boost as "lodged in the grain itself—a built-in productivity" (Cullather 2010, p. 170). The fact that the spectacle of yields required heavy use of purchased chemicals was downplayed.

The whole approach was seen by some leading Asian agricultural minds as profoundly misguided. The dean of a top Philippine agricultural college pointed out that this performance depended on resources that were well beyond the capacity of most Filipino farmers (Cullather 2004, p. 240). When the head of the Nepali Department of Agricultural Research pointedly asked how farmers could afford the crucial nitrogen fertilizer in particular, Chandler replied that "the poor farmer can afford to apply nitrogen…if he can find the money" (Richards 1997, p. 206). Of

[11] This disembedding was reduced somewhat by placeless elite strains being distributed to other research centers where they were crossbred with other varieties. Well after the Green Revolution, IRRI breeders became more interested in non-ideotype breeding, as discussed below.

[12] In Mexico, Borlaug had gone a step beyond ideal field conditions to outright rigged demonstrations in which conventional varieties were fertilized so heavily they fell over (Cullather 2010, p. 191).

course, as Richards points out, "by definition, poverty is the condition of not being in a position to find the money" (1997, p. 206).

But the heavy dependence on external inputs was part of what made the seed attractive to technocrats and American aid officials; it was not a drawback but a benefit. USAID distributed IR-8 in a package together with farm chemicals supplied by Esso and Atlas (Cullather 2010).

In fact, IRRI breeders were concerned that IR-8 might not be such an outstanding variety after all, yet it was quickly embraced by Marcos's new government and anointed "miracle rice" by the Philippine press. Senior officials argued that the yield performance of the new seeds was not the most important thing; they would train Filipino farmers to think "in terms of techniques, machines, fertilizers, schedules, and experiments" (Cullather 2010, p. 171). Rice farmers' attitudes and values would be transformed, and agricultural science would be the door to democracy and more progressive values. Creating "an American time pressure culture" was an essential feature of the program, according to a USAID official (Cullather 2010, p. 171). The point, in other words, was not only to displace locally adapted seeds, but to transform locally embedded cultivation and breeding practices and even local food cultures and rural ways of life (Cullather 2004; Harwood 2015).

Golden Rice

Golden Rice is an example of crop *biofortification*, a term coined to label a collection of projects and programs that seek to enrich the micronutrient content of food crops. Other examples include increasing the iron in rice, zinc in wheat, and beta-carotene in sweet potato. Biofortification extends productivist thinking to a molecular scale in the sense that it seeks to maximize the nutritional value of each crop unit while neglecting the ways in which the crop might be embedded within a wider system of farm production and food consumption. A challenge for all such projects is how to deliver real nutritional benefits to specific populations at risk, often rural communities that lie beyond the reach of traditional food fortification programs. The notion that one just has to get the seed (or root) into the hands of farmers in such communities oversimplifies the complexity of this challenge (Brooks 2013), in part by its neglect of how seeds are embedded in production and dietary systems.

It is instructive to consider the embedment difficulties of an earlier biofortified (non-GM) rice seed (Brooks 2008, 2010, pp. 48–62). In the 1990s the rice variety IR-68144, conventionally bred at IRRI, was identified as a "high-iron" variety. However, sustaining its high iron content turned out to require new ways of milling, washing, and cooking the rice—measures that would be hard to enforce beyond the scope of the project. Even then, the iron content of IR-68144 proved to be unstable across locations and seasons, probably indicating that the high iron characteristic was more environmental than genetic. The variety did not yield very well and was susceptible to pests and diseases. Yet IR-68144 appeared at an opportune moment in Philippine rice policy and was eventually released to Filipino growers under a special designation used for lower-yielding rices with special or novel characteristics. The variety served a discursive purpose within the Philippines as the pioneer release of a hoped-for pipeline of biofortified crops bred using conventional techniques. A research paper stating 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, p. 2823) lifted the research out of its Philippine context and was interpreted as a "proof of concept" that underpinned a new, multimillion dollar global program on crop biofortification, called HarvestPlus. The disembedding of IR-68144 was a crucial step that transformed it from a flawed rice variety in the Philippines national seed registry into an icon to mobilize international policy, research, and donor communities (Brooks 2011).

The disembeddedness of GM rice is in some ways even more pronounced than that of Green Revolution rice. It is disembedded in both its biological and its discursive construction. With GM crops in general, the complex biological process of a living organism interacting with a human-shaped environment is reduced conceptually to a discrete bundle of genetic information. Under controlled laboratory conditions, individual genes are isolated and reassembled in new configurations. While Green Revolution breeders focus their attention on plant types (both ideotypic and phenotypic), genetic engineers focus on genotypes, gene constructs, and individual genes. A preoccupation with the molecular scale favors a form of reductionist thinking that conceives of traits of interest as being governed primarily by genetics rather than through interactions with the environment or management (Charles 2001; McAfee 2003). DNA sequences might come from anywhere, disembedded from their genetic and biological contexts, recombined with other DNA segments, and inserted into different organisms where their expression may produce different results. With Golden Rice, these aspects of disembeddedness are overlaid onto the disembedded qualities of the Green Revolution varieties into which it is being crossed.

The iconic status of Golden Rice is also largely an artifact of timing, and it has also been disembedded as a discursive object (Brooks 2013). This technology has functioned more as a public relations project than anything

else, as industry and allies have worked since 2000 to position this one unusual technology as the face of genetic modification, a life-saving plant for the poor and malnourished wherever they may live. It fell into this role partly because of timing: following Monsanto's disastrous introduction of GM foods into Europe from 1996 to 1998 (Charles 2001; Lambrecht 2001), the GMO industry and allies began to muster public relations resources into a narrative featuring the smallholder and the undernourished of the Global South (Glover 2010; Stone 2002). By 2000 there was a flood of promotional materials (Fig. 3), including a quarter-billion dollars' worth from the newly formed Council for Biotechnology Information (Lambrecht 2001), troubled slightly by the absence of any GM crops offering any particular advantages to poor people in the Global South.

A small group of Rockefeller-supported biologists had been working since 1984 on endosperm carotene expression, with potential benefits for the undernourished (Enserink 2008), with scant media attention. But their achievement of low levels of endosperm carotene (Ye et al. 2000) coincided with the new public relations push. Since 2000, when it appeared on the cover of *Time*, Golden Rice has served as a ubiquitous talking point in GMO promotions, often called the "poster child" for GM agriculture (Brooks 2010; Nestle 2001).[13] Rhetoric on Golden Rice has featured an interesting reversal of the pattern of self-interested scientists creating false doubt about a scientific consensus, most famously regarding the health effects of tobacco (Stone 2015). In Golden Rice pronouncements, scientists and others insist with great certainty the plausible—but really quite uncertain—prediction that this rice could have a major health impact. The rhetoric often takes vitriolic turns, including charges that opponents who have delayed Golden Rice are guilty of mass murder. For example Patrick Moore, who claims to have founded Greenpeace, tirelessly blames that organization for delaying the arrival of Golden Rice (AllowGoldenRiceNow.org 2015). Ironically, the biotechnology industry and individual biotechnologists have simultaneously claimed that Golden Rice is already in use: "It's helped save many, many lives and improved the quality of life of those who eat it," explained biotechnology leader Roger Beachy (Krock 2009). These claims have caused considerable discomfort to the IRRI and PhilRice scientists who are actually doing the Golden Rice breeding (Dubock 2014, p. 73).

Most important for our analysis is that during its 15 years of work as a public relations vehicle, Golden Rice has consistently been constructed as medicine for a generic patient (Fig. 3). Its targets are only children located geographically only in "poor countries" (Beachy 2003), "developing countries" (Enserink 2008), or occasionally "Asia" (Dawe and Unnevehr 2007). This portrayal is generally backed up by aggregated statistics on the prevalence of VAD-related blindness and deaths on a global scale. Even economic analyses purporting to calculate the cost of delaying approval (Wesseler et al. 2014) and the potential impact and cost effectiveness of Golden Rice (Stein et al. 2006) make no mention of the Philippines.[14]

But it is specifically in the Philippines that Golden Rice is moving toward release, and it must be bred into rice varieties that grow well in the Philippines and meet with the approval of Filipino regulators, planters, and consumers.[15] In short, Golden Rice must become embedded in the Philippines, and this is precisely where it has floundered.

The Golden Rice trait involves a multigene engineering of a metabolic pathway that could affect various plant functions. Gene expression may be affected by where the genetic construct is deposited by the random insertion process.[16] Altering the location of beta-carotene may affect the plant's sensitivity to sunlight (Golden Rice Project nd). Any of these effects may vary with the genetic background, that is, the variety into which the trait is crossed. Golden Rice seeds first arrived at IRRI in January 2001 (Dawe and Unnevehr 2007; Dubock 2014) in the *javanica*[17] subspecies that is commonly commercialized in the United States (Dubock 2014, p. 76); it then began the long journey of being crossed into varieties of the *indica* subspecies

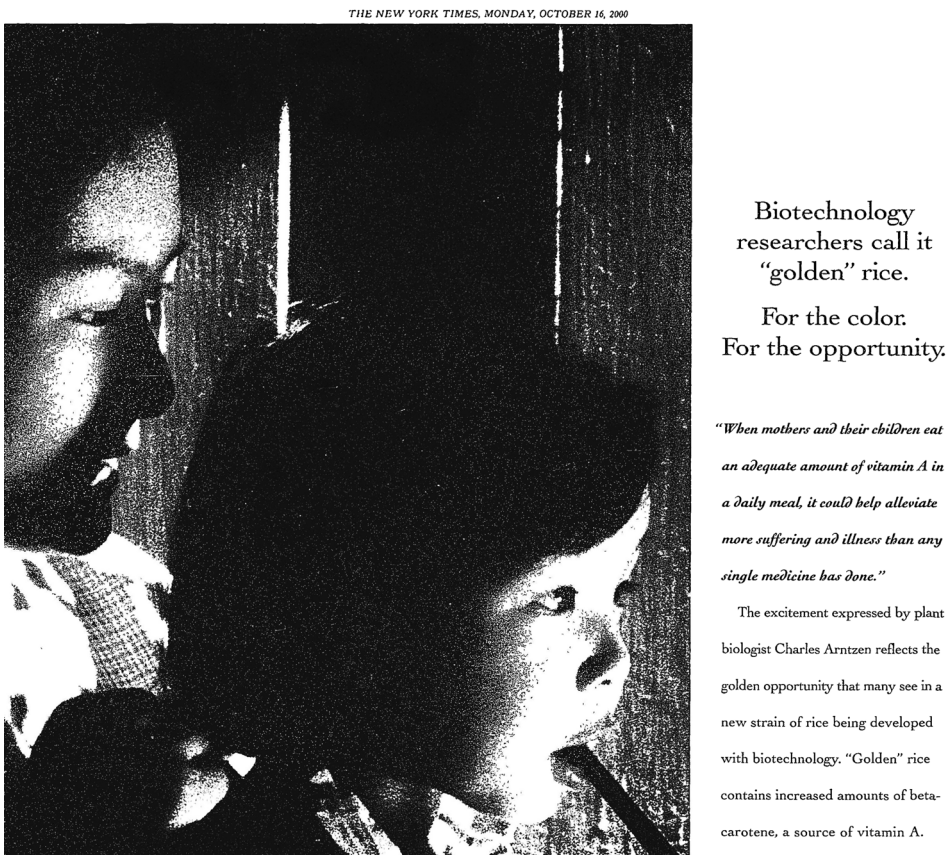
[13] Monsanto has been eager to take credit for Golden Rice (Stone 2011b), although it neither funded nor conducted research on Golden Rice. It did waive some of its patent rights on a promoter gene used in early experiments, but this gene has long since been replaced.

[14] There are two publications specifically on potential impacts of Golden Rice in the Philippines. One of these (Zimmermann and Qaim 2004) includes no actual information about the Philippines beyond a few outdated countrywide health statistics. The other (Dawe et al. 2002) is an empirical study of VAD levels in an area where rice is neither a major crop nor a dominant starch in local diets.

[15] Field trials of Golden Rice are also planned for Bangladesh and Indonesia, but commercial release in these countries appears to be much farther off.

[16] The normal method of creating a GM crop is to (1) engineer a genetic construct containing one or more genes for desired traits, and then (2) expose cells from the target plant to an agent capable of inserting the construct into the cells' DNA. Each instance where the construct is successfully integrated into the target cell DNA is a unique "transformation event." Transformed cells are then selected and grown into whole plants that can be bred conventionally. There are several different Golden Rice 2 (GR2) transformation events; at least one is located in an exon and one in an intron associated with root development (Dubock 2014, p. 81).

[17] The *javanica* subspecies is now often classified as the tropical variant of the *japonica* subspecies.


THE NEW YORK TIMES, MONDAY, OCTOBER 16, 2000 A9

Biotechnology researchers call it "golden" rice.

For the color.
For the opportunity.

"When mothers and their children eat an adequate amount of vitamin A in a daily meal, it could help alleviate more suffering and illness than any single medicine has done."

The excitement expressed by plant biologist Charles Arntzen reflects the golden opportunity that many see in a new strain of rice being developed with biotechnology. "Golden" rice contains increased amounts of beta-carotene, a source of vitamin A.

Fig. 3 Golden Rice advertisement by the Council for Biotechnology Information in the *New York Times*, October 16, 2000. The description of potential benefits is placeless, referring only to "the world's children"

commonly grown in the Philippines. By 2003 the trait had been crossed into the Green Revolution standby IR-64 (an *indica* variety), and the next year saw the first open-field-grown and harvested Golden Rice (Dubock 2014). By 2008 IRRI was running confined field trials of nine different genetic transformation "events" from two different "constructs" (a "cassette" or "cartridge" comprising genes of interest) in four different rice varieties. From 2011 to 2013, IRRI and PhilRice ran confined and open field trials of the most promising event (GR2R), again crossed into IR-64. Meanwhile they were attempting to achieve good yields using the variety Rc82 ("Peñaranda"), which is popular in the Philippines and also suited to testing because it is well characterized (A. Alfonso, pers. comm.). But as of this writing, over 14 years after IRRI began trying to adapt Golden Rice to the Philippines, the best varieties still exhibit a "yield drag" compared to isogenic seeds (i.e., lower productivity than seeds that are identical except for the Golden Rice trait) (Dubock 2014; Eisenstein 2014; IRRI 2014a). Contrary to claims that millions of children are dying worldwide because of Greenpeace's opposition to Golden Rice, the new strains simply are not ready and are not expected to be ready for at least several years. They are proving very difficult to embed.

Looking ahead, even if Golden Rice is brought up to speed agronomically, approved, released, and adopted by farmers, the stated goal saving of millions of lives, or even having any significant public health impact, is also complicated by the specific conditions of the Philippines. Recognizing major public health problems with a range of micronutrient deficiencies, the country has undertaken programs including food supplements, nutrition education, and a law in 2000 requiring food fortification of common ingredients with vitamin A, iron, and iodine (Phillipines Department of Health nd). As a result, the incidence of childhood VAD in the Philippines dropped from a peak of 40.1 % in 2003 to 15.2 % in 2008 (Food and Nutrition Research Institution nd). VAD figures from the 2013 national nutrition survey have not been released, but as other types of malnutrition have continued to fall, the VAD rate must be expected to have fallen too.

IRRI itself acknowledges that VAD is being effectively reduced without Golden Rice, but holds that the reductions may be due in part to nutrition and breastfeeding programs that may have less impact in "difficult to reach" areas (IRRI nd). Thus, as Golden Rice becomes embedded, it shrinks from a sure solution, to a pervasive public health crisis of the developing world, to a possible dietary supplement in certain, unnamed, difficult-to-reach spots in the Philippines (Brooks 2013).

Undernourished children in underserved corners of the Philippines are also likely to suffer from intestinal

infections and parasites that can impede absorption of beta-carotene and conversion to vitamin A. They are virtually certain to have poor diets lacking in fats, which the body needs to absorb vitamin A (Dawe et al. 2002; Haskell 2012; Nestle 2001), but human feeding trials have only been conducted with well-nourished individuals. In the heavily cited (and since retracted)[18] study by Tang et al. (2012), children were fed balanced meals with 20 % energy from fat, demonstrating only that Golden Rice worked in children who did not need it.

In contrast to the confidence and certainty found in most Golden Rice rhetoric, announcements from IRRI itself have been more transparent about the unknowns of the technology. IRRI's position is that "it has not yet been determined whether daily consumption of Golden Rice does improve the vitamin A status of people who are vitamin A deficient" and that the trait will not be released unless and until a planned study finds Golden Rice to be "safe and efficacious" (IRRI 2014b). However all indications are that the planned feeding study will not address two further important questions. One is whether beta-carotene in the rice grains will survive periods of storage, not to mention cooking; there are reasons to fear it will not, because carotenoids can break down in the presence of oxygen, light, and heat (Pénicaud et al. 2011). As Michael Hansen (2013) points out, "the real question is what are the carotene levels in rice that has sat in storage at room temperature for month or two, similar to the local storage conditions for those who might grow this rice…no studies have been done." The second question is whether opening up the metabolic pathway for carotene in the endosperm reduces the flow of compounds into other nutrients. This is quite plausible, but it is unclear if the planned trials will investigate it. A study focused on vitamin A delivery will be misleading unless it assesses levels of other nutrients as well.

Heirloom rice

Around the same time that Golden Rice came to IRRI, an enterprise started up based on cultivation and export of "heirloom" landrace varieties in the spectacular terraces of the Cordillera mountains of northern Luzon (see Fig. 4). Although a much smaller enterprise than the Green Revolution or Golden Rice, and given less attention here, this project constitutes a distinct rice world with important contrasts in both productivism and embedment.

The heirloom rice project was preceded by developments in the mid-1990s, including the passage of the Indigenous People's Rights Act (bringing recognition to Cordilleran groups such as the Ifugao) and UNESCO's recognition of the Ifugao rice terraces as a World Heritage Site. At the same time, the aging of the Cordillera's farming populations and out-migration contributed to the replacement of heirloom landrace rices in some parts of the highlands by "lowland" (Green Revolution) varieties (Domoguen 2011). The reversal of this decline and the valorization of the heirloom rices are aims of the Cordillera Heirloom Rice Project (CHRP).

Founded in 2005, the CHRP comprises the US-based firm Eighth Wonder, founded and run by American Mary Hensley, a former Peace Corps volunteer in the Cordilleras; Philippines-based RICE Inc., founded and run by Filipina Vicky Garcia; the Rice Terraces Farmers Cooperative (RTFC), a farmer organization based in Ifugao; and some assistance and personnel from provincial agriculture departments. Operating in Ifugao, Mountain, and Kalinga provinces (see Fig. 2), RICE Inc. collects information on landrace rices and cultivation practices, recruits local farmers to grow selected landraces to export standards, and buys and processes harvests. The cultivation practices are a mixture of local and introduced: for instance, farmers receive training in organic techniques.[19] Most of the rice is exported to the United States, where it is marketed by Eighth Wonder, but there is an increasing market within the Philippines. By 2015 the project's sales had risen to 27.5 metric tons (MTs), with 21.5 MTs going to North America and 6 MTs to Manila. The RTFC also sells directly to customers locally and as far away as Manila, but sales figures are unavailable. These amounts are tiny in a country that produces around 12 million tons and imports over 1.5 million tons of rice each year,[20] but still attract considerable attention from government and scientific institutions as well as the international press (Mann 2012, pp. 386–392).

The CHRP exemplifies an emerging trend of business models promoting socially and environmentally responsible consumption of products that are marketed explicitly at their place of origin and with connections to local agrarian communities. Cereal grains have been largely absent from this kind of embedding; indeed, grains led the way to the anonymous food commodity chains of modern times (Cronon 1991). Historically, Indian/Pakistani basmati and Thai jasmine rices have been the main exceptions to this general

[18] The study by Tang et al. (2012) was retracted in July 2015 after an investigation revealed breaches of ethical procedures. See *Retraction Watch* (2015).

[19] The rice is certified organic by the Organic Certification Center of the Philippines, but since OCCP standards are not yet recognized internationally, it is only labeled organic in the Philippines.

[20] World Rice Statistics, http://ricestat.irri.org:8080/wrs2/entrypoint.htm (Accessed 27 June 2015).

Fig. 4 Rice terraces, Ifugao Province. Copyright G.D. Stone

rule, although the identity and embeddedness of both types have been seriously diluted by uses of intellectual property law that many regard as biopiracy (Woods 2002–3). Importing upmarket, identity-preserved rices into North America was pioneered by California-based Lotus Foods, founded in 1995. Lotus sells heirloom rices from China, Thailand, Viet Nam, Madagascar, and Bhutan. Though Lotus's marketing philosophy does underscore *terroir*, a culinary concept more usually invoked in relation to products such as wine, cheese, and tea, the company ties rices to geography and culture in an abstract way. The company's products are mostly marketed without place (e.g., "Jade Pearl Rice") or identified only by country of origin (e.g., "Madagascar Pink," "Bhutan Red") (Lotus Foods 2015).

The CHRP deals in rices that are identify-preserved but embedded with greater geographical specificity. Rices are sourced only from terrace growers in the mentioned provinces, and marketed explicitly as products of the Cordilleran terraces and grown by indigenous farmers. Its brands are named mainly with ethno-regional designations and terms taken from local languages ("Kalinga Jekot," "Tinawon White"), and its promotional materials feature the terraces, peoples, and even specific rice rituals (Eighth Wonder 2015). This ethos is propagated throughout the project, as when the Cordillera Regional Agriculture Director, who supports the project, says: "More than profit, we are promoting the rich Cordilleran cultural heritage through this export" (Medina 2013). Terrace imagery is featured in all of Eighth Wonder's promotional materials, slogans, and even trademark (Druguet 2010).

While originally conceived as a connection between heirloom farmers and North American gourmets, the CHRP has increasingly found a market for its rices in Manila, and it has spawned several such initiatives, including small-scale direct farmer-to-consumer sales (Sekimoto and Augustin-Jean 2012).

This symbolic embedding of heirloom rice creates a diametrical contrast with the Green Revolution's placeless ideotypes. Heirloom varieties are not only plants of the kind the Green Revolution displaced, they are essentially connected to production practices the Green Revolution sought to eliminate. They resist the Green Revolution's

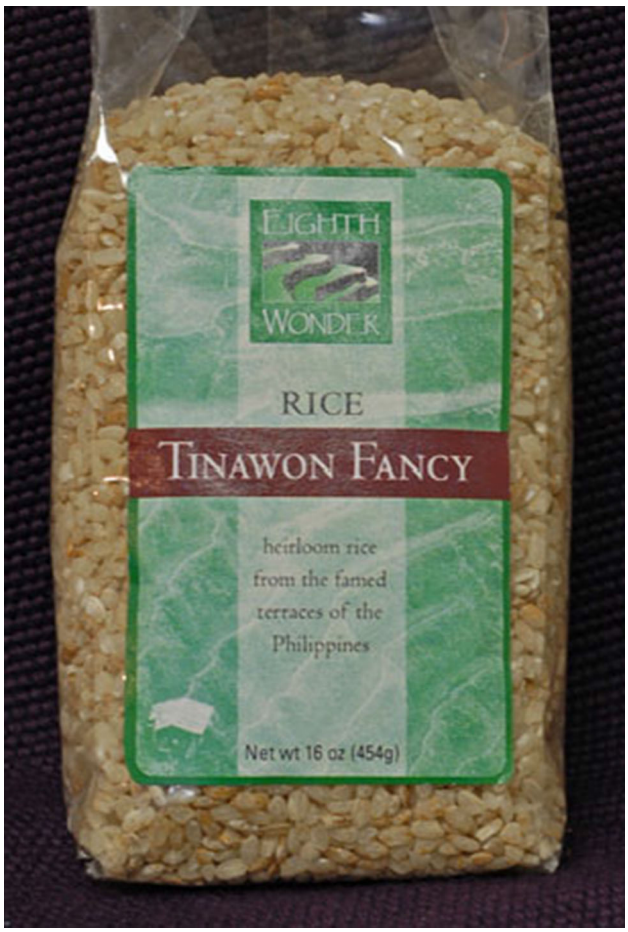


Fig. 5 An Eighth Wonder heirloom rice product. The Ifugao term tinawon literally means "once per year"—a distinguishing trait of pre-Green Revolution rice. Copyright G.D. Stone

imposed dependence on external inputs and instruction, as well as its promulgation of a de-situated, disembedded style of agriculture.

The market for heirloom rice also challenges productivism's fixation on yield, as these rices all have a significantly lower maximum potential output than Green Revolution rice varieties. Their pre-Green Revolution nature is even reflected in the name: the Ifugao word for heirloom landrace rice, *tinawon*, literally means "once a year" (Fig. 5). *Tinawon* rices are slow-maturing, long-season varieties that can only be grown once in every 12 months, in contrast to the short-season, multicropped rices that are a defining hallmark of the Green Revolution. They are normally grown with minimal external inputs, since they are prone to lodging (toppling over) if heavily fertilized.[21]

[21] CHRP growers produce yields of 2.8–3.8 MT/ha of unmilled rice. Elite rice cultivars such as China's Y Liangyou 900 achieve yields approaching 15 MT/ha. in ideal conditions (Cheung 2014).

The CHRP also constructs rice heirlooms on eating qualities, including flavor, aroma, and nutrition. Green Revolution rices were never promoted on eating qualities and, indeed, the placeless early workhorse varieties were widely felt to be poor tasting. Golden Rice is obviously promoted on the basis of one aspect of its nutrition, but there can be little informed discussion of flavor, aroma, or other nutritional qualities until it is known what variety or varieties will appear on the market with these traits.

However the valorization of the eating qualities of rices touted as products of the Philippine Cordillera confronts a serious obstacle in North America. Despite a large population of Filipino immigrants, Filipino cuisine has little following there and Filipino restaurants are scarce. Consequently, unlike basmati rice sold in Indian restaurants, sticky (sushi) rice in Japanese restaurants, arborio (risotto) rice in Italian restaurants, and jasmine rice in Thai restaurants, Filipino heirloom rice is largely a culinary orphan.

A related problem arises from valorizing the rice's production by smallholders using preindustrial methods. In North America, patrons of alternative food networks (AFNs) and "sustainable" production overwhelmingly prioritize the "local" in food products. To many AFN enthusiasts, the fact that the rice has *place* is valued; it's just the wrong place. This "unreflexive localism" has been contested on several fronts; some see it as depoliticizing farming while promoting nativism (DuPuis and Goodman 2005; Harris 2010; Holloway and Kneafsey 2004), and it may be co-opted by corporate food production (Guthman 2004). Moreover, in the United States, virtually no rice is grown outside of six states, so "local rice" is an oxymoron for most Americans. Nevertheless, the sentiment continues to undermine the heirloom rices' claims to embeddedness, complicating Eighth Wonder's marketing efforts.

But recent years have brought a major boost to the heirloom project from a somewhat ironic development. IRRI, the very institution that earlier had aimed to replace rice landraces with disembedded ideotypic rice, and which currently promotes disembedded GM rice, is now committed to a project promoting and celebrating heirloom rice. This is intriguing not only because of IRRI's earlier opposition to heirloom seeds and traditional agriculture, but also because the leaders of CHRP today are fundamentally opposed to the GM rice that IRRI is also championing. Project founder Mary Hensley opposes GM crops in general on safety and philosophical grounds, and sees Golden Rice as a misguided approach to improving nutrition (Hensley pers. comm. 2015). Clearly, there is a deep divide between the two rice worlds and their philosophies of valorizing place. But as of 2014, IRRI has entered into a major intervention program and partnership with the CHRP. IRRI has begun to produce pamphlets, web postings, and videos extolling the wonders

of the low-input, locally adapted landraces that it sought to wipe out in the 1960s. Transgenics are not mentioned. In a striking reversal of the Green Revolution mandate of overhauling seeds, agriculture practices, and culture, an IRRI scientist appears in a promotional video explaining: "[t]he value of these heirloom varieties comes from combining them with the communities where they have been traditionally grown…[where] their whole culture is built around them" (IRRI 2015).

The reasons behind IRRI's new appreciation of pre-Green Revolution seeds and practices are partly financial; funding has been in serious decline at IRRI (Bradsher and Martin 2008), as at other CGIAR centers, so researchers have had to become more entrepreneurial. Major funding for this large-scale four-year project came from the Philippine Department of Agriculture. But the interest in rice grown on terraced mountain slopes is also consistent with a growing interest at IRRI in non-ideotype seeds and in the realities of nonoptimal growing environments. In 2002 IRRI organized a Consortium for Unfavorable Rice Environments (CURE) to promote such research. But another reason is that the need for spectacle that helped drive Green Revolution breeding policies has never left, and indeed the dwindling revenues make attention-getting agricultural headlines singularly important. The famously photogenic terraces feature prominently in IRRI promotional materials, along with traditional bundles of grain and appealing images of Cordillera farmers discussing heritage and tradition. As of this writing, collaboration with RICE Inc. is featured more prominently in IRRI promotional materials than is Golden Rice.

Conclusions

Golden Rice will probably be released within 5 years. We have not attempted to make predictions on its acceptance and impact; there are many unknowns, but IRRI's own assessment that the rice may augment the already successful nutrition and breastfeeding programs, at least in some "difficult to reach" areas, is plausible. What we do predict is that its release will be greeted with fanfare and consternation by its supporters and opponents, respectively. Lobbies on each side will treat the rice as an index of GM crop progress in the developing world, and both sides will be able to marshal some evidence to support their existing positions on GM crops in general.

This discussion has made clear that such essentializing interpretations will be seriously blinkered. More than a transgenic vitamin tablet, Golden Rice stands at the center of what we term a rice world, with a particular set of ideas about disembedded DNA, strong linkages to the history of crop genetic engineering, and a unique development at the interface of molecular biology and conventional breeding.

Moreover, Golden Rice's past struggles and future impacts cannot be understood apart from the context of the Philippines. If and when it is released, Golden Rice will appear in specific cultivars from Philippine breeding programs, marketed and distributed through particular channels to farmers who cultivate Philippine landscapes, and eaten by Filipino children with their own patterns of nutrition. But in a broader sense, Golden Rice cannot be understood apart from the rich history of divergent rice worlds of the Philippines. IRRI, the very institution producing Golden Rice, was a product of the Green Revolution, and its rice world centered on replacing Philippine landraces with disembedded grain and reformed peasant farming. The varieties into which the Golden Rice trait is being crossed are late Green Revolution varieties. However the use of GM technologies, disembedded rices, and even industrial cultivation methods are being challenged actively by the rice world centered on Cordilleran heirlooms. This last rice world is small but rapidly growing, gaining international attention and converts—including IRRI, which ironically has emerged as a leading proponent of heirloom rice.

The key concept we have used for unpacking and contrasting these rice worlds has been embedment. We do not champion or disparage the forms of embeddedness or disembeddedness we have described in the three rice worlds. They offer advantages and disadvantages, depending on one's perspective and purpose. Using ideotype breeding to disembed varieties from their origins has clear advantages in the development of improved cultivars, although it has led to well-known problems in agro-ecology, including a strong trend toward monocultural cropping and a steep decline in crop biodiversity (Tripp 1996). The disembedding and reassembling of genes and varieties was probably essential in the creation of rice with beta-carotene in the endosperm, although it now appears that the rices thus produced will not get to farmers until 20 years after this achievement. Promoting heirloom rices may obviously benefit agro-biodiversity and local, small-scale Cordilleran growers, but it also faces some resistance in the Philippines for exporting heirloom rice to foreign elites (Licnachan 2015). There are also serious critiques of embedded alternative food networks for potentially reproducing the economic arrangements they seek to challenge (DuPuis and Goodman 2005; Guthman et al. 2007; Harris 2009). These debates have focused on goods produced and consumed locally; rice that is marketed on the basis of its local agro-ecological context but sold to consumers half a world away will require further consideration in the future.

Acknowledgments Major funding for this research came from the John Templeton Foundation initiative, "Can GM Crops Help to Feed the World?" Additional funds came from the ESRC STEPS Centre at Sussex University, UK. For assistance and insights we are grateful to Bruce Tolentino and Nollie Vera Cruz of IRRI; Marlon Martin and Jacy Moore of SITMo; Stephen Acabado of UCLA; Jovy Camso of Mountain Province Agriculture Department; Vicky Garcia, Mary Hensley, and Jimmy Lingayo of the CHRP; Tony La Viña of Ateneo School of Government; Tony Alfonso formerly of PhilRice; Amber Heckelman of University of British Columbia; Priscilla Stone of S.I.T.; and two anonymous referees.

References

AllowGoldenRiceNow.org. 2015. http://www.allowgoldenricenow.org. Accessed 22 March 2016.

Beachy, R.N. 2003. Editorial: IP policies and serving the public. *Science* 299: 473.

Borlaug, N.E. 1972. Breeding wheat for high yield, wide adaptation, and disease resistance. In *Rice breeding*, ed. IRRI, 581–589. Los Baños: International Rice Research Institute.

Bowen, S. 2011. The importance of place: Re-territorialising embeddedness. *Sociologia Ruralis* 51: 325–348.

Bradsher, K., and A. Martin. 2008. World's poor pay price as crop research is cut. *New York Times*, 18 May.

Bray, F. 1994. Agriculture for developing nations. *Scientific American* 271: 30.

Brooks, S. 2008. *Global science, public goods? Tracing international science policy processes in rice biofortification*. Brighton: Institute of Development Studies, University of Sussex.

Brooks, S. 2010. *Rice biofortification: lessons for global science and development*. London: Earthscan.

Brooks, S. 2011. Living with materiality or confronting asian diversity? The case of iron-biofortified rice research in the Philippines. *East Asian Science, Technology, and Society* 5: 173–188.

Brooks, S. 2013. Biofortification: Lessons from the Golden Rice project. *Food Chain* 3: 77–88.

Charles, D. 2001. *Lords of the harvest: Biotech, big money, and the future of food*. Cambridge: Perseus.

Cheung, F. 2014. Yield: The search for the rice of the future. *Nature* 514: S60–S61.

Cronon, W. 1991. *Nature's metropolis: Chicago and the great west*. New York: W.W. Norton and Company.

Cullather, N. 2003. Parable of seeds: The Green Revolution in the modernizing imagination. In *The transformation of Southeast Asia: International perspectives on decolonization*, ed. M. Frey, R.W. Pruessen, and T.T. Yong, 257–267. London: Routledge.

Cullather, N. 2004. Miracles of modernization: The Green Revolution and the apotheosis of technology. *Diplomatic History* 28: 227–254.

Cullather, N. 2010. *The hungry world: America's cold war battle against poverty in Asia*. Cambridge: Harvard University Press.

Datta, S.K. 2004. Rice biotechnology: A need for developing countries. *AgBioForum* 7(1–2): 31–35.

Dawe, D., R. Robertson, and L. Unnevehr. 2002. Golden rice: What role could it play in alleviation of vitamin A deficiency? *Food Policy* 27: 541–560.

Dawe, D., and L. Unnevehr. 2007. Crop case study: GMO Golden Rice in Asia with enhanced Vitamin A benefits for consumers. *AgBioForum* 10: 154–160.

Domoguen, R.L. 2011. Cordillera losing its heirloom rice varieties. *Sun Star*. Baguio, 28 Feb.

Donald, C.M. 1968. The breeding of crop ideotypes. *Euphytica* 17: 385–403.

Dowd-Uribe, B. 2014. Engineering yields and inequality? How institutions and agro-ecology shape Bt cotton outcomes in Burkina Faso. *Geoforum* 53: 161–171.

Dowd-Uribe, B., D. Glover, and M. Schnurr. 2014. Seeds and places: The geographies of transgenic crops in the global south. *Geoforum* 53: 145–148.

Druguet, A. 2010. From the invention of landscapes to the construction of territories: The terraces of the Ifugaos (Philippines) and the Cevenols (France). PhD thesis, Anthropology, National Museum of Natural History.

Dubock, A. 2014. The present status of Golden Rice. *Journal of Huazhong Agricultural University* 33: 69–84.

DuPuis, E.M., and D. Goodman. 2005. Should we go "home" to eat? Toward a reflexive politics of localism. *Journal of Rural Studies* 21: 359–371.

Eighth Wonder. 2015. http://www.heirloomrice.com/index.php?p=project. Accessed 22 March 2016.

Eisenstein, M. 2014. Biotechnology: Against the grain. *Nature* 514: S55–S57.

Enserink, M. 2008. Tough lessons from golden rice. *Science* 320: 468–471.

Evans, N., C. Morris, and M. Winter. 2002. Conceptualizing agriculture: A critique of post-productivism as the new orthodoxy. *Progress in Human Geography* 26: 313–332.

Evenson, R.E. 2004. Food and population: D. Gale Johnson and the Green Revolution. *Economic Development and Cultural Change* 52: 543–569.

Evenson, R.E., and D. Gollin. 2003. Assessing the impact of the Green Revolution, 1960 to 2000. *Science* 300: 758–762.

Evenson, R.E., and D. Gollin. 1997. Genetic resources, international organizations, and improvement in rice varieties. *Economic Development and Cultural Change* 45: 471–500.

Food and Nutrition Research Institute. nd. Seventh national nutrition survey 2008–2009. Department of Science and Technology (Philippines).

Glover, D. 2010. The corporate shaping of GM crops as a technology for the poor. *Journal of Peasant Studies* 37: 67–90.

Golden Rice Project. nd. Testing the performance of Golden Rice. http://www.goldenrice.org/Content2-How/how8_tests.php. Accessed 22 March 2016.

Granovetter, M. 1985. Economic action and social structure: the problem of embeddedness. *American Journal of Sociology* 91: 481–510.

Guthman, J. 2004. *Agrarian dreams: The paradox of organic farming in California*. Berkeley: University of California Press.

Guthman, J., et al. 2007. Commentary on teaching food: Why I am fed up with Michael Pollan et al. *Agriculture and Human Values* 24: 261–264.

Haas, J.D., J.L. Beard, L.E. Murray-Kolb, A.M. del Mundo, A. Felix, and G.B. Gregorio. 2005. Iron-biofortified rice improves the iron stores of nonanemic Filipino women. *The Journal of Nutrition* 135: 2823–2830.

Hansen, M. 2013. Golden Rice myths. GMWatch website. http://gmwatch.org/index.php/news/archive/2013/15023-golden-rice-myths. Accessed 22 March 2016.

Harris, E. 2009. Neoliberal subjectivities or a politics of the possible? Reading for difference in alternative food networks. *Area* 41: 55–63.

Harris, E. 2010. Eat Local? Constructions of place in alternative food politics. *Geography Compass* 4: 355–369.

Harwood, J. 2015. Global visions vs. local complexity: Experts wrestle with the problem of development. In *Rice: Global networks and new histories*, ed. F. Bray, P.A. Coclanis, E.L.

Fields-Black, and D. Schäfer, 41–55. New York: Cambridge University Press.
Haskell, M.J. 2012. The challenge to reach nutritional adequacy for vitamin A: β-carotene bioavailability and conversion—evidence in humans. *The American Journal of Clinical Nutrition* 96: 1193S–1203S.
Holloway, L., and M. Kneafsey. 2004. Producing–consuming food: closeness, connectedness, and rurality. In *Geographies of rural cultures and societies*, ed. L. Holloway, and M. Kneafsey. London: Ashgate.
IRRI. nd. Why is Golden Rice needed in the Philippines since vitamin A deficiency is already decreasing? IRRI website. http://irri.org/golden-rice/faqs/why-is-golden-rice-needed-in-the-philippines-since-vitamin-a-deficiency-is-already-decreasing. Accessed 22 March 2016.
IRRI. 1977. *IR8 and beyond*. Los Baños: International Rice Research Institute.
IRRI. 2014a. What is the status of the Golden Rice project coordinated by IRRI? IRRI website. http://irri.org/golden-rice/faqs/what-is-the-status-of-the-golden-rice-project-coordinated-by-irri. Accessed 22 March 2016.
IRRI. 2014b. When will Golden Rice be available to farmers and consumers? IRRI website. http://irri.org/golden-rice/faqs/when-will-golden-rice-be-available-to-farmers-and-consumers. Accessed 22 March 2016.
IRRI. 2015. *Heirloom rice: people place purpose* (video). https://www.youtube.com/watch?v=blU9b3cQvoY. Accessed 22 March 2016.
ISAAA. 2014. The global status of commercialized biotech/GM Crops: 2014 (Brief No. 49). Ithaca: The International Service for the Acquisition of Agri-biotech Applications.
Kijima, Y., K. Otsuka, and D. Sserunkuuma. 2011. An inquiry into constraints on a Green Revolution in Sub-Saharan Africa: The case of NERICA Rice in Uganda. *World Development* 39: 77–86.
Kloppenburg Jr, J.R. 1991. Social theory and the de/reconstruction of agricultural science: Local knowledge for an alternative agriculture. *Rural Sociology* 56: 519–548.
Krock, B. 2009. Researchers look to enriched crops to solve childhood malnutrition. In Researchers look to enriched crops to solve childhood malnutrition. Student Life (Washington University), 28 Sept.
Kudlu, C., and G.D. Stone. 2013. The trials of genetically modified food: Bt eggplant and Ayurvedic Medicine in India. *Food Culture and Society* 16: 21–42.
Laborte, A.G., K. de Bie, E.M. Smaling, P.F. Moya, A.A. Boling, and M.K. Van Ittersum. 2012. Rice yields and yield gaps in Southeast Asia: Past trends and future outlook. *European Journal of Agronomy* 36: 9–20.
Lambrecht, B. 2001. *Dinner at the new gene cafe: how genetic engineering is changing what we eat, how we live, and the global politics of food*. New York: St. Martins Press.
Licnachan, E. 2015. Response from community stakeholders. Symposium on the Ifugao Rice Terraces. National Museum, Manila, Philippines, 18 June 2015.
Lobell, D.B., K.G. Cassman, and C.B. Field. 2009. Crop yield gaps: Their importance, magnitudes, and causes. *Annual Review of Environment and Resources* 34: 179–204.
Long, S.P., A. Marshall-Colon, and X. Zhu. 2015. Meeting the global food demand of the future by engineering crop photosynthesis and yield potential. *Cell* 161: 56–66.
Lotus Foods. 2015. Products. http://www.lotusfoods.com/index.php/products/. Accessed 22 March 2016.
Maat, H., and D. Glover. 2012. Alternative configurations of agricultural experimentation. In *Contested agronomy: agricultural research in a changing world*, ed. J. Sumberg, and J. Thompson, 131–145. London: Routledge.
Mann, C. 2012. *1493: Uncovering the New World Columbus created*. New York: Vintage Books.
McAfee, K. 2003. Neoliberalism on the molecular scale. Economic and genetic reductionism in biotechnology battles. *Geoforum* 34: 203–219.
Medina, J. 2013. FilAms urged to buy Philippine heirloom rice. *Inquirer.net*, 1 Oct. http://business.inquirer.net/145403/filams-urged-to-buy-philippine-heirloom-rice. Accessed 22 March 2016.
Montgomery, J.D. 1998. Toward a role-theoretic conception of embeddedness. *Journal of Sociology* 104: 92–125.
Morris, C., and J. Kirwan. 2011. Ecological embeddedness: an interrogation and refinement of the concept within the context of alternative food networks in the UK. *Journal of Rural Studies* 27: 322–330.
Murdoch, J., T. Marsden, and J. Banks. 2000. Quality, nature, and embeddedness: Some theoretical considerations in the context of the food sector. *Economic Geography* 76: 107–125.
Nestle, M. 2001. Genetically engineered "Golden" Rice unlikely to overcome vitamin A deficiency. *Journal of the American Dietetic Association* 101: 289–290.
Niblio, S.R. 1995. *War, diplomacy, and development: The United States and Mexico, 1938–1954*. Wilmington: Scholarly Resources.
Normile, D. 2006. Consortium aims to supercharge rice photosynthesis. *Science* 313: 423.
Ohnuki-Tierney, E. 1993. *Rice as self: Japanese identities through time*. Princeton: Princeton University Press.
Otsuka, K., F. Gascon, and S. Asano. 1994. "Second-generation" MVs and the evolution of the Green Revolution: the case of Central Luzon, 1966–1990. *Agricultural Economics* 10: 283–295.
Peng, S., G.S. Khush, P. Virk, Q. Tang, and Y. Zou. 2008. Progress in ideotype breeding to increase rice yield potential. *Field Crops Research* 108: 32–38.
Pénicaud, C., N. Achir, C. Dhuique-Mayer, M. Dornier, and P. Bohuon. 2011. Degradation of β-carotene during fruit and vegetable processing or storage: Reaction mechanisms and kinetic aspects: A review. *Fruits* 66: 417–440.
Philippines Department of Health. nd. Micronutrient program. http://www.doh.gov.ph/micronutrient-program. Accessed 22 March 2016.
Polanyi, K., C. Arensberg, and H. Pearson. 1957. *Trade and market in the early empires*. New York: Free Press.
Qaim, M., and D. Zilberman. 2003. Yield effects of genetically modified crops in developing countries. *Science* 299: 900–902.
RAFI. 2000. Golden Rice and Trojan Trade Reps: A case study in the public sector's mismanagement of intellectual property. RAFI Communique 66, Sept/Oct 2000. http://www.etcgroup.org/sites/www.etcgroup.org/files/publication/305/01/com_goldenrice.pdf. Accessed 22 March 2016.
Retraction Watch. 2015. Golden rice paper pulled after judge rules for journal. 30 July 2015. http://retractionwatch.com/2015/07/30/golden-rice-paper-pulled-after-judge-rules-for-journal/. Accessed 22 March 2016.
Richards, P. 2004. Private versus public? Agenda-setting in international agro-technologies. In *Agribusiness and society: Corporate responses to environmentalism, market opportunities and public regulation*, ed. K. Jansen, and S. Vellema, 261–284. London: Zed.
Richards, P. 1997. Toward an African Green Revolution? An anthropology of rice research in Sierra Leone. In *The ecology of practice: studies of food crop production in sub-Saharan West*

Africa, ed. A.E. Nyerges, 201–252. Amsterdam: Gordon and Breach.

Schurman, R., and W.A. Munro. 2010. *Fighting for the future of food: Activists versus agribusiness in the struggle over biotechnology*. Minneapolis: University of Minnesota Press.

Sekimoto, S., and L. Augustin-Jean. 2012. An export niche in the Philippines: The commodification of a speciality rice in Ifugao Province. In *Geographical indications and international agricultural trade: The challenge for Asia*, eds. L. Augustin-Jean, H. Ilbert, and N. Saavedra-Rivano, 181–203. Palgrave Macmillan.

Shiva, V. 2000–1. World in a grain of rice. *The Ecologist* Dec–Jan. 30:9.

Sievers-Glotzbach, S. 2014. Reconciling intragenerational and intergenerational environmental justice in Philippine agriculture: the MASIPAG farmer network. *Ethics Policy and Environment* 17: 52–68.

Soleri, D., D.A. Cleveland, G. Glasgow, S.H. Sweeney, F. Aragón Cuevas, M.R. Fuentes, and H. Ríos. 2008. Testing assumptions underlying economic research on transgenic food crops for Third World farmers: Evidence from Cuba, Guatemala, and Mexico. *Ecological Economics* 67: 667–682.

Stein, A.J., H.P.S. Sachdev, and M. Qaim. 2006. Potential impact and cost-effectiveness of Golden Rice. *Nature Biotechnology* 24: 1200–1201.

Stone, G.D. 2002. Both sides now: Fallacies in the genetic-modification wars, implications for developing countries, and anthropological perspectives. *Current Anthropology* 43: 611–630.

Stone, G.D. 2011a. Field versus farm in warangal: Bt cotton, higher yields, and larger questions. *World Development* 39: 387–398.

Stone, G.D. 2011b. Golden Rice, soon. Or not. FieldQuestions blog. http://fieldquestions.com/2011/05/30/golden-rice-soon-or-not/. Accessed 22 March 2016.

Stone, G.D. 2015. Biotechnology, schismogenesis, and the demise of uncertainty. *Journal of Law and Policy* 47: 29–49.

Tang, G., Y. Hu, S. Yin, Y. Wang, G.E. Dallal, M.A. Grusak, and R.M. Russell. 2012. b-Carotene in Golden Rice is as good as b-carotene in oil at providing vitamin A to children. *American Journal of Clinical Nutrition* 96:658–664 [Retracted, August 2015].

Tripp, R. 1996. Biodiversity and modern crop varieties: sharpening the debate. *Agriculture and Human Values* 13: 48–63.

von Caemmerer, S., W.P. Quick, and R.T. Furbank. 2012. The development of C4 rice: Current progress and future challenges. *Science* 336: 1671–1672.

Wesseler, J., S. Kaplan, and D. Zilberman. 2014. The cost of delaying approval of Golden Rice. *Agricultural and Resource Economics Update* 17(3): 1–3.

Winter, M. 2003. Embeddedness, the new food economy, and defensive localism. *Journal of Rural Studies* 19: 23–32.

Witt, H., R. Patel, and M. Schnurr. 2006. Can the poor help GM Crops? Technology, representation, and cotton in the Makhathini Flats, South Africa. *Review of African Political Economy* 109: 497–513.

Woods, M. 2002–3. Food for thought: The biopiracy of Jasmine and Basmati rice. *Albany Law Journal of Science and Technology* 13:123–143.

Wright, A. 1984. Innocents abroad: American agricultural research in Mexico. In *Meeting expectations of the land*, ed. W. Jackson, et al., 135–151. Berkeley: North Point Press.

Ye, X., S. Al-Babili, A. Kloti, J. Zhang, P. Lucca, P. Beyer, and I. Potrykus. 2000. Engineering the provitamin A (beta-carotene) biosynthetic pathway into (carotenoid-free) rice E. *Science* 287: 303.

Zimmermann, R., and M. Qaim. 2004. Potential health benefits of Golden Rice: A Philippine case study. *Food Policy* 29: 147–168.

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