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The sticky materiality of neo-liberal neonatures: GMOs and the agrarian question

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ABSTRACT

This article uses Marxist theories of agrarian capitalism to explore the political economy of genetically modified organisms (GMO) agriculture. It argues that the successes and failures of GMO agriculture have been partly circumscribed by the structural requirements of the capitalist system, as well as by the materiality of GMO crops themselves. Successful innovations have been able to mitigate the material barriers to accumulation found in agricultural production, and thus appeal directly to farmers as comparatively profitable capital inputs. In this way, they cohere with David Goodman’s notion of appropriationism, where manufactured capital inputs (such as pesticides, machinery and fertilisers) replace ‘natural’ inputs (such as manure or draft animals), reducing labour time and biological contingency, and thus creating a competitive advantage for those farmers who adopt the new technology (at least temporarily). Conversely, innovations that are geared at consumers rather than farmers have largely failed due to their status as value-added products (whose value is subjective and market-driven) rather than capital goods. The article uses contrasting case studies of herbicide-tolerant soybeans, beta-keratin-enhanced rice and slow-ripening tomatoes to demonstrate how and why the structural imperatives of global capitalism have enabled the success of some, and the failure of other innovations.

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The late-twentieth-century rise of biotechnology – and GMOs (genetically modified organisms) in particular – garnered tremendous popular, activist, scholarly and corporate attention. Evaluations of GMO technologies ranged from apocalyptic to utopian, but few doubted that GMOs would significantly transform our food system. Some thought they would yield a cornucopia ofhardier, tastier and more nutritious crops, while others prophesised an invasion of chimeric Frankenfoods. However, two decades since the commercial release of the first GMO food, FlavrSavr tomatoes, GMOs have been neither a global panacea nor a pandemic. Their modest, if not underwhelming, performance may be what needs accounting.

This is not to say there have been no successes, particularly early on in the late 1990s. Two transgenic events – tolerance to herbicides and resistance to pests – have been remarkably implemented, capturing substantial control over some of the world’s most significant crops, including corn (32 per cent), soybeans (75 per cent), cotton (82 per cent) and canola (26 per cent) (James 2011). From the perspective of Monsanto and a few other corporations, such as Syngenta and Bayer Life Sciences, these innovations have been cash cows, enabling near-monopoly control over not only transgenic...
seed sales, but also often other agricultural inputs, such as herbicides. But these innovations – among them Roundup Ready soybeans and canola and Bt corn and cotton – are virtually the only commercially successful GMOs. Moreover, all of these innovations were already commercially available in the late 1990s. In the meantime, no further innovations of significance have emerged, while many have faltered, such as Bt potatoes, Roundup Ready wheat and perhaps most notably, beta-keratin-enhanced ‘Golden Rice’. Not unrelated to their economic and technical failures, GMOs have met staunch resistance from both well-organised activists and national, regional and local governments around the world, leading to moratoria, mandatory labelling, rigorous safety assessments and a legally binding precautionary accord on trade in GMOs in the Cartagena Protocol of 2000. Only two dozen or so countries grow GMO crops as more than a tiny fraction of total agricultural acreage, while Europe, Asia and Africa have almost completely resisted GMO food crops, with only a few exceptions. 

No single factor accounts for either the early success or subsequent setbacks of the GMO food economy. To understand the contemporary context, we have to examine its juridico-political, economic, biophysical and cultural dimensions. However, this article focuses on the material, in particular the economic, considering from a Marxist perspective how the logic of capital has both enabled and constrained the development of the GMO food economy, and how the biophysicality of GMO crops has been manifested as both an opportunity and a challenge to capital.1 It locates GMOs within the historical context of agrarian capitalism, linking with earlier debates over the problems that agriculture poses to capital as a site of profitable accumulation, showing how both the successes and failures of GMO agriculture can be understood in the wider context of agrarian capitalism, and the problems (and opportunities) that agriculture’s unique spatial, temporal and biophysical demands pose to capital. I argue that technologies that can temporarily overcome or reduce these barriers to accumulation hold the potential to be highly profitable and thus successful, while those that do not directly alter the conditions of production will likely be ignored by industry. This dialectic can, therefore, help explain both the successes and failures of GMO agriculture to date, and demonstrate the extent to which corporate profitability rather than social utility has driven GMO innovation thus far.

The trajectory of GMO technological innovation has been heavily structured by the logic of capital, a condition that accounts for the lack of success in innovations not targeted at reducing the temporal, spatial and biophysical constraints to capital within the production process. For example, herbicide tolerance and pest resistance are both innovations that affect production by changing the ways farmers address the problems posed by weeds and pests. Innovations geared at consumers (such as nutrient enhancement or slower ripening), which yield value-added end products but make no difference in the actual production process, have largely failed.

The article begins with an historical overview of the agrarian question, discussing how Marxists have dealt with the problems agriculture poses to capital accumulation and how capital has sought to overcome these problems. Section II theorises the conditions under which GMO agriculture has been successful, considering how GMOs fit a wider tendency within agricultural capitalism to mitigate spatial, temporal and biophysical barriers to the reduction of labour and production time (and thus to added surplus value) through capital inputs, or what Goodman et al. (1987) have termed ‘appropriationism’ (1). However, at stake in GMO agriculture is not simply the way biophysical inputs are replaced with synthetic industrial inputs, but how property rights are managed throughout the commodity chain with patents and technology use agreements (TUAs), ensuring the extraction of rents for patent holders, a logic of accumulation that Pechlaner (2010) has termed ‘expropriationism’ (245). Through both of these logics, capital is able to subsume elements of the production process, extracting greater surplus value than under an unsubsumed system of production. While others have theorised the role of intellectual property rights (IPR) in enabling capital accumulation in biotechnology (see Kloppenburg 2004, Rajan 2006), Pechlaner’s contribution is unique in the way she theorises expropriationism in relation to (and in contrast to) appropriationism, enabling us to clearly understand both the continuity and change in the ways capital has sought to accrue profits in agriculture, both now and before the advent of biotechnology.
However, while Goodman et al. and Pechlaner, respectively, have emphasised the roles of appropriationism and expropriationism in the successes of GMOs, little attention has been paid to how these same logics work to circumscribe the scope of GMO development. My analysis builds on these earlier accounts by arguing and demonstrating that the logic of capital works to both enable and constrain the trajectory of GMO development. Appropriationism and expropriationism are thus significant in understanding not only how and why certain innovations have met with success, but also why so many others have failed. This demonstrates that although capitalism’s competitive logic may promote innovation, in biotechnology and elsewhere, it is only certain innovations – and by no means the most socially useful – that can ever be profitably pursued. To date, no accounts of GMO crops have sought to synthesise the theoretical insights of Goodman et al. and Pechlaner to demonstrate how appropriationism and expropriationism work in tandem to make certain GMOs profitable for biotech firms and inescapable for farmers. Through a case study of Roundup Ready soybeans in the USA, one of the most successful GMO crops to date, this article traces exactly how and why these logics made Roundup Ready so successful, while simultaneously circumscribing the success of later innovations.

Section III turns to a theorisation of the barriers to accumulation posed by both the logic of capital and the materiality of GMOs. It considers how consumption-oriented innovations have failed to provide an impetus for capital to invest and have thus been ignored, despite great potential benefits to the public. Just as the logic of capital has enabled the development of certain innovations, it has hindered the development of others. The section also considers a separate set of constraints: the ecological and biophysical barriers to accumulation that are in part a consequence of the inherent dynamism and complexity of the life sciences. Empirically, this section is animated by two case studies. The first considers the Flavr Savr tomato, a genetically modified tomato designed to stay ripe longer without spoiling that met with commercial failure. The second examines Golden Rice, a beta-keratin-enhanced transgenic rice variety, which despite being successfully grown since 1999 has failed to gain approval for commercial release and attracted little interest from investors.

Ultimately, the argument advanced here is not meant to dismiss GMOs as a failed technology. Their failures are overdetermined by the structural contours of global capitalism, among other factors. Today’s GMO food economy emerged in the context of the particular political economic configuration of neo-liberal globalisation, and its real-world manifestations cannot be detached from this context. However, a different political economic context, driven by motives other than profit and capital accumulation, would enable a different, and perhaps more hopeful, GMO food economy. The story of GMO agriculture is today only a recent iteration of the story of capitalist agriculture. The future of GMO agriculture holds the potential for a wholly different narrative.

**Lineages of the agrarian question**

Since the nineteenth century, various Marxist theorisations of capitalism have sought to understand how and why capital’s penetration of agriculture remained partial and contradictory, especially in contrast with industrial manufacturing (Kautsky 1899, Marx 1967, 1973). Marx argued that the substantial gap between labour time (where value is produced) and production time (which included periods of natural growth that took place outside of human intervention) greatly reduced the potential profitability of agriculture in relation to industry, dissuading capitalists from investing there, since surplus value – and thus profits – can only be accrued while labour is engaged (Mann 1989). For Kautsky (1899), the spatial nature of agricultural production precluded unrestrained expansion and thus accumulation as agricultural producers could only expand by buying other farmers’ land, which needed to be situated adjacent to the buyer’s existing productive property. Such spatio-temporal restraints, coupled with peasants’ willingness to ‘overexploit’ themselves, meant that peasant modes of production were able to resist real subsumption by the capitalist system. Kautsky further argued that petty commodity producers may even have a role to play in the maintenance of capitalist political economy by providing a cheap labour source for large farms that would
otherwise have insufficient labour power to be viable. Kautsky’s position stood in contrast to that of Lenin (1900), who argued that it was inevitable that the competitive pressures of the market would turn all farmers into either capitalists or proletarians, leading to the erasure of the peasant classes of old. However, at the time, it was Lenin’s Development of Capitalism in Russia that made the bigger impact, often being heralded as akin to the fourth volume of Capital, while Kautsky’s work was left relatively untouched (Kautsky 1899). Despite ample evidence to the contrary, agriculture was expected to conform to the inescapable prerogatives of the market, to become indistinct from industrial production. However, it was only in the late 1970s – partially in the context of a revived Marxist research programme – that the agrarian question – and the missteps of past approaches – was revisited both in the work of Harriett Friedman (1978) and in the work of Susan Mann and James Dickenson (1978), with what became known as the ‘Mann–Dickenson thesis’ (Mann 1989: 4).

Mann and Dickenson observed how American agriculture in the 1970s remained largely the domain of ‘family farms’ employing only a couple of seasonal workers, and relying almost exclusively on family labour. That this remained (and remains) the most prevalent relation of production in agriculture seemed bizarre, given the centrality of agriculture and food to everyday life and the relative speed at which capital had been able to penetrate manufacturing, services and other natural resource industries. Reiterating Marx’s earlier claims, they proposed that ‘capitalist development progresses most rapidly in those spheres where production time can be successfully reduced and where the gap between production time and labor time can be minimised’ (Mann 1989: 34). Furthermore, because production time involves natural, biophysical processes, it has, traditionally, been a difficult barrier to overcome, stunting the development of capitalist agriculture. The persistence of the petit bourgeois labour relation as dominant within agricultural production thus emanates from the barriers to subsumption (and thus accumulation) that the biophysicality of agriculture poses to capital. Importantly, Mann (1989) did not propose these barriers to be absolute, but rather, like all barriers to capital, relative to a particular historical moment.

The materiality of agricultural production poses barriers of temporal delay, spatial distance and biological contingency. However, following Henderson (1998), we must consider how the very existence of these barriers – if they can be overcome – pose new opportunities for capital accumulation that would not otherwise exist. In this vein, Goodman et al. (1987) have developed a framework for understanding how capital might overcome the spatial, temporal and biophysical barriers in agriculture. Focusing less on the problem of labour’s subsumption within agriculture than on the challenges posed by agriculture’s materiality, Goodman et al. argued that it was agriculture’s status as a ‘natural production process’ that made it distinct from industrial production (1). They argued that because ‘there was no alternative to the biological transformation of solar energy into food’, the industrialisation of agriculture ‘was determined by the structural constraints of the agricultural production process, represented by nature as the biological conversion of energy, as biological time in plant growth and animal gestation, and as space in land-based rural activities’ (1–2). These material barriers to accumulation could only be worked around – and not removed directly – through the industrialisation of discrete elements of agricultural production. Thus rather than altering the fundamental biophysical processes inherent to agricultural production, they saw capital as pursuing two distinct accumulation strategies that allowed industrial inputs to replace natural ones: ‘appropriationism’ and ‘substitutionism’ (2). ‘Appropriationism’ refers to the replacement of natural, biophysical elements of the agricultural production process with industrially manufactured ones. Examples of this include the use of machinery rather than draft animals, or chemical fertilisers and pesticides instead of manures and natural pest-eaters. In each case, natural, non-commodified inputs (that are not valorised through human labour inputs) are replaced with industrially produced inputs. These inputs reduce labour time and biological contingency, and thus create a competitive advantage for those farmers who adopt the new technology (at least temporarily). Substitutionism refers to the replacement of agricultural foods with synthetic foods, bypassing agricultural production completely in the total industrial production of food and fibre.  


In theorising the structural basis for the problem agriculture poses to capital (Mann 1989) and the means by which this problem can be overcome (Goodman et al. 1987), Mann and Goodman et al. have provided a useful starting point to theorising the relationship between biophysical properties and the logic of capital in agriculture, and in understanding (at least in part) why we have the food economy that we have. Moreover, there exists a synergistic tension between the two arguments, as Mann (1989) discusses at length in a critical review of Goodman et al. If Mann’s theory suggests that the problem with agriculture is that its valorisation process involves considerable time lag and uncertainty, Goodman’s theory accounts for how this problem can be overcome through synthetic inputs that reduce time lag (since value is realised much more efficiently through industrial production, where, not incidentally, labour time and production time are more synchronised) and uncertainty. The contributions of both authors serve as an important starting point, enabling us to understand GMOs as a new wave of appropriationist solutions to the barriers to accumulation located by Mann. However, a deeper analysis is needed to truly understand what is at stake in the GMO food economy. Following Pechlaner (2010), I want to show how GMOs differ from earlier appropriationist innovations in the role patents play in the valorisation process, and more to the point, how both the successes and limitations of the GMO food economy are specific to the particular biophysicality of GMOs and to the historical moment of neo-liberal capitalism.

**Theorising the GMO food economy: (fast)-ripened for profit**

Appropriationism has been the dominant accumulation strategy for capital within agriculture throughout the twentieth century. In 2007, there were roughly three million people engaged in farming in the USA, and 2.2 million farms; that is only 1.4 people per farm (EPA 2007). Moreover, in 2012, there were only 787,000 hired farm labourers (USDA 2013a). While most of these labourers work on large farms – the nine per cent of farms with at least $500,000 per year in sales that account for seventy-five per cent of total agricultural output – even these farms employ only a few people (less than four on average) – fewer than a small coffee shop or restaurant. Agribusiness may be big business. Farming is not. Capital has penetrated agriculture not through the actual cultivation process but in the upstream (and downstream) industries that fuel agricultural production. Indeed, the twentieth century has seen a substantial conversion of agricultural input expenses along these very lines: labour costs have fallen precipitously as a percentage of total expenses, while purchased capital inputs, including machinery, chemicals, seeds and feed, have skyrocketed. According to Goodman et al. (1987), between 1930 and 1974, labour costs fell by 75 per cent, while chemical costs increased thirteen-fold, feed and seed costs nearly quadrupled, and machinery increased by 2.5 times. Why has appropriationism been the dominant accumulation strategy within American agriculture? The reasons for this are threefold.

First, the actual production process is difficult to control through human labour, produces little surplus value and has thus generally failed to attract investment from capital. However, industrially produced capital inputs can be very profitable because they overcome or mitigate immediate barriers to accumulation on the farm (Mann 1989). Moreover, these inputs are produced in a factory setting. This means that labour time and production time are more synchronised, leading overall to a higher value agricultural economy. Furthermore, none of the spatial, temporal and biological contingencies that (sometimes literally) plague agriculture are present in industry. All these factors are more conducive to the steady accumulation of profits, and thus render appropriationist input production more attractive to capital than the cultivation process itself. Finally, insofar as they reduce labour time per output (or land per output), they immediately provide farmers with a competitive advantage. If some farmers acquire a technology, then all others are compelled to obtain it in order to compete with the new standard that has been set, creating a treadmill of production (see Schnaiberg 1980, Gould et al. 2004). However, once the new standard is generalised, the competitive advantage is erased, and the overall profit rate is reduced for everyone. But the industrial firms that produce appropriation technologies can continue to generate large profits from their technology. Moreover,
they will likely yield greater control over farmers, given that farmers tend to be caught in an hourglass power matrix within the agricultural commodity chain, pinched between the industrially oriented upstream input suppliers, on one hand, and downstream retailers and processors, on the other.

For these various reasons, we can understand why capital has largely favoured manufacturing tractors and combines, producing synthetic fertilisers and pesticides, and even breeding high-yielding varieties of hybrid seeds to the dirty work of in-field production (of course, downstream industries such as processing, packing, shipping and retailing are equally important). But to what extent do GMOs fit with the appropriationist model? Writing in 1987, before the practical implications of biotechnology could be known, Goodman et al. argued that biotechnology could develop as either an appropriationist or a substitutionist technology, with some innovations such as herbicide and pest-resistant crops fitting the framework of earlier appropriationist technologies, while others such as GMO-based artificial sweeteners fitting the logic of substitutionism. Nearly two decades on we must ask how the practical reality of GMO agriculture may fit (or complicate) existing theories of agrarian capitalism.

In many ways, GMOs – or at least the ones that have met with commercial success – hold parallels with earlier appropriationist technologies. Produced in the high-tech research labs of chemical companies such as Monsanto and Bayer, their transgenic traits have been isolated and spliced into existing seeds to make the production process more efficient and predictable. Like other appropriationist technologies, they are synthetic capital inputs that farmers inevitably become compelled to buy if they want to stay competitive. Insect-resistant crops hold much the same function as a newer, more efficient insecticide. Herbicide-tolerant crops enable greater ease (and thus savings) in herbicide applications. However, in one fundamental way, GMOs (as well as hybrid seeds) differ from other appropriationist technologies: they are alive. Their liveliness provides capital with a unique opportunity to synthetically alter the biophysical process of plant growth itself. Yet this liveliness also poses new challenges to capital not encountered in the ‘harder’ fields of chemical and mechanical engineering: specifically, their reproducibility and vivacious dynamism.

While GMOs’ status as lively commodities sets them apart from many earlier appropriationist technologies, this dichotomous distinction is complicated by the history of hybrid seeds. Kloppenberg (2004) has carefully documented the way hybrid seeds shifted from a public good created through university research programmes to a privatised accumulation strategy for capital. Through his analysis, we can see how GMOs appear as an extension of the logic of accumulation inherent to hybrid seeds, rather than as a categorically different phenomenon. However, there are certain important differences between GMOs and hybrid seeds as accumulation strategies. After considering what sets both hybrid seeds and GMOs apart from other appropriationist technologies, I will explore the differences between hybrid seeds and GMOs.

As Kloppenburg (2004) argues, seeds are unique in their simultaneous role as both product and means of production. That is to say that any crop can be harvested, sold and eaten, or have its seeds saved and replanted the following year. Indeed, the inability of capital to compel farmers to buy seeds every year instead of saving them has held back capital’s penetration of the seed ‘industry’, at least until the advent of hybrid seeds. With hybrid seeds – initially the creative domain of public research universities – farmers had access to high-yielding varieties and other seeds with desirable traits. The catch was that these desirable traits could only last for one generation, and seed-saving meant that these traits would be progressively watered-down, resulting in smaller, less consistent yields. In the 1960s and 1970s, capital foresaw seed breeding as an area of potential profitability; in the emerging context of neo-liberalism, control was wrested from public breeders and placed in private hands (Kloppenburg 2004). However, capital required one more safeguard to ensure secure access to profits from seed breeding. It needed laws to ensure complete control over the reproductive capacities of their seeds. These came in the Union for the Protection of New Varieties of Plants (UPOV) agreement of 1961, which made it illegal for farmers (or anyone else) to sell saved seeds that came from a patented parent variety. Farmers could still replant their own seeds;
but with diminishing returns from the diffusion of desirable traits, seed breeders figured that farmers would rather buy new hybrid seeds every year than save their less desirable offspring.

Much of the story of hybrid seeds applies to GMOs as well; the key difference is the use of transgenic engineering rather than traditional breeding practices to produce targeted phenotypic advantages. However, while hybrid seeds have been bred for the selection of particularly desirable phenotypes – often expressed through the interaction of multiple genes – GMOs are created through the isolation and insertion of a few specific genes of a different species. This means that while qualitatively GMOs may be more distinct from native species, quantitatively it is hybrids that have perhaps the greater genetic differentiation. For this reason, saved GMO seeds are more likely to contain the specific set of transgenes needed to produce the desired trait than hybrid seeds (Kloppenberg 2004). Farmers’ ability to save GMO seeds introduced a new contingency into the equation, and thus a new barrier to profitable accumulation that needed to be rectified. The solution to this was a new IPR regime, even more stringent than the UPOV.

Emphasising this increasingly important role for IPR, Pechlaner (2010, 2012) has proposed an alternative framework for conceptualising the political economy of GMO agriculture with her concept of expropriationism. While keeping intact the relevance of Goodman et al.’s earlier concepts of appropriationism and substitutionism, expropriationism refers to the set of patent laws specific to seeds – in particular GMOs – that ensure that their value is controlled by the patent holder throughout the chain. In this way, expropriationism functions as a means of accumulation by dispossession for capital, enclosing the genetic composition of GMOs as private property and exploiting ownership rights over those genes for profit (see Prudham 2007). However, while Pechlaner recognises that this is not simply a preference but a requirement for capital accumulation to be possible in plant biotechnology, the question of why expropriationism is a requirement for GMOs in particular to be profitable to capital remains. While patent safeguards are important to the profitability of other inputs such as pesticides, the following reasons account for their unique significance to GMOs.

The costs associated with creating a transgenic plant are very high, and must be borne in every single seed. In industrial manufacturing, the value of a machine is reflected in the labour and capital (dead labour) costs embedded in it. Each new machine of the same type will be produced with the same labour and capital costs, and will thus have the same value. However, with GMOs, this is not the case. This is because what is produced is not a durable good, but a code. While tremendous labour and capital are expended in the creation of one successful GMO plant, those that follow reproduce naturally, with little human labour inputs in their actual production. For that reason, patent laws that exclude the saving of seeds are necessary (otherwise the value of GMO seeds would be virtually zero – no more than any other seeds – considering how little it costs a farmer to save seeds and sell them). In other words, because the amount of socially necessary labour time embedded in a first-generation GMO is enormous, and the amount embedded in posterior generations is virtually zero, biotech firms require control over the distribution of second-generation seeds to make sure that the costs of creating the first generation can be amortised across the second generation (and beyond).

Expropriationism has been advanced through two means: traditional patent laws, and what are termed TUAs. With traditional patent laws, biotech firms simply rely on the patent protection granted to biotechnological innovations under the Diamond vs. Chakrabarty ruling of 1980, which declared that patents could be claimed on organisms containing a novel gene produced through biotechnology. TUAs, on the other hand, reflect a more rigorous attempt by biotech firms – Monsanto in particular – to control profits, and in the process, to control their farmer customers. TUAs are private agreements signed between farmers and patent holders at the time of purchase that grant the patent holder a number of rights, and the farmer a number of restrictions over the use and control of the seeds (Charles 2001, Andree 2007). Apart from forbidding farmers from saving or selling seeds, they require farmers to use specific chemical inputs (such as herbicides), usually manufactured by the biotech firm itself. They also grant biotech firms the right to periodically inspect the buyer’s farm for up to three years (Kloppenburg 2004, Andree 2007). TUAs operate as if the licencing
agreement behind a particular software, just as Microsoft requires its computer hardware manufacturers to include other software packages along with its Windows operating system (in effect requiring consumers to buy these other software packages when they buy a Windows computer), biotech firms sell their own software (i.e. codes) – transgenic traits – embedded in the ‘hardware’ of actual seeds, and likewise linked through licencing agreements to the purchase of other commodities, in this case chemical inputs. While it may seem dramatic, this software analogy was at the centre of the mind of Monsanto CEO Robert Shapiro when the company decided to pursue its TUA policy (Charles 2001). Overall, IPR has been the solution to the problems posed by the seed’s status as a lively commodity, with both reproductive and contingent properties. It has enabled GMOs – albeit in certain limited instances – to be profitable for lead firms such as Monsanto. In examining one of the most profitable cases – that of Monsanto’s Roundup Ready soybeans in the USA – we can see how the logics of appropriationism and expropriationism have been successfully applied in practice.

**Super soya: riding the train to profits**

Herbicide-tolerant soybeans are often invoked as a paradigmatic example of the success of GMO crops, and with good reason. In 2012, herbicide-tolerant soybeans accounted for 93 per cent of soybeans in the USA (having peaked around 2007), and 75 per cent globally (James 2011, USDA 2013b). Moreover, they have represented close to 100 per cent of soybeans in Argentina (the world’s third largest producer of soybeans) since the early 2000s and have steadily been taken up in the world’s second largest producer, Brazil, where they accounted for 71 per cent as of 2009 (GMO Compass 2010). Two types of herbicide-tolerant soybeans (and other crops) exist: Liberty Link soybeans made by Bayer Crop Industries and resistant to the glufosinate-based herbicide Liberty (Basta) and Roundup Ready soybeans made by Monsanto and resistant to the glyphosate-based herbicide Roundup. However, 91 per cent of GMO soybeans planted belong to the Roundup Ready variety (Pechlaner 2012). Roundup Ready soybeans were first created in 1989, achieved regulatory approval in the USA in 1994, and first went on the market in 1996 (Charles 2001). Their success for Monsanto has been unprecedented, and they represent a leading example of the dual logics of appropriationism and expropriationism.

The herbicide Roundup, or glyphosate, first emerged in the 1970s. It was different from earlier herbicides because it degraded quickly and did not kill weeds for a week or more, rather than immediately (Charles 2001). Roundup’s relatively low toxicity also made it seem more environmentally friendly than other options and its broad-spectrum applicability made it useful in a variety of situations. Glyphosate kills plants by deactivating an enzyme (only found in plants) necessary for amino-acid creation, thus starving the plants of nutrients (Charles 2001). Even in 1995, glyphosate only accounted for a fifth of all herbicides used on soybeans in the USA (Carpenter and Gianessi 1999). Monsanto figured that the broad-spectrum applicability and relatively low environmental impact of Roundup could be a major draw, but only if they could make its application easy for farmers, a task that required that the crop itself become tolerant. If farmers could replace all other herbicides with Roundup, they would save money, and Monsanto’s profits from Roundup sales would be substantial. Monsanto would have a massive market for both their transgenic soybean seeds and their trademark herbicide. Consequently, ‘Roundup tolerance became the project that bankrolled Monsanto’s pursuit of genetically engineered crops’ (Charles 2001: 60).

However, Monsanto faced challenges from the outset. Soybeans were initially recalcitrant crops, refusing to accept transgenic DNA (Charles 2001). Approaches that had worked with earlier test crops were unsuccessful with soybeans. Monsanto needed both a bacterium capable of synthesising the target enzyme whose DNA could be used and a means of inserting that DNA into the soybeans (Charles 2001). The solution to the problem of glyphosate’s target enzyme came in an unorthodox place: not in Monsanto’s St. Louis laboratories but in a sludge pond on the edge of its Louisiana Roundup factory, where glyphosate-resistant bacteria had festered in the slime of glyphosate...
residue ponds. Scientists at Monsanto had stumbled across the source of their target gene, but the question of how to insert it into a soybean plant remained. It was only through the invention of the gene gun – a tool that enabled scientists to shoot strands of DNA into target cells – that this was made possible (Charles 2001). After developing their herbicide-tolerant soybeans in a laboratory setting in 1988, Monsanto formed a partnership deal with Asgrow, a major soybean seed breeder, to develop herbicide tolerance in the most productive breeds of soybeans to which Asgrow had patents. This partnership also included Agracetus, the company that had invented the gene gun in 1986. By 1991, they had succeeded in creating Roundup tolerance in Asgrow’s soybean varieties (Charles 2001).

Monsanto now faced a new problem of how to infiltrate the soybean seed market. While Pioneer Hi-bred, the largest breeder of soybean seeds in the USA, was unwilling to pay more than half a million dollars for the use of Monsanto’s Roundup Ready gene, Monsanto needed another revenue stream if it was going to make any profits from their innovation directly, besides simply through increased herbicide sales (Charles 2001). The solution to this came in the form of technology fees, whereby Monsanto would licence its genes directly to the farmers themselves. Licence agreements would also prevent farmers from saving seeds. When farmers would buy the seeds, they would buy the physical seeds from a seed breeder and the legal right to use the seeds (under certain conditions) from Monsanto. Seed companies could concentrate on selling seeds for the same prices they normally would, and Monsanto could continue to sell their value-added inputs; only now, those inputs took the form of genetic material within the seeds themselves, as well as their trademark herbicide. Since Monsanto’s TUAs precluded farmers from saving seeds, it meant that seed breeders had the benefit of selling seed every year to farmers without the cost of being blamed by farmers for this infringement on their freedom. Monsanto could mandate that farmers use Roundup exclusively (rather than off-patent glyphosate herbicides), and had the right to monitor and inspect fields to ensure compliance. Farmers who did not comply were forced to pay 120 times the cost of the technology fee (Pechlaner 2010).9

What effect did the near-unanimous switch to Roundup Ready soybeans have on the American soybean industry? For Monsanto, it meant unprecedented sales of Roundup: the herbicide became the highest selling chemical input in the history of agriculture as early as 2001 (Mascarenhas and Busch 2006). For the farmers, switching to Roundup Ready enabled reduced labour costs, as fewer herbicide applications were required (Benbrook 2001). Roundup Ready also enabled a switch to no-tillage growing practices, which also amounted to reduced labour costs (Qaim and Traxler 2005). Furthermore, herbicide costs fell due to the ability to rely on Roundup alone. Table 1 evidences these trends: it shows how chemical input costs, including herbicides, declined following the 1996 introduction of Roundup Ready soybeans. Conversely, the costs of seeds increased rapidly during the 2000s, owing to the ability of seed breeders to charge more for their high-demand transgenic seeds as well as the new costs for farmers of entering TUAs with Monsanto. Thus aside from farmers and Monsanto, Roundup Ready soybeans have been profitable for Monsanto’s partnership seed breeders. For them, the TUAs have meant that farmers are required to return to them, year after year, to buy new seeds; consequently, their sales have increased as well. Initially, the losers were the producers of other herbicides, who saw their share of the herbicide market plummet as early as the late 1990s (Carpenter and Gianessi 1999).

Table 1. US annual soybean production: input costs in US dollars per planted acre.

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</thead>
<tbody>
<tr>
<td>Seeds</td>
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<td>15.01</td>
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<td>10.19</td>
<td>12.37</td>
<td>20.48</td>
<td>24.95</td>
<td>22.32</td>
<td>14.46</td>
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<tr>
<td>Variable expenses</td>
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<td>49.08</td>
<td>69.69</td>
<td>80.00</td>
<td>77.28</td>
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</tbody>
</table>

Note: Costs/revenue in dollars per planted acre.
Roundup Ready soybeans fully evidence how the dual logics of appropriationism and expropriationism are at work in the contemporary project of agricultural biotechnological capitalism. Roundup Ready soybeans represent a productive capital input that gives adopters a competitive advantage over non-adopters. It enables reduced labour and capital costs, thus generating savings and increased revenues. Farmers have the option of reducing their labour costs or expanding acreage for the same amount of labour (Pechlaner 2012). Consequently, other farmers are compelled to participate in the new regime in order to keep up with the competition. Like earlier appropriationist innovations, it enables farmers to employ industrial inputs to control the agricultural process more directly. Costs are reduced, as well as contingencies. The crops themselves are rendered part of the industrial fabric of production, as they are immune to the toxic effects of the herbicide. Farmers can spray without worrying about the volatility of their soybeans; the beans are engineered to withstand chemical inputs. In this way, the seeds become machine like, synthetically designed to work with rather than against the other synthetic inputs.

However, while the logic of appropriationism is central to Roundup Ready soybeans’ success as profitable fixes for Monsanto and its seed-breeding partners, perhaps even more so is the logic of expropriationism. Through the TUAs, Monsanto is able to guarantee access to stable profits, as farmers are prevented from saving seeds and required to buy Roundup. Monsanto is able to set the price of these inputs – both licences for its genes and its herbicide – at rates low enough to ensure that farmers continue to sign on, rather than being driven by market forces. In fact, without these agreements, both the off-patent availability of glyphosate and the ability of farmers to save seeds would render Roundup Ready a losing endeavour for Monsanto. Roundup Ready soybeans’ appropriationist benefits may be what renders them beneficial – even necessary – for farmers in a competitive context; but only under the expropriationist legal regime can Monsanto ensure that the greatest benefits of its investment return home. It then follows that the logic of expropriationism is indispensable to understanding the success of agricultural biotechnology.

Unruly transgenes, uninterested markets

If the logic of capital has enabled certain GMO technologies to be wildly profitable, as competitive market pressures compel farmers to adopt transgenic varieties or lose out, it has also played a role in hindering the development of others. While herbicide tolerance and insect resistance for soy, cotton, maize, canola, sugar beet and alfalfa have been successful, there are three factors that make these crops distinct from most others. First, they are all among the most widely grown crops in the USA and beyond; they thus each hold the potential for enormous profits. Second, none of them are primarily consumed directly as foodstuffs; all of them are used in processed foods (maize, sugar beet and soy), fed to animals (alfalfa, soy and maize), made into oils (canola and soy) or not eaten at all (cotton). They thus lack the symbolic value of culturally significant dietary staple foods such as wheat and potatoes, both of which failed to launch in North America in Roundup Ready and Bt varieties respectively. Third, they have all relied on appropriationism, making agricultural production more efficient for farmers, rather than appealing to consumers’ desires for more nutritious or tasty food. These anomalies are not incidental; rather, they define both the successes and limitations of the GMO food economy. While there is a multitude of factors that explain this context – cultural, political, economic, ecological and social10 – this section will focus on the economic and ecological rationales behind the lack of success of GMO innovations that stray from the three above conditions.

First, market size is a significant factor in structuring which sorts of innovations will be seen as worthwhile for biotechnology capital. From the outset, the costs of producing a transgenic variety for a major crop such as corn are not much different from the cost of developing a transgenic variety for a minor crop such as parsnips. But the potential profits are wildly different. This is why biotech firms have only seriously taken on the most widely grown crops. Second, because GMO foods are not usually consumed directly, consumer backlash has been smaller than for foods with
a greater symbolic value, such as wheat or potatoes (Andree 2011). Perceived consumer and produc-
er backlash against Roundup Ready wheat led Monsanto to pull research on the product after
farmers said they would be unwilling to grow it (Pechlaner 2012, Eaton 2013). The same corporation
withdrew its Bt potato, the NewLeaf, after two of the largest commercial buyers of potatoes, McCain
and McDonalds, announced that they would only be using GM-free potatoes, citing consumer con-
cerns (Pechlaner 2012). Even GMOs that use standard transgenic traits (herbicide tolerance and insect
resistance) in these two widely grown crops have failed due to public concerns, articulated through
farmers and major buyers alike. The relative symbolic value held by wheat and potatoes led to a back-
lash where there had been none for other, less symbolically important crops.

Third, GM crops that do not make the production process more efficient for farmers— that is,
evince appropriationism— have failed, such as the FlavrSavr tomato and Golden Rice. This is be-
because there is no structural pressure on farmers to adopt these technologies. Without providing
increased yields or decreased production costs, the only way these innovations can be profitable
is if publics are willing to pay significantly more for them. However, the historical success of the
anti-GMO movement, coupled with people’s unfamiliarity with the technology and its implications,
has meant that there is very little reason for the industry to bank on public opinion remaining con-
sistently favourable. Appropriationist GMOs are profitable insofar as the public accepts them as ‘sub-
stantially equivalent’ or interchangeable with cisgenic varieties. Value-added GMOs could only be
profitable if publics valued them higher than cisgenic varieties, an unlikely proposition at best,
save for a sea change in the public’s perception of GMO foods.11

To these three main reasons for the limitedness of the GMO food economy can be added two
more. Fourth, there is the issue of biological contingency. Fifth, and related to all of these, is the
issue of cost. As the case study of Roundup Ready soybeans has shown, successful GMO develop-
ment sometimes requires both substantial amounts of R&D funding and a good dose of luck. The complex-
ity and contingency of living matter are still beyond our coherent grasp, and have thus frustrated
many biotech firms used to dealing with the relative predictability of inert chemicals.

Calgene learned this the hard way with its FlavrSavr tomato. While it may have ultimately gotten
the molecular science right for its slow-ripening gene that enabled test-tube tomatoes to remain ripe
for weeks without spoiling, its first (and only) year of commercial development was an unmitigated
disaster. On one hand, Calgene had failed to account for the complexity of growing tomatoes in the
real world: in order for its tomatoes to compete with existing cisgenic varieties, Calgene had to
produce transgenic versions of specific tomato varietals that had been bred to thrive in the
ecology of each region where they were planted (Charles 2001). There was not simply this thing
called a ‘tomato’ that would be the same anywhere; there were dozens of different tomatoes,
each bred to be optimally attuned to the unique and dynamic biophysicality of the microclimates
within which it was embedded. Calgene’s harvests ended up being significantly smaller than those
of non-GMO tomatoes, and the FlavrSavr lost it millions of dollars in revenue. On the other hand,
the ripeness of Calgene’s tomatoes ended up having negative side effects: many of the tomatoes
ended up getting crushed in transit (Charles 2001). Once again, the biophysicality of the crop instan-
tiated new barriers to the realisation of a business venture that had made sense in the abstract.12

One might suggest that the failure of FlavrSavr speaks more to the bunglings of one small upstart
biotech firm than to inherent barriers to the successful commercial development of GMO crops that
stray from the principles articulated above. True, Calgene might have taken more care to ensure
better control of tomato production before planting transgenic seeds. But the fact that slow-ripening
tomatoes did not attract interest from more established biotech players such as Monsanto, or that
existing seed breeders did not seek partnerships with Calgene suggest that there is more at stake
here than the mismanaged business ventures of one company. Tomatoes, ubiquitous as they are,
simply did not have the profit potential to interest the big players in agbiotech who might have
had the resources to successfully make the product a commercial success. Moreover, without the
structural incentive for adoption that an appropriationist technology would provide farmers, there
was no competitive advantage for farmers who adopted the FlavrSavr tomato and thus no guarantee
of any profits to biotech firms or farmers. Without significant consumer demand, nobody – neither the seed breeders, nor the large biotech firms, nor farmers themselves – could justify getting involved in such a precarious project.

If FlavrSavr tomatoes mark the first major failure of commercial agricultural biotechnology, Golden Rice marks the most disappointing instance for proponents of biotechnology. Golden Rice was developed as a public research project, spearheaded by Ingo Potrykus and Peter Beyer, university researchers in Switzerland (Potrykus 2001). Funded primarily by the philanthropic Rockefeller Foundation (and only to a limited extent by for-profit sources), they created rice that had enhanced levels of beta-keratin, a precursor to vitamin A, through the insertion of genes from bacteria and daffodils, and presented their results in March of 1999. Their goal was to solve the problem of vitamin A deficiency in the Global South by offering the rice for free to peasant farmers, while maintaining a for-profit side project developed in partnership with British agrichemical firm Zeneca that would sell the rice to commercial growers. After successfully demonstrating the technology and eventually publishing the results of their research (Potrykus 2001), Potrykus was surprised to find out that nearly seventy patents on gene sequences and gene transfer techniques had been infringed upon in the creation of Golden Rice (Hessler 2011). Unable to navigate these regulatory hurdles alone, Potrykus and Beyer made a deal with Zeneca, who agreed to help the Golden Rice developers negotiate the IPR barriers in exchange for the commercial rights to the technology (Potrykus 2001). However, beginning with Monsanto, the biotech firms who held these patents granted free licences to the creators of Golden Rice. Given the positive press this generated, coupled with the failure of Golden Rice to generate any commercial revenue 15 years on, this appears in hindsight to have been a wise choice. Although Zeneca initially agreed to support Potrykus through a partnership, the corporation eventually rescinded its commercial project, ‘... because the chance for a financial return at the level of the investment was too low’ (Potrykus 2012: 468). Even though Zeneca had been spared conducting any R&D prior to the successful development of Golden Rice plants, and had opportunistically made use of Potrykus’ sudden need for an industrial partner, it still concluded that it had nothing to gain from involvement in the Golden Rice project.

Why has Golden Rice remained in a time warp for 15 years, while other GMO varieties have surged ahead? Potrykus categorically blames onerous regulations and testing requirements for stalling its development (2010, 2012). Certainly, the regulatory barriers, themselves the result of public ambivalences over the technology, have drastically slowed the process of approval and commercial release. However, faced with the same regulatory barriers, corporations have had little trouble achieving regulatory approval in significantly less time. For example, seven years separated the successful creation of herbicide-tolerant soybeans and the first season of commercial planting of Roundup Ready soy. Similar timelines apply to the other commercially successful crops. If Golden Rice had been pioneered by a multi-billion dollar corporation like Monsanto or Syngenta, which had the resources to negotiate regulatory barriers and conduct extensive health, safety and environmental testing, it may have been approved for commercial release by now. But the point remains that such an innovation is unlikely to interest any profit-seeking corporation, given the remote possibility that any profits would ever result from it. Golden Rice neither enhances productive efficiency for farmers nor benefits consumers in the West – those with money. It neither relies on appropriationism to ensure farmer uptake, nor expropriationism to guarantee revenue streams for the patent holder. And despite its humanitarian goals and nutritional benefits, it has still sparked popular backlash and consumer ambivalence. In short, within the confines of a capitalist GMO economy, it remains unlikely that Golden Rice will provide the profit motivation necessary for commercial success.

Conclusion

The story of GMOs – their successes and failures – is only the latest chapter in the story of agricultural capitalism. The path of their development has been significantly conditioned by the materiality of agricultural capitalism. GMOs have been successful because they help overcome barriers to
accumulation inherent to the biophysicality of agriculture. In this way, their commercial success has paralleled earlier appropriationist technologies, including machinery and chemical inputs. As on-farm labour and production are replaced with off-farm, industrial labour and production, the barriers to accumulation posed by agriculture’s inherent materiality are diminished. However, GMOs, like hybrid seeds before them, differ from other appropriationist technologies. Their liveliness and in particular their reproducibility present both new challenges and new opportunities. There are challenges of maintaining control, not just of the reproductive capacities of the seeds, but of how ownership rights can be preserved for patent holders beyond the first generation of the plants. This challenge has necessitated a stringent IPR regime, which has substantially empowered biotechnology firms, and been termed expropriationism (Pechlaner 2010). This paper has demonstrated how the dual accumulation strategy of appropriationism and expropriationism has made certain GMOs profitable for capital and inescapable for (most) farmers.

The converse of this process has been the failure of numerous innovations that do not cohere with the industrial logic inherent to successful GMOs. Biotechnology multinationals have eschewed innovations that address consumer health, nutrition or aesthetic considerations because of the uncertainty of any success in these innovations. Without any structural impetus for farmers to adopt transgenic crops that do not inherently improve the production process, there is no guarantee that such crops would even be planted, let alone sold for a premium in grocery stores. In this way, the logic of agricultural capitalism has significantly narrowed the spectrum of GMO development. However, if the current situation is the result of a particular set of material constraints inherent to the logic of capital, this does not render it inevitable. A categorical rejection of GMOs without consideration of the contingency of their location within capitalist political economies only serves to further entrench and naturalise the hegemony of capitalism. A critical reformulation of the global food economy must start with a decoupling of the biotech baby from the capitalist bathwater.

Notes

1. Following Marx (1976), I understand capital as an abstract social relation that takes on concrete forms through actors who possess capital and seek profit through the exploitation of human labour. For our purposes here, capital generally refers to biotech corporations and other upstream producers of appropriationist technologies (such as machinery), although it can also manifest itself in the form of farmers, who take on the role of capital to varying degrees when they operate as profit-seeking owners of the means of production in the cultivation process.

2. According to Mann (1989), Marx argued that competitive pressures will inevitably transform all small-scale farmers into either capitalists or proletarians, a notion which Lenin (1900) documented empirically in Russia. For a discussion of value, the production of nature and agriculture, see Eaton (2011).

3. Marx (1976) differentiates between formal and real subsumption as stages in the historical development of capitalism characterised by changing relations between labour and capital. Under formal subsumption (the earlier stage), workers do not own the means of production but maintain control over the process of production, merely giving up control of the product of their labour at the final moment. Conversely, real subsumption involves a full-scale detachment of labour from the worker, as the worker loses control over the production process, and her labour becomes another cog in the wheel of production.

4. Margarine, a synthetic foodstuff developed in a wholly industrial context, is often cited as a key moment in substitutionism (Goodman et al. 1987).

5. Although the treadmill tendency is pervasive, it is important to note that not all farmers comply with the treadmill, with some instead seeking to avoid the risks associated with the early uptake of a new, unproven innovation.

6. Kloppenburg (2004) shows how although public breeders developed it, the creation of hybrid corn made seed breeding appear profitable to capital, and thus led to the creation of a private seed-breeding industry. Beginning in the 1930s and culminating in the 1960s in the USA, private seed breeders gradually gained market share and eventually full control over commercial hybrids, as public breeders ceased to devote research to an area that capital now found profitable enough to invest in.

7. I use the term value in a Marxist sense according to the labour theory of value.

8. One reason why Monsanto mandated separate TUAs with its customers was because its herbicide Roundup was already off-patent by the mid-1990s. TUA’s enabled Monsanto to go further than it could under existing patent
law in requiring its customers to use its brand of glyphosate herbicide only, rather than generic alternatives (Pechlaner 2012).

9. The 120-multiplier clause was ultimately struck down by the US Supreme Court, but the other provisions of the TUAs remain (Pechlaner 2012).


11. For this reason, we have seen little research into nutritionally or taste-enhanced GMOs, and the one such GMO that has been brought to market – Calgene’s FlavrSavr tomato – was an abject failure. A second such GMO, which became the poster child for GMOs’ potentially humanitarian ends – beta-keratin-enhanced Golden Rice – was of no interest to capital, and has yet to gain regulatory approval now 15 years after it was first tested in the field. However, we must also remember that this situation is not absolute and unchanging; nor is there a dichotomous distinction between producer-oriented innovations and consumer-oriented innovations: GMOs that incorporate both producer benefits such as herbicide tolerance and consumer benefits such as enhanced nutrition could be both immediately appealing to producers and facilitate an eventual shift in consumer attitudes and thus valuations of GMOs.

12. It is nonetheless important to remember that the materiality of the crop can be mobilised as a productive force in capital accumulation as much as it can be a barrier to accumulation. Pechlaner (2012) provides contrasting examples of this potentiality: on one hand, she shows how the spread of GM canola pollen into neighbouring organic fields created significant backlash and a legal challenge to Monsanto from a group of organic farmers in Saskatchewan. On the other hand, she documents how the drift of Roundup herbicide from Roundup Ready cotton fields to conventional cotton fields in Mississippi compelled conventional farmers to adopt Roundup Ready cotton so that their crops would not be destroyed by the drifting Roundup. It is the political response of those affected by the ‘messiness’ of GMOs’ biophysicality that determines whether that messiness can hinder or advance a project of capital accumulation.


14. Indeed, regulatory requirements have often been a major setback to GMO development. See, for example, Drezner (2007), Murphy (2007) and Pellegrini (2013).

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