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Winged promises: Exploring the discourse on transgenic mosquitoes in Brazil

Luisa Reis-Castro*, Kim Hendrickx

Université de Liège, Boulevard du Rectorat 7, Bât. B-31, Bte 29, 4000 Liège, Belgium

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ABSTRACT

The bioeconomy is a strategic program strongly promoted within OECD countries. This paper discusses an example of how the purposes and promises of the bioeconomy are enacted in Brazil, in line with local environmental and political specificities. We focus on scientific and political discourse portraying a technological solution to tackle dengue disease as a public health problem. The technology involves genetically modified mosquitoes that are released into the environment in order to suppress populations of disease-carrying mosquitoes. We show how the promise of tackling dengue, through technical and scientific arguments, becomes connected to political discourse about the welfare and 'progress' of Brazil as a nation. We argue that this connection comes about through two types of rhetoric devices that downplay risk and uncertainties in favor of the promises inscribed in laboratory-bred mosquitoes. In line with a basic tenet in the field of Science and Technology Studies, it becomes clear that science and politics are intertwined in both discourse and practice. In addition, we highlight the experimental and political character of public health interventions from a spatial perspective. The mosquitoes are set free in an environment that is considered a natural environment while at the same time responding to certain laboratory conditions such as relative isolation. In addition, the genetically modified mosquitoes, as bio-objects, are expected to act like natural mosquitoes in the wild. With these types of proximity between technology and nature in mind, we argue that the mosquitoes are meant not only to enact the pest management program they have been designed for, but also a political program claiming an avant-garde position of Brazil in a global bioeconomy.

1. Introduction

In the face of a range of environmental, economic and social challenges, both large amounts of money and high hopes are invested in technological solutions. Within OECD countries, technological innovation is a key priority, and a strategic program has been elaborated through the concept of the "knowledge-based bioeconomy" [1]. In such *bio-economy* a substantial share of economic output is dependent on the development and commercialization of biological materials through technological innovation [2]. According to this model, cutting-edge and competitive biotechnology is to be developed by promoting close collaborations between universities and industry, and their joint mission is held to be "serving the dual purpose of creating wealth and improving quality of life" [3]. The expansion of the bioeconomy has been strongly promoted within OECD countries [4]. This may explain why most studies tend to limit themselves to examine and discuss ongoing developments within those countries, although the bioeconomy's strategic program is not limited to this part of the world.

Together with other articles in this Special Issue, this paper aims at discussing biotechnology and bioeconomy

* Corresponding author. Tel.: +32 31617049720.
E-mail address: luisareiscastro@gmail.com (L. Reis-Castro).

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outside the "charmed circle" of OECD countries [5], focusing on case studies from Latin America. Indeed, it is interesting to study the existing contrasts and similarities with OECD countries, but there is more to that: an in-depth analysis of current cutting edge biotechnology-related innovations in Latin America also stresses different research objects and their related discourse, which are of foremost importance for STS scholarly research. In this paper, the case study we will introduce is a particular matter: genetically modified mosquitoes (GMMs).[1] We find it particular for two reasons. Firstly, genetically or otherwise engineered animals have received much less attention worldwide than transgenic crops. With the exception of experiments that have become iconic by their sheer visibility or potential to arouse reactions, such as 'Dolly', the cloned sheep, or the Vacanti mouse with a human ear attached to it (also known as the *earmouse*), laboratories over the world are populated with biotechnologically engineered animals with a more anonymous and ambiguous status than those public icons with an outspoken science fiction or 'freak' dimension. We are interested in how these animals become discursively associated to scientific progress, public health and national welfare. We begin by explaining the technology in itself and the releases of GM mosquitoes in open field trials in Brazil (Section 2). Then, in Section 3, we take a closer look at how the genetic technology is presented by the promoters of the technology in scientific publications and websites. In scientific discourse about genetically modified mosquitoes, it becomes clear that their abnormality is played down by inserting them in a genealogy of former technological developments on the one hand, and that their 'ordinariness' is upgraded by inscribing them with promises for public health address the issue of dengue fever. We will discuss this by drawing on the concept of *ordinary treasures* [6]. At the same time we will discover another particularity of the mosquitoes: they move beyond the confinements of the laboratory, thereby extending its boundaries. They are released into the 'wild'. In the fourth section, we will discuss the GM mosquitoes as part of a larger debate on GMOs, stem cell research and a particular rhetoric of hope in present-day Brazil. In the final discussion section we explain that both scientific discourse and Brazil's rhetoric of hope are connected through the promises of a new technology – promises that in our case become embodied by a mosquito.

2. The releases of genetically modified mosquitoes[2]

Recently there has been an increase of activities concerning transgenic insects. The most notorious events have been the open field trials of genetically engineered mosquitoes occurring since 2009. All the transgenic insects released in the environment are a product of the British company Oxitec – the Oxford Insect Technologies, a spin-off company from Oxford University. In this section we explain why these GMOs are being set free and how this mosquito-technology works. Up to now, mosquitoes have been released in the Cayman Islands, in Malaysia, and in Brazil. We will focus on the Brazilian releases that have been the most important in scale and scope.

2.1. Why GM mosquitoes?

The GMMs have been developed as a technological solution to tackle dengue fever disease. There has been a worldwide increase in cases and outbreaks of dengue. The World Health Organization considers it the most rapidly spreading mosquito-borne viral disease in the world, turning it into a public health emergency of international concern [7].

The vector for dengue – i.e. the mosquito transmitting the disease – is the *Aedes aegytpi*, which can also be the vector for avian malaria and yellow fever viruses [8]. The released GMM technology aims to reduce the number of dengue cases, by targeting the vector of the disease: the population of *Ae. aegypti* in its natural habitat. The British biocompany Oxitec has developed the Release of Insects Carrying a Dominant Lethal (RIDL) system.[3] The RIDL strategy is part of GM pest management approach that aims for *population suppression, containment or eradication*.[4] In a nutshell, the *Ae. aegypti* population is to be reduced by releasing genetically modified counterparts that contain conditionally lethal genes. These GM mosquitoes will mate with the wild ones and produce an offspring that should die before adulthood.

The core of the RIDL system is the protein tetracycline-repressible (tTA) transcription[5] [9]. In a few words, it conditions the insects to only survive to adulthood if in the presence of the antibiotic tetracycline. One can still mass rear these GMMs, since inside the lab the growing insect can be fed tetracycline.

Only the female *Ae. aegypti* bites for blood in order to mature the eggs. This means only females transmit dengue

[1] The terms 'genetically modified' and 'transgenic' are not synonymous, the latter being more specific and referring to the introduction of genes from other species. Any transgenic species is genetically modified, but the reverse doesn't necessarily apply. The GMM is both and we use the two terms alternatively.

[2] The case study on the genetically modified mosquito in Brazil has primarily been conducted by Luisa Reis-Castro, in the framework of her previous researches. For more information see Ref. [56].

[3] Other laboratories were also working on this type of system as pointed out in the article written by Oxitec's researcher [9]; (see also Ref. [57]). Oxitec has two types of RIDL approach: the *bisex* and the *female specific* RIDL. They have a similar working mode but on the latter the system has the specificity to induce repressible female-specific lethality [33]. All the releases of GM insects conducted until now were bisex. Besides the transgenic mosquito *Ae. aegypti*, another Oxitec bisex RIDL insect has been released before the GM mosquitoes. This first release of GM insects was done in order to deal with an agricultural pest in cotton farming. Open-field experiments of a genetically modified pink bollworm – the OX1138 – were conducted during three years in Yuma County, Arizona, USA. Preliminary field releases with OX1138 were carried out in 2006 and larger-scale ones in 2007 and 2008. Nonetheless, besides the genetic modification, OX1138 was also irradiated before being released to guarantee sterility [56].

[4] Another approach aims at population transformation or replacement. Strategies under this group introduce a transformation that reduces or blocks the insect's ability to transmit a disease.

[5] Also defined as Tetracycline-Controlled Transcriptional Activation.

fever. The released transgenic mosquitoes are from the RIDL strain *Ae. aegypti* OX513A. Oxitec proposes to release OX513A males, which would compete with their wild counterparts. The lab GMMs are homozygous[6] for the lethal gene, and the latter is a dominant one. That means that the offspring of GM males with wild females will be heterozygous[7] for the lethality and will still express it. Some promoters of this technology define these offspring as the "doomed heterozygotes" [10].

The sex-separation of the bisex OX513A strain is done mechanically. The criterion for sorting them is the size difference between male and female [11]. Nevertheless, in an article where some of the authors are researchers from the British company Oxitec it is acknowledged that sex separation based on pupal size contains a small error margin, from less then 1% female to 0.1%, if larger males are also discarded [10]. This might seem a small percentage, but on a large scale the error margin becomes consequential: some females are inevitably also being released.

Furthermore, although Oxitec defines its product as *sterile*, the heterozygotes survive through larvae phase but should not reach adulthood. That is, they are characterized by *late-lethality*. An article written by Oxitec's researchers acknowledges a 3–4% survival rate to adulthood of the heterozygotes in lab experiments [10]. Numbers could be even higher in case tetracycline is present in the environment.[8] A confidential Oxitec report made public by NGO GeneWatch UK showed a 15% survival, most probably because the larvae were being fed cat food contaminated with tetracycline in the laboratory (for the report see Refs. [12]; for Oxitec's response see Refs. [13,14]. In sum, the successful implementation of the technology is not straightforward but depends on a number of factors such as a correct mechanical sex-separation and a survival rate of the heterozygotes as close as possible to 0%. In the final section of this paper, we will return to the problem of evaluating an implementation as 'successful', or a technology as 'working'. Before that, we have to sketch a larger picture of the GM mosquito technology and its embedding in society, starting with the releases of these mosquitoes in the environment.

2.2. Brazilian releases and the problem of dengue

Oxitec's OX513A has been released in three different locations, with the experiments being conducted by local institutes. The first field trial of GMMs happened in the Cayman Islands,[9] a British Overseas Territory. The second release happened in Malaysia and was carried out by the local Institute for Medical Research (IMR). In Brazil, researchers from Universidade de São Paulo (USP) are responsible for carrying out the trials. The Social Organization[10] Moscamed is responsible for mass rearing the mosquitoes; it is located in Juazeiro, in the state of Bahia, the same location where the first Brazilian experiments were conducted. Moscamed already worked with insects on a large scale, developing fruit flies (*Ceratitis capitata*) sterilized through irradiation. In September 2009, the request to import three batches of five thousand embryos from Oxitec was approved by the Brazilian National Technical Commission for Biosafety (*Comissão Técnica Nacional de Biossegurança*/CTNBio) [15]. CTNBio is the institution assigned to assess the safety of requests concerning the use of all types of genetically modified organisms in the country. In December 2010, the request for a planned release of GMMs into the environment was authorized [16].

In February 2011, the first phase was carried out: some releases in smaller numbers to evaluate the transgenic mosquito behavior. In April, the second phase started, with larger releases up from 50,000 up to 100,000 mosquitoes per week [17]. The general information provided by the Brazilian media was that the releases would be conducted in five locations around Juazeiro, in the Bahia state, during an eighteen-month period throughout 2011 and 2012 (e.g. Refs. [18,19]). In March 2012, a workshop was organized to discuss the project's progress. According to the report presented in this workshop, the conducted releases only happened in one of the locations near Juazeiro (the suburb of Itaberaba). One of the authors contacted Professor Margareth Capurro, the project coordinator, and she informed us by email that contrary to what had been said in the media, "Itaberaba is only the first year project. Two new locations are scheduled for the second year of the project. Mandacaru already started in March. The project is at least 3 years long".[11] In May, the government of the Brazilian state of Tocantins announced that it would also adopt genetic mosquitoes as a strategy to tackle dengue disease [20].

Among the three locations, Brazil is the only one where the transgenic mosquitoes are still currently being set free. It is by far the largest release in scale with more than fifteen *million* insects released between 2011 and 2012 [21]. Moreover, the GMM project seems to continue and expand, as there are plans to increase its scale, with announcements of new release locations and the construction of a new Production Unit of Transgenic *Aedes* (UPAT) that can mass rear four million mosquitoes per week [22]. Furthermore, it is also important to point out that in Brazil dengue is considered a very serious public health issue. The issue is considered severe, mainly because of the geographical spread of the disease, present in all 27 states of the country or 3794 municipalities [23], and the recent increase of cases of dengue hemorrhagic fever (DHF) since the 1990s. Dengue fever becomes fatal if it develops into DHF. However, in Brazil the morbidity rates of DHF are relatively low: during the 1990s, the proportion of DHF cases attained 0.06%, and this percentage has gone up to 0.3% in

[6] The two alleles of the gene are identical.

[7] The two alleles of the gene are different.

[8] Tetracycline is "an antibiotic used to treat bacterial infections such as urinary tract infections, chlamydia and acne" [58].

[9] Some have suggested that the choice of locating these releases at the Cayman Islands was due to its biosafety considerations being not well developed [59]. There is a gap in the legislation: the Cayman Islands are a non-party of the Cartagena Biosafety Protocol because UK's ratification is not extended to its overseas territories (for more information on this legal controversy see Ref. [60]).

[10] In Brazil, to be a *social organization* means that the company can sell its products and services and make profit, but all has to be reinvested back into the business. As a social organization Moscamed is linked to the Ministry of Agriculture, Livestock and Supply (MAPA).

[11] M. Capurro, personal communication, April 4, 2012.

recent years. This increase is significant, but the proportion is still considered relatively low as compared to Southeast Asia. DHF lethality has varied in Brazil from 1.45% (1995) to 11.25% (2007) [24]. The case-fatality DHF can typically be dealt by trained physicians, since “access to health practitioners who are trained to identify DHF and treat its effects can reduce that rate to about 1%” [25]. Dengue costs an estimated amount of one billion reais – approximately 400 million euros – annually to Brazilian public funds [26].

3. Genetically modified mosquitoes as *Ordinary Treasures* … Flying around

In this section we examine how the researchers from Oxitec present their mosquito-technology, by exploring the shifts of interpretative repertoire in their articles. We grounded this analysis on the concept of *ordinary treasure* from Holmberg and Ideland [6] in their study of another genetically engineered animal, the lab mouse. When analyzing transgenic mice used in laboratory experiments, Holmberg and Ideland noted a tension in the discourse of lab workers and members of ethical committees. They concluded that GM animals “are framed as normal, ordinary and thereby unproblematic on the one hand, and as valuable treasures in which are embedded hopes and expectations of future medical treatments on the other” [6]. The authors observe shifts in the interpretative repertoire – i.e., a shift in the set of explanatory statements used to describe them – made through different categories of rhetorical comparison. For them, these shifts construct the transgenic lab mice as normal and *ordinary* and at the same time *treasures* filled with future medical expectations. According to Holmberg and Ideland, this flexible use of terms and concepts related to normality on the one hand and novelty on the other, has the discursive effect of making only certain aspects visible, while others are excluded and become hidden or silent. Promises related to technological innovation are emphasized, while uncertainties concerning *trans*genetics are downplayed through rhetorical comparison with genetic processes in cross-breeding or natural selection. These shifts between repertoires about ordinariness and treasured novelty contribute to the construction of what Holmberg and Ideland call *transgenic silences*. In the case of laboratory mice, scientific uncertainty, the suffering of animals, human agency, and responsibility become ‘ethical non-issues’. When looking at the comparisons made between genetic modification and irradiation, or GM and wild mosquitoes, we observe very similar discursive shifts in the promotion of the GMM technology.

3.1. Genetic modification compared to irradiation

Promoters of the OX513A tend to describe the mosquito-technology in a dichotomous manner. Usually they present the Release of Insects Carrying a Dominant Lethal (RIDL) bisex strain as a continuation (e.g. Refs. [8–10,27])[12] or a variant (e.g., [28]) of the Sterile Insect Technique (SIT).

The SIT is a pest management technique that aims at diminishing the size of the pest population. Reproductive sterility can be induced in different ways, such as chemicals or the more commonly used ionizing radiation method. The approach means that these sterile insects are released in large numbers; the males will mate with wild females, but will produce no viable offspring. Continuous releases must be done to effectively reduce population over several generations [29].

When presenting the RIDL OX513A, promoters of this mosquito-technology usually highlight the already established history of the Sterile Insect Technique and some of its successful cases. For example, Luke Alphey, the chief scientific officer and one of Oxitec’s founders, starts his article *Re-engineering the sterile insect technique* presenting all the advantages from SIT and describing cases where it has been successfully adopted [9]. In Beech et al., where all authors are from Oxitec, they argue that

> Genetics-based insect control strategies, based on the classical Sterile Insect Technique (SIT), are becoming increasingly viable. The close affinity to established SIT and biological control methods means that there is a large body of experience on which to draw when using GM insects in this way [30].

In this sense, the Release of Insects Carrying a Dominant Lethal approach would not be something novel, but just a continuation of the already long used SIT.

Nevertheless, at the same time, they distance themselves from ‘classical’ irradiation-based Sterile Insect Technique. After highlighting the advantages and the long history of SIT, the disadvantages are pointed out, as for example:

> Despite its environmental benefits, SIT has been used against only a rather modest number of target species. This is in large part due to a fundamental problem with the system. The released insects are required to compete for mates with wild insects. The production process, however, and in particular the need to sterilize the insects by irradiation, causes a dramatic loss of competitive mating ability relative to wild type. Irradiated insects are less competitive and also have reduced life spans [9].

In this context, the RIDL genetically engineered approach is presented as maintaining the advantages from ‘classical’ SIT and at the same time overcoming its weaknesses. They claim that “with the advent of modern biotechnology it becomes possible to improve the applicability, efficacy, safety and efficiency of the SIT” [8]. Thus, concomitantly to being part of SIT as an *ordinary* and established approach, it becomes a new and innovative *treasure* for pest management and public health policies. By keeping SIT as a fixed point of comparison, the ‘trans’-matter is not problematized, but merely a technical issue in the background: nothing really changes, but the GMM’s will simply perform better.

This tension between shifting repertoires of being or not SIT can be noticed in other technical characteristics of the mosquito-technology. Beech et al. argue that

[12] Interestingly, an article entitled ‘Why RIDL is not SIT’ and one of the authors is Oxitec’s researcher Luke Alphey, has just argued the opposite: that RIDL is not SIT [61]. Nevertheless, in this article they only discuss the other type, the female specific RIDL. The arguments used to declassify Release of Insects Carrying a Dominant Lethal as SIT are only valid for the latter, and not for the bisex strain – which is the one we have been discussing.

> The use of genetically "sterile" insects is a clear example of a self-limiting approach. (…). This approach builds on the operational precedents established by the successful use over 50 years of radiation-sterilised (non-GM) insects to control certain agricultural pest insects, known as Sterile Insect Technique (SIT) [30].

The word "sterile" is used with inverted commas because the irradiated SIT insects are sterile, whereas the RIDL insects are not. As mentioned before, the RIDL mosquitoes produce offspring that can only survive in the presence of the antibiotic tetracycline. If this antibiotic is not present in the natural environment, the wild larvae should not reach adulthood. In an interview, the researcher responsible for the Brazilian releases, Margareth Capurro, pointed out that difference and highlighted that she does not agree with calling the RIDL OX513A sterile.[13]

Having in mind this distinction, it is interesting to point out the shifts between including the OX513A as SIT or not. For example, Phuc et al. – where several are Oxitec researchers – argue that the RIDL approach is better and should substitute SIT. As mentioned in Section 3, not all heterozygotes die before adulthood, with a 3–4% survival rate in lab experiments. In order to justify this "incomplete penetrance of lethality", Phuc et al. cite the work of H.J. Barclay who "concluded that moderate levels of non-sterility, e.g. 8%, would have little adverse effect" on the effectiveness of the suppression program [10]. The work of Barclay, however, is about mosquitoes irradiated with the SIT technique, and not the genetically engineered RIDL insects [31]. This example evidences the shift between being part of the SIT, and thus adopting its standards, or being something different. The net result is that uncertainties are downplayed by discursively putting RIDL in the prolongation of SIT, while the novelty and performance of RIDL are emphasized by distinguishing it from SIT. When analyzing mice used in laboratory experiments, Holmberg and Ideland also noted these shifts of interpretative repertoire in the discourse of lab workers and members of ethical committees. Holmberg and Ideland show that GM mice are presented as a continuation of older techniques, such as cross-breeding, while being invested with hope for medical applications, because of the scientific breakthrough these mice come to stand for at the same time.

3.2. GM mosquitoes compared to wild mosquitoes

In the previous paragraph, the GM mosquito, being the *product* of a specific technique of genetic modification, was compared to irradiated mosquitoes, obtained through a different technique. Next to comparisons between techniques and their outcomes or final products, the GM mosquitoes are also compared to their wild counterparts, both male and female. We have already seen that the transgenic males are different compared to their wild counterparts, as they should not produce any viable offspring. As mentioned before, some blood-sucking GM females are bound to be released and be present in the environment as well. Oxitec answers this question by underlining the distinction between the transgenic and the wild female mosquito:

> Few GM females are likely to survive long enough to transmit disease: *GM females are essentially the same as wild females, except they are likely to be much shorter lived*. Because the dengue virus takes a long time to develop in a mosquito to the point where it can be transmitted, shorter-lived females are less likely to pass on the disease. So any surviving RIDL females *are likely to be much less dangerous than wild females*. […] Any released females pass on their 'sterile' genes; so their offspring will not reach adulthood [emphasis added] [32].

These particularities that distinguish OX513A males and females transform the mosquito into a "new and innovative solution to controlling the dengue mosquito, Aedes aegypti" [33], leading to releases of thousands of mosquitoes. At the same time the OX513A is also presented as an *ordinary Ae. aegypti.* According to Oxitec, their approach makes use of a 'natural' instinct of the male mosquito: its capacity and desire to find females. The company website highlights that "the Oxitec solution harnesses the natural instincts of male mosquitoes to find females in the wild" [33]. At this point, a distinction must be made between the discursive framing of the GM mosquito as ordinary on the one hand, and its *functional ordinariness* on the other. Indeed, the transgenic technology can only work if the transgenic mosquito has the same phenotypical and behavioral features as its wild counterpart. In this case it means that the male OX513A has to find females just as an ordinary *Ae. aegypti* does. In addition, the male OX513A not only has to find the female, but also needs to be able to mate with it. Oxitec claims that females would not distinguish between their product and the wild *Ae. aegypti.* On their website they explain that

> With irradiated males, she [female *Ae. aegypti*] might [be able to recognize Oxitec's males] – but that's the clever part of using genetic modification; because Oxitec's insects don't have to be irradiated, they are fit and healthy. *Like all male mosquitoes*, they will *naturally seek out* females and mate with them. This means that Oxitec's approach will be much more effective than other treatments, like pesticides, at targeting mosquitoes in difficult-to-reach places – people's homes and gardens. And […] they [female mosquitoes] *won't be able to tell the difference* until it's too late… [emphasis added] [34].

The transgenic mosquitoes must behave and look like their wild male counterparts. This is essential, as the GM mosquitoes are not confined to the laboratory but designed to fly out. The mosquitoes are not used as subjects of further experiment within the lab. Many other GM animals are created as laboratory instruments for further experimentation. The reason of their existence is the generation of new knowledge within the lab – knowledge that will serve to design applications. In contrast, the mosquitoes are a living application in itself. They are bred as *agents* –

[13] M. Capurro, personal communication, September 17, 2012.

undercover agents, at that – with an intervention mission outside of the lab.[14] The reason for their existence is not the generation of knowledge in the first place, but the suppression of dengue as a public health problem. This raises interesting questions as to the status and the boundaries of the laboratory: are the boundaries transgressed or rather extended? Where does scientific experimentation stop, and where do public health policies begin? The term 'open field trial' neatly captures the ambiguity of the lab's boundaries. The 'isolated' aspect of the chosen areas are also emphasized and seen as a necessity for the functioning of the project [35]. In the case of transgenic mice, a comparison with GM crops out in the environment enable the researchers to put forward the *laboratory* as a closed system and a 'guarantee against negative ecological effects' [6]. This is not possible in the case of transgenic mosquitoes. In fact, the phenomenology of the GM mosquito has certain features in common with that of GM crops: first, both types of product are designed as a solution or application to be implemented outside of the laboratory, although the commercial circuits of transgenic mosquitoes may remain more restricted than GM crops, available to individual farmers. Second, their difference to natural counterparts raises issues of uncertainty and possible adverse ecological effects. Third, both transgenic crops and mosquitoes must look and act like their natural counterparts, while playing out the advantages of their difference as discretely as possible. In what follows, we will discuss another common feature between the transgenic mosquito technology and transgenic plant technology: the technological fix that these technologies propose, and the political and economic stakes this creates. Different contributions to this Issue discuss how the promises of transgenic crops, such as soy and cotton, have created important political and economic alliances, initiatives and infrastructures. As the transgenic mosquito technology is only at the stage of (open) field trials, we cannot speculate upon the consequences of a broader application or commercialization. As in the previous sections, we will limit ourselves to explore the discursive positioning of the transgenic mosquito, and how Oxitec's technology has been received in Brazil. By looking at how the mosquito technology is narrated, we will discover how the promises of the transgenic mosquito have come to be related to the progress of an entire nation.

4. The embeddedness of ordinary treasures in the rhetoric of hope and scientific progress

The introduction of genetically engineered organisms in Brazil has some particularities that deserve to be highlighted to further develop our case study. From 1995 to 2004 there was a dispute within the country on the question of who should be authorizing/prohibiting and regulating the research, release and commercialization of transgenic organisms in Brazil. The Brazilian Institute of Environment and Renewable Natural Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renovaveis*/IBAMA) linked to the Environmental Ministry has been responsible for delivering permits and assessing the environmental impact of all enterprises and activities in the country since 1981. Meanwhile, the National Technical Commission for Biosafety (*Comissao Tecnica Nacional de Biosseguranca*/CTNBio), associated with the Ministry of Science and Technology, was established in 1995. While IBAMA tended for a more skeptical and precautionary approach, CTNBio adopted a more pro-transgenic attitude [36].

A new Brazilian Biosafety Bill aimed to settle this dispute. A key point is that this bill dealt not only with the issue of genetically modified organisms, but also with stem cell research. This fact had a strong impact on how transgenic organisms were *framed* in Brazil.

4.1. GMOs in Brazil and the rhetoric of hope

In the framework of dealing with stem cells and GMOs together, there was a discursive and political alliance between the groups that advocate in favor of these two technologies. It was common in their arguments to bring forward historical events to illustrate how sometimes scientific development is not 'well understood' or even punished. The most cited example was of Galileo Galilei and his incrimination by the Church in 17th century. The Brazilian example of Oswaldo Cruz and the Vaccine Revolt[15] from 1904 in Rio de Janeiro was also frequently mentioned [36].

Another alliance emerged concomitantly: those against GMOs or those in favor of a more precaution-oriented approach towards transgenic organisms allied with the *bancada evangélica*, the fiercest supporters for banning stem cells researches. The *bancada evangélica* is the informal organization of evangelical parliamentarians whose lobbying power has grown enormously in Brazil in recent years.[16] Those who advocate against or are skeptical of GMOs decided to back banning stem-cell research in exchange of the *bancada evangélica*'s support on the matter of genetically modified organisms [37]. As a result of this second alliance, those who praised for faster liberation of transgenic and stem cell research could more easily define their opponents as the forces outside science that attempt to hold back scientific development.

In this context, GMOs together with the stem cells were framed as an answer to take Brazil out of the backwardness and to put it on the path of progress and development. Stem cell research was presented as a potential cure to a series of diseases, and transgenic crops as the solution to the problems of hunger, pest and plague management in the country. Such associations can be included in what

[14] Another transgenic animal that is also present outside the lab is the fluorescent fish GloFish®. It was developed by Zhiyuan Gong, at the National University of Singapore, as a strategy to monitor water quality. There is a link between color genes and the genetic elements that respond to pollutants. Since 2003 it has been available in USA market as a fish pet [62].

[15] Popular uprising which occurred as a reaction to the attempt from Oswaldo Cruz, then General Director of Public Health to impose mandatory, universal vaccination against smallpox.

[16] Rafael Bruno Gonçalves wrote an interesting paper on how religion (having in mind the evangelicals) have become an important source of political recruitment and political identity in Brazil. He highlights that between 2003 and 2006 seventy evangelical parliamentarians were elected in the country [63].

Michael Mulkay defines as a ‘rhetoric of hope’: “an idealized vision of the relationship between science and society which enables its users to project an indefinite range of science-based technologies into a radically simplified future where scientific knowledge necessarily extends control over disease, disability and death” [38]. In addition, to question the technologies is perceived as a criticism not only of the promises they contain, but also of their beneficiary: Brazil, wrestling itself out of the backwardness.

The same rhetoric is visible in the genetically engineered *Aedes aegypti* case, in Brazil and other countries. In several academic and media articles, before presenting the mosquito-technology, an account is given of the problem and severity of dengue fever for public health. STS literature already points out how skepticism and even mere questioning about certain technologies are sometimes labeled as an anti-technology sentiment [39]. Arguments about the (possible) negative effects of a new technology or business activity are perceived as a threat to economy and development [40]. In the case of dengue – as well as other diseases and starvation – this perception is even stronger, since being skeptical or against a technology has come to equal not caring for the suffering people. An example of such argumentation can be found in a news article about Oxitec, stating that “the company hopes that it will reduce populations of disease-carrying mosquitoes by 80% but public opposition to anything “genetically modified” remains a significant obstacle to the possibility of saving thousands of lives” [41].

4.2. Vector control and the double technological fix

Vector control has been the main approach in public policies dealing with dengue in Brazil and around the world [42]. In other words, the main method to tackle the disease has been to suppress or eliminate the population of *Ae. aegytpi.* Nevertheless, there are controversies concerning the influence of the mosquito population size in the number of dengue fever cases [23].

Roriz-Cruz et al. compared two Brazilian neighboring cities, Rio de Janeiro and Niteroí. Both have similar variables which would contribute to an elevated *Ae. aegypti* infestation rate – usually associated with incidence of dengue: “(i) vapor pressure (a combined variable of humidity and temperature), (ii) population density, and (iii) environmental availability of disposable recipients that accumulate (rain) water”. Nonetheless,

> Though sharing the same climate (vapour pressure = 68) and having similar population density (approximately 4000 people/km^2) and sanitation rates, Rio had twice the dengue incidence (2036 cases per 100,000 inhabitants) of Niterói (1038 cases per 100,000 inhabitants) in 2008 [43].

The reason for that, according to the authors, is the difference between the cities’ primary health care. Looking again at the two cities, they notice that:

> In Niterói, the past 20 years have seen an increase in primary health care coverage from less than 1 to 77.4%. This was paralleled by a significant reduction, not only in the Aedes aegypti domiciliary infestation rate (from approximately 10% in 1986 to 1.7% in 2006), but also in the incidence of dengue cases during these years (from 1383 cases per 100,000 inhabitants in 1986 to 189 cases per 100,000 inhabitants in 2006). Conversely, only 7.2% of Rio’s population had primary-care coverage in 2008 (the lowest among Brazilian state capitals), and two aforementioned dengue indicators have not changed significantly in the last 20 years (Aedes infestation rate: from around 10% in 1986 to 7.2% in 2006; incidence: from 205 cases per 100,000 inhabitants in 1986 to 232 cases per 100,000 inhabitants in 2006) [43].

The authors challenge the argument that vapor pressure is the best natural predictor for dengue potential (see Ref. [44]). For them there has been an ecologically biased approach: the places with high vapor pressure are mainly located in the so-called developing countries and most of these do not present a fully implemented and comprehensive primary-care system. Thus, they argue that primary-care system should be the focus of public policies. Furthermore, Mendonça, Souza and Dutra point the ineffectiveness and negligence when it comes to public health policies and sanitation services as the possible reasons why the disease keeps coming back in Brazil [45].

Even though there are some controversies, vector control has been the mainstream approach for dealing with dengue and other illness transmitted by mosquitoes. This point is made by Timothy Mitchell when discussing the emergence of experts in controlling mosquito-borne diseases at the beginning of the 20th century. In this case, the experts focused on malaria and yellow fever. He mentions how ‘brigades’ of uniformed men would attack the mosquitoes with spray guns and concludes that “disease was to be defeated not by improved social conditions or medical intervention but by the physical elimination of the enemy species” [46].

Hence, although it promotes itself as a very innovative strategy, the RIDL transgenic insect technique follows a deep-rooted logic that focuses on the mosquito, rather than analyzing and improving social conditions, health care or medical interventions. This is obvious in the Brazilian case. The town of Juazeiro in the Northeast state of Bahia – the chosen location to experiment this cutting edge technology – does not have running water supply.

This is not just a matter of showing disparities, but it is a key point, since the female *Ae. Aegypti* needs to put its eggs in still water. One inhabitant of Juazeiro points out “What I know is that, if we had running water supply, things here would be very different. Without still water that we must collect for basic things, how can we wash clothes or cook food? (With running water supply) there would be no mosquito, from dengue or any type of such diseases” [18].

Margareth Capurro – the USP scientist responsible for the Brazilian experiments – distinguishes two aspects of the dengue problem. First, she says that the government does not provide basic living conditions, such as a running water system. As a consequence, all houses must have tanks to collect water, which become breeding sites for the mosquito. Second, she points to a lack of responsibility on the part of individuals. As an example, she mentions that the Juazeiro municipality distributed plastic covers to put over the water tanks, but she said most people leave it constantly open. Capurro showed pictures of a backyard full of waste and objects that could potentially be breeding sites.[17]

Within this framing of the dengue problem, the genetically modified mosquito becomes a *double technological fix* within the vector control approach. Alvin Weinberg coined the concept of "technological fix" in the 60s and it is now part of the STS lexicon. It is used to describe technologies that "eliminate the original social problem without requiring a change in the individual's social attitude, or would so alter the problem as to make its resolution more feasible" [47]. The GMM would allow overcoming two 'social' problems: a government that does not offer basic living conditions – i.e., running water and good primary health care – and a population that does not take responsibility in the control of breeding sites. It becomes a double technology fix; it is neither the government nor the population that will bring the solution to the dengue problem, but rather techno-science. In this sense, the case of the transgenic mosquitoes in Brazil evidences a technological fix that proposes to overcome not only a problem in the individual attitude or the government's actions, but an entire deficient infrastructure.

4.3. Brazil on the map of vanguard science

In Brazil, it is noticeable that reports on governmental websites, media articles, and the scientists developing the technology in the country, link the adoption of the technology to Brazil's international emerging status. Some media articles have associated the adoption of the transgenic mosquito with a Brazilian pioneer technological vanguard.[18] An example is the statement that "Juazeiro has entered the *map of vanguard science*. It has become the first place in the Americas [sic][19] to free into the wild – in a controlled manner, it should be stressed – genetically modified mosquitoes to fight dengue" [authors' translation, emphasis added] [48].

The tendency to point out the national pioneering technological attitude has been even clearer in the case of the New Production Unit of Transgenic Aedes (UPAT), inaugurated July 07, 2012 in Juazeiro, Bahia, the same locations where the releases had been done. The new 'bio-factory' has 720 m^2 and the capacity to produce four million male mosquitoes per week [49]. In several official statements, the large capacity of the factory is emphasized and confers prestige to the Brazilian nation on the worldwide scene of scientific development. Here are some examples:

> Brazil is *pioneer* in terms of the *dimension of mosquito production*' affirms the biologist Margareth Capurro, from the University of São Paulo (USP), coordinator from the Transgenic Aedes Project (PAT). With the inauguration of the *largest factory* of dengue transgenic mosquitoes *in the world*, in the beginning of July, Bahia [state where Juazeiro is located] intends to produce four million insects per week [authors' translation, emphasis added] [50].

On the website of the Brazilian government, the announcement of the New Unit is presented in the following way:

> Brazil will produce, on a large scale, transgenic Aedes Aegypti mosquitoes that will be allies in the fight against dengue. This Saturday (7) *the factory with the largest sterile mosquito production capacity worldwide was inaugurated.* (…) The *action is unprecedented worldwide*: it is the *largest release* of transgenic insects to control the urban dengue mosquito [authors' translation, emphasis added] [51].

In the inauguration event of the New Unit, the Minister of Health, Alexandre Padilha, declared that:

> This is a new technology that can become part of the already adopted techniques for dengue control and it *makes Brazil occupy a place in the production not only of the* [genetically modified] *dengue mosquito, but other types of insects that transmit diseases in the country and the world* [authors' translation, emphasis added] [22].

The new Production Unit shows that Brazil's rhetoric of hope, expressed in terms of technology, science, and national progress, goes on a par with an active engagement in the *production* of GM mosquitoes. In other words: Brazil is not interested in being just a beneficiary of foreign technology, but aims at being part of the technological elite. This enthusiasm is not shared by everyone. Brazilian civil organizations have emphasized possible risks and the lack of information about the GMM. In the context of the 'bio-factory' inauguration and its repercussion, several NGOs published a letter about the transgenic mosquitoes (e.g., AS.PTA – Familiar Agriculture and Agroecology; Land of Rights; Peasant's Popular Movement). It said that:

> Before the method's efficacy was even tested, these novel mosquitoes took to national and international news programs. A new mosquito plant was inaugurated with pomp and circumstance, before no less than the Minister of Health and the governor of Bahia, both surrounded by entourages of other authorities. […] Only a party-pooper could think of bursting their bubble with questions about how risky millions of transgenic mosquitos might be, released since 2011 into populous neighborhoods of the city of Juazeiro, Bahia [52]

In the UK, home of Oxitec and where the mosquito was first designed and bred, there have been accusations that Oxitec's choices of locations and releases have been characterized by a colonialist attitude. One of the major voices of these accusations has been the "not-for-profit policy research and public interest group", GeneWatch UK. For example, concerning the first releases of genetically engineered mosquitoes in the Cayman Islands, Helen Wallace, the NGO's director, argued that "The British scientific establishment is acting like the last *bastion of colonialism*, using an *Overseas Territory as a private lab*" [emphasis added] [53].

Oxitec has answered these accusations in the same 'postcolonial framework'. For example, Hadyn Parry, the company's chief executive, stated that

[17] M. Capurro, personal communication, September 17, 2012.

[18] A very few number of articles related this pioneering activity not with a vanguard attitude but with the experimental characteristic of the technology, pointing out how Brazilians are being guinea pigs for the GM mosquito adoption (for example see Ref. [64]).

[19] The first releases were conducted in the Cayman Island, which is also in the Americas.

> GeneWatch UK also alleged yesterday that Oxitec is '*using poor regions in the global south*, such as cities in the north east region of Brazil, as its *laboratory* for genetically modified mosquitoes'. This insinuation that we are somehow targeting exploitable populations is also particularly irksome and *patronizing* [emphasis added] [54,55].

He also points out that Oxitec has been "completely open with the regulators and collaborators". His argument is grounded on the basis that

> The institutions who determine the acceptability of any new public health technology are that *nation's regulators*. (…) We are [sic] committed to full transparency in the regulatory process. This means sharing all research with these experts, who are in a position where they regularly evaluate risk–benefit relationships [emphasis added] [54].

While in the UK a debate was initiated in terms of a colonialist attitude from Oxitec or a patronizing one from civil organizations such as GeneWatch UK, it is noteworthy that these issues have not shown up in the Brazilian discussions. Indeed, as we have noted, the inauguration of the Production Unit for transgenic *Aedes* shows that Brazil sees itself as an active player in the global science community and not an importer of foreign technology. Criticism of this ambitious project deals with safety issues, and the lack of information about the releases and potential hazards[20].

5. Discussion: bioeconomy and bio-objects enacted through discourse

The bioeconomy agenda displays a specific way of presenting or narrating the role of biotechnological solutions in the face of global economic, environmental and public health challenges. In the bioeconomy, a substantial share of economic output is dependent on the development and commercialization of biological materials through technological innovation. Genetically modified plants are an example of how biological organisms can become lucrative economic resources, as several contributions of this Issue show. We argue that the valuation of biological materials involves a specific way of portraying these materials and their related technologies. Discourses on bioeconomy are not universal, nor free-floating: they are backed up by actors and institutions and always locally enacted. Through a case study on transgenic mosquitoes we have been able to shed some more light on the rhetoric devices of a strategic program in line with the OECD's bioeconomy, but analyzed here in a Brazilian context.

One such rhetoric device we identified is the *technological fix*: a technological solution is envisioned to the global public health problem of dengue fever. By proposing a mosquito population suppression program through the release of GMMs, the vector of dengue disease is emphasized as the most important cause, leaving other factors backgrounded. We have stressed that other sources, however, suggest the importance of primary health care with respect to the prevalence of dengue. One of the Brazilian releases of GMMs was conducted in an area without running water, showing how technological solutions are foregrounded for a disease, which, as a consequence, seems unrelated to other determinants than the vector of the disease itself. Through the technological fix, dengue becomes strongly depoliticized and dependent on technological innovations. Another rhetoric device, related to the technological object itself, is the *ordinary treasure*. Uncertainties about the technological solution are downplayed by inscribing it into a genealogy of former technological developments, suggesting that the whole constitutes a body of generally accepted and mastered practices. By the same token, the novelty of GM mosquitoes, like that of GM mice in Holmberg and Ideland's study, appears under the guise of hope and promises for a better future. In the case of Brazil, this ordinary treasure finds itself embedded in a rhetoric of hope and progress, which is not only expressed by scientists developing the GMMs, but also in official and media discourse on the future of an entire nation. We have put to the fore some particularities of the Brazilian case which contribute to a better understanding of how a rather abstract rhetoric of hope takes root in concrete circumstances. Considering the government's discourse on Brazil as a pioneer in GMM technology, and the recent inauguration of the New Production Unit of Transgenic *Aedes*, it becomes clear that such rhetoric is closely associated to the defense of science and progress, turning it into a geopolitical and economic cause. The transgenic mosquito is to put Brazil on the global scene of vanguard science. The association of the GMM with Brazil's position on the world scene and the emphasis on the productive capacity of the New Production unit show that the mosquito is not only a treasured icon of hope, but that it becomes invested with national prestige.

The transgenic mosquito qualifies as a *bio-object*. Bio-objects refer to: "first, new living materials that disrupt formerly established boundaries and modes of ordering, as well as, second, to 'old matters of life' that are 'revitalized' when brought into new spaces".[21] We might add that the 'new' and the 'old' become ambiguous categories in the portrayals of the transgenic mosquito. Depending on the issue at hand, the mosquito is like any mosquito, or it is not. Accordingly, the laboratory has different 'faces' ranging from a production site of an extraordinary bio-object or product, to an experimentation site extending into the natural environment, where the 'product' is released and where its extraordinary character must go unnoticed. Like GM plants, the laboratory-reared mosquito is 'set free' to occupy new spaces. However, the technological and functional requirement is that the mosquitoes must deploy their difference in a discrete manner, in order to outwit their wild female counterparts and attain the objectives

[20] These points have not been made only by NGOs, but by scientists as well. In the article Scientific Standards and the Regulation of Genetically Modified Insects, researchers point to a lack of "scientific publication of experimental data". They argue that GM technologies cannot progress without accessible accurate scientific information [65]. In a news article some Brazilian scientists also expressed their doubts and skepticism towards the mosquito-technology [66].

[21] The definition of bio-objects can be found at http://www.univie.ac.at/bio-objects/bioobjects.htm. For more information also see Ref. [67].

they have been programmed for. Holmberg and Ideland's transgenic silence seems to have a visual counterpart, which is not rhetoric but essential to make the technology work. However, if the 'working' of a technology is seen in a larger picture that is not only 'purely' technical, but related to the cooperation of non-human actors (mosquitoes) and to its embedding in society (see van Zwanenberg and Arza, this issue), one may well ask to what extent the discursive framing and functional characteristics of a technology are really different things. Even from a 'technical' viewpoint it is by no means clear when the mosquito technology can be said to work: does it mean diminishing the prevalence of dengue? To what extent? Does "working" mean suppressing the population of wild mosquitoes – if so, by how much, for how long? Further research will be necessary to see how the mosquitoes are made to work, under what sort of geographical and economic conditions, and with what types of political alliances.

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