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THE ROLE OF ALTERNATIVE TECHNOLOGIES IN THE ENACTMENT OF (DIS)CONTINUITIES

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It would almost seem that the decline of agricultural pesticides is now a foregone conclusion. Identified as problematic technologies for decades (Carson 1962; Gunter and Harris 1998), scientific evidence now abounds to demonstrate their effects on the health of agricultural workers (Evangelakaki et al. 2020) and rural populations (Dereumeaux et al. 2020), on populations of pollinating insects (Durant 2019) or on quality of water and soil (Pelosi et al. 2021). Collective movements in rural areas (Arancibia 2013) have also played an essential role in increasing the visibility of problems associated with the use of these technologies. In response to this evidence, public policies in many countries are becoming increasingly stringent in regulating their registration and use, reflecting a willingness to engage pesticides and their regime in a discontinuation dynamic (Stegmaier et al. 2014). In parallel, the burgeoning market for "pesticide-free" organic agriculture seems, even if it is still mostly a niche, to leave no doubt about the growing preference of consumers.

But clearly, all this is not enough. The global market for pesticides is also constantly growing, even in industrialised countries (Shattuck 2021). And the forecasts in this area are rather pleasing for the industry, which is constantly claiming the interest of these technologies to face major challenges such as world hunger or demographic growth (Fouilleux et al. 2017). Molecules are indeed regularly withdrawn from the market, but only to be replaced by molecules with similar functions, as is the case in the pharmaceutical sector (Kessel 2022). These elements contribute to making pesticides a set of technologies torn between a desired decline and a still promising future. Of course, pesticides are not the only technology in this situation, and it is probably one of the contributions of transition studies to have shown that changes rarely occur suddenly (Geels and Schot 2007). Work on technology life cycles is consistent with this (Taylor and Taylor 2012). It shows that decline is a long-term process (see Newman 2023), and that technologies that are set to decline can coexist for some time with emerging technologies that are set to replace them, and sometimes even hybridise (Pistorius and Utterback 1997).

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It is precisely this relationship between incumbent and alternative technologies that I propose to address in this chapter. By alternative technologies, I mean technologies that fulfil the same purposes or functions as dominant technologies, but from different mechanisms, components or entities, which do not present the same problematic effects as dominant technologies. In the context of this book's reflection on the decline of technologies, I propose to address the following question: How does the emergence of alternative technologies contribute to the decline of incumbent technologies? The answer might seem intuitively obvious: a technology deeply embedded in an incumbent regime can only be interrupted when alternatives make it possible to replace it (see also discussion in Koretsky 2023). At least, if we stick to the case of pesticides, this is how politicians and public decision-makers tend to put things. In the high-profile case of glyphosate, for example, French President Emmanuel Macron declared in 2017 that glyphosate would be banned in France "as soon as alternatives have been found". The development of alternatives would thus be a decisive element, an obligatory point of passage (Callon 1986b) on the path to decline. But the reverse is not necessarily true: technological alternatives can exist in a niche for a long time, without managing to disrupt the existing regime and its dominant technologies. Michel Callon showed us in the 1980s how electric vehicle technology failed to impose itself against the combustion engine (Callon 1986a). And if we widen the focus beyond technologies, the replacement of one technology by another does not in any way presume the wider transformation of the socio-technical regime in which the problematic technologies are inserted. This is what Levain et al. have shown, still in the context of pesticides, with the ban on DDT (Levain et al. 2015).

The role of alternative technologies and their emergence in the decline of problematic technologies is therefore complex. In this chapter I propose to contribute to this reflection by focusing on a specific stage in the trajectory of alternative technologies: their expansion. By expansion I mean the stage in which alternative technologies are officially supported by public policies and increasingly important industrial actors. This is therefore not the stage of design or prototyping, but rather the stage of expanding existing technologies, even if they obviously continue to be the subject of R&D and innovation. In this spirit, I will focus on biopesticides, also known as biocontrol technologies (Box 7.1), which have been around for several decades but have undergone intensified development in recent years. I will focus on the cases of Argentina and Brazil. These two Latin American giants are distinguished first of all by their unwavering support for the agro-industrial sector, which is a major consumer of pesticides and which, thanks to the exports it generates, is essential to the fiscal revenues of the States. However, in recent years they have also seen the implementation of public policies to support innovation in biocontrol, and an undeniably dynamic market for these biological alternatives. By analysing how the state manages these emerging technologies, and how the landscape of the agricultural pesticide industry has been reconfigured to develop them, I show that the expansion of alternative technologies can support both the decline and the permanence of problematic technologies (in this case chemical pesticides). I thus draw attention to the interest of following the processes of expansion of alternative technologies to better understand the processes of decline and the dynamics of (dis)continuities.

7.1 Biocontrol: Disruptive technologies and historical trajectory

Biocontrol is a breakthrough alternative technology compared to synthetic pesticides. Both technologies aim to eliminate crop pests, mainly through insecticide or fungicide functions. However, the action of pesticides is based on molecules derived from chemical synthesis, whereas biocontrol is based on the use of living beings or substances of biological origin (see Box 7.1). Beyond this composition, the break between the two families of technologies occurs on various levels. First of all, the effects on pests are contrasting: chemical pesticides cause a rapid death of almost the entire pest population, whereas the effects of biocontrol products are only observable after a longer period of time, and with often less radical lethal effects. From a practical point of view, pesticides are most often applied by spraying solutions containing the active ingredients, either on the soil or on plants. Biocontrol technologies can also be sprayed, but are also often used by releasing them into cultivated fields. This is how, for example, the control of the corn borer works with trichogramma: trichogramma are tiny insects which, once present in infested plots, lay their eggs in those of the corn borer, a parasitic moth, and thus prevent them from hatching. Finally, pesticides and biocontrol differ logistically. Chemicals are stable materials that can be used under most climatic and biological conditions and transported or stored over long distances. This is not the case for biocontrol. These are living materials, which are by definition fragile, and which are moreover sensitive to the ecological conditions of their use. While some insects or micro-organisms may be effective in certain climates and against certain strains of pests, their effectiveness is not universal. In this sense, biocontrol and its use are based on more localised agricultural practices, adapted to agricultural production regions and their constraints.

BIOCONTROL TECHNOLOGIES

Biological control, or **biocontrol**, refers to a set of biological techniques used in plant protection to control plant pests (micro-organisms, insects, mites, nematodes, etc.). Biological control agents are generally divided into four main categories:

- Invertebrate beneficial macro-organisms, such as insects and mites.
- Micro-organisms (fungi, bacteria, viruses) used to protect crops against pests and diseases or to promote plant vitality.
- Chemical mediators, especially including insect pheromones, which help to control insect populations through sexual confusion methods or by attracting pests to traps.
- Natural substances from plants, animals or minerals.

Biological control technologies have been used and developed for a long time, since the end of the 19th century with the first work on auxiliary insects (Kogan 1998). Organic agriculture, which developed throughout the 20th century, is of course a particularly important sector for biocontrol. The same is true of the agroecological movements in the last quarter of the 20th century, particularly in Latin America, which support the development of these technologies and advocate a holistic approach to plant health, breaking with the agro-industrial model.

However, biocontrol is also developing in conventional agriculture, in crops such as grains, fruits and vegetables (Bonnaud and Anzalone 2021). Rather than competing with pesticides, it is rather an 'integrated pest management' approach (Flint and van den Bosch 1981) that has been gaining ground since the 1970s, mainly supported on the scientific front by entomologists. This integrated approach defends the idea that farmers should be able to use the full range of technical solutions available to protect their crops, without discrimination. Biological solutions, essentially based on macro-organisms, can thus coexist in certain plots with the use of pesticides. However, just as alternative agriculture such as organic agriculture cultivates its differentiation from conventional agriculture (Lehtimäki 2019), the chemical control and biological control industrial sectors were originally two very separate entities. From the 1970s onwards, there were large agrochemical companies developing molecules used throughout the world, and small and medium-sized companies, based locally, developing and marketing biocontrol products. The latter were only organised on a global scale very recently, compared to the agricultural chemical industry, with the creation of the International Biocontrol Manufacturer Association in 1995.

The development of biocontrol is therefore taking place in a fractured and polarised agricultural landscape with regard to pesticides, between alternative farmers who categorically reject chemical inputs, and a conventional sector that uses biological inputs without abandoning chemical control. For the latter, which is evolving under increasing pressure in industrialised countries, biocontrol has nevertheless recently become an increasingly attractive solution. It has been expanding rapidly since the end of the 20th century, as evidenced by the increasing number of studies examining the ways in which farmers adopt these technologies (Villemaine et al. 2021), or the ways in which they are authorised by the public authorities (Kvakkestad et al. 2020). But the modalities of this expansion quickly triggered warnings from the pioneers of biological control or agroecology. The latter called into question the idea of a pure and simple substitution of chemical inputs by biological inputs (Lockwood 1997), and favoured an in-depth transformation of industrial production systems (Rosset and Altieri 1997). As early as the late 1990s, they also warned against the growing investment of the input industry in biocontrol, calling for a reappropriation of these technologies by farmers to emancipate themselves from the industry (Altieri et al. 1997). But despite these warnings, the biotechnology sector, both public research and private companies (Schwindenhammer 2020), has become dominant in the field of biological control since the 1990s. Biological control research has had its ups and downs since its origins (Warner et al. 2011), but the turning point at this time is major. While innovations and uses of macro-organisms remain, a new wave of microbiology and biotechnology has profoundly reconfigured the research and development fronts of biocontrol. Bacteria or microscopic fungi selected and cultivated in the laboratory have become the new pillars of biological control. For example, in Brazil, the main South American biocontrol market, the registration figures for new products are unequivocal. Between 2000 and 2020, more than 60% of new biocontrol products registered were based on micro-organisms, compared to 17.6% on macro-organisms (the rest being chemical mediators and other natural substances). And this figure is only an average, as this proportion has increased drastically over this period, reaching 80% in 2020.

In the course of this expansion, biocontrol technologies have become an increasingly broad set of propositions. They constitute a diverse set of "configurations that work" (Rip and Kemp 1998), combining macro/micro-organisms and agricultural practices more or less compatible with the foundations, values and socio-technical systems of agroecology or industrial agriculture. But how has this expansion of biocontrol, and more precisely this microbiological and biotechnological turn, contributed to the evolution of the position of pesticides in the field of plant health? Has this development of biocontrol gone hand in hand with a desire to reduce the use of pesticides? Argentina and Brazil provide some answers to these questions. More specifically, the public policies implemented by the states to support biocontrol, as well as the reorganisation of the agricultural inputs sector, offer privileged observation sites for the transformations at work.

7.2 Public policies to manage technological coexistence

Biocontrol products have been used for several decades by farmers in Argentina and Brazil, as described in the previous section. They were first used by small farmers, often based on indigenous knowledge. They are promoted by many NGOs advocating agroecology to rural communities. They are also used by many agricultural producers using modern production techniques, whether in organic or conventional agriculture. This is the case, for example, of Argentinean fruit producers in Patagonia, major exporters to North American and European markets, who have developed the use of biocontrol in order to comply with the low pesticide residue levels required by these countries. But in parallel with these biocontrol developments, both Argentina and Brazil have developed an export sector of agricultural commodities, particularly soybeans, which has been extremely pesticide-intensive since the mid-1990s. The consumption of these chemical inputs has thus soared since this period, generating major local debates on how to reduce the associated damage. It is in this complex context that, from the mid-2010s onwards, Argentina and then Brazil have developed public policies aimed at supporting the development of biocontrol for all farmers, including those in the agro-industrial regime. The shaping of a new category, called bioinputs, played a central role in these processes.

7.2.1 The dilution of biocontrol in bioinputs

The emergence of a policy dedicated to the promotion of biocontrol occurred in 2013 in Argentina, and in 2019 in Brazil. Argentina is the first country in the region to develop such a policy, and is accompanied at the time by IICA (Inter-American Institute for Cooperation on Agriculture), an international organisation whose mission is to provide support for public agricultural policies. IICA notably encourages the construction of policies favouring sustainable agriculture or the development of a bioeconomy on a regional scale. It is within this framework that biocontrol is being promoted as an option that would enable Latin American agriculture to be transformed, while ensuring its competitiveness in world markets that are increasingly demanding with regard to pesticide residues.

But biocontrol is then captured by the Argentine government in a broader category, bioinputs, which also includes biofertilisers. The latter, which are alternatives to chemical fertilisers, refer to a heterogeneous set of technologies ranging from plant residue composts, to manures, or to advanced technologies such as bioinnoculants. Let us focus on the latter, as they played a key role in the way the category of bioinputs has been set up, and how biocontrol products were approached by the state. Bioinoculants are technologies based on micro-organisms, rhizobium bacteria. These bacteria exist naturally in soils and develop symbioses with the roots of plants of the legume family such as soybeans. This symbiosis allows the plants to take up nitrogen from the soil. This mechanism is important because nitrogen is an essential element for plant growth, and most fertiliser applications are aimed at this chemical element. The presence of rhizobia thus makes it possible to reduce the use of synthetic fertilisers necessary for plant growth. Laboratory work carried out since the 1980s has made it possible to isolate, select and improve these bacteria, and to fix them to the surface of seeds implanted in the soil. Plants inoculated in this way require less nitrogen fertiliser during their life cycle. The 1990s saw a massive expansion in soybean cultivation in Argentina and Brazil. The market for bioinnoculants literally boomed from this period onwards, becoming a flourishing industry for national biotechnology companies. In a few years, small national companies have become major entities, exporting to international markets and investing heavily in R&D, particularly in partnership with public microbiology laboratories.

In the mid-2010s, when the Argentine government wanted to encourage biocontrol, these bioinnoculants and their success story were a key reference in the field of biological inputs. But the link between bioinnoculants and biocontrol is made all the more easily since the latter has, as I have mentioned, taken a microbiological turn. While it was originally essentially a matter for entomologists, biocontrol is gradually becoming a research front for microbiologists and biotechnologists. This rapprochement is clearly taking place in Brazil at the end of the 2010s. Embrapa, the public agricultural research organisation, has traditionally been organised into thematic portfolios that structure its major research areas. Until 2019, there was a portfolio dedicated to biological control, and another dedicated to biological nitrogen fixation, i.e., bioinnoculants. That same year, the two portfolios were merged into a single "biological inputs" portfolio. As a microbiologist specialising in biocontrol points out, this merger seemed obvious in the end, given that both research groups work on a microscopic scale and depend on common banks of micro-organisms:

> EMBRAPA has collections of microorganisms, so we are organizing ourselves as a biological resources centre and the activities are very similar (between N fixation and biological control)… It was easier to work together to exchange more information and so on, we more or less have the same line of work, the same skeleton of work, we have the collection.
>
> *(Interview, Brasília, 11/04/2019)*

Supported by a transformation of the scientific field, the notion of bioinput is therefore making its way onto the political agenda, in an integrated approach to biological inputs combining bioinnoculants and biocontrol. This framing makes it possible to support the development of biocontrol while relying on the existence and reputation of bioinnoculants, for which an industry and public policy support are already well developed. This approach allows biological alternatives to pesticides, and more broadly to chemical inputs, to be considered as compatible—and in no way as a threat or explicit hindrance—with the industrial agricultural regime and its technologies. Bioinoculants, a product of biotechnology in the same way as GMOs, which are essential to the agroindustry, are one of the pillars of this model. In this sense, the way in which the State takes charge of biocontrol contributes to diluting the latter within a set of technologies that is not defined, on the contrary, by its alternative character to the intensive agricultural regime using pesticides.

7.2.2 Institutional location and political framing

In both Argentina and Brazil, with the support of IICA, the concept of bioinputs gained increasing visibility in the mid- to late 2010s. Argentina set up the Cabua (Argentinean Commission of Agricultural Bioinputs), an institutional space that brings together the various stakeholders in organic inputs, and Brazil developed the National Bioinputs Programme. The institutional location of these bioinput initiatives confirms the compatibility of this process with the technologies and institutions of the agro-industrial regime. As mentioned earlier, biocontrol has long been promoted within the Argentine Ministry of Agriculture, but by the department in charge of family farming and agroecology, which is radically opposed to the agroindustrial model. In Brazil, the same is true. Biocontrol is historically the preserve of the Planapo (National Plan for Agroecology and Organic Production), developed and coordinated by the MDA, the ministry in charge of agrarian development, small producers and agroecology. However, it is not the historical promoters of biocontrol and bioinputs who have been mandated to ensure their expansion. In fact, Cabua was created in Argentina within the Biotechnology

Division, and is dependent on Conabia, the Argentine biotechnology cenacle. From this point of view, Argentina is making a choice that is in continuity with the precursory action of IICA, which promoted bioinsumos from its Biotechnology Area. In Brazil, the National Bioinputs Programme is being created within the Secretariat for Innovation, Rural Development, and Irrigation, an entity created in 2019 within the Ministry of Agriculture. This positioning comes after the Ministry and the services working in favour of agroecology and family farming were dissolved following the impeachment of Dilma Roussef and the arrival of the right wing in power in 2016.

The anchoring of biocontrol in the institutional landscape in Argentina and Brazil thus contributes to making these technologies compatible with the dominant agroindustrial regime. The officials in charge of these commissions or programmes clearly defend this compatibility, stating that it is not a matter of the state defending a clean break from pesticides. Rather, it is a question of a slow transition, based on a diversification of available technologies, which will coexist to ensure plant health without compromising production. The Argentinian head of the Biotechnology Division thus mentions the fact that adopting a more radical point of view, in terms of technological breakthrough, could even be counterproductive for biocontrol:

> We must avoid thinking of it as a clash of technologies, as a substitution of technologies. We prefer to talk about the fact that bio-inputs can complement classical phytosanitary products and so on. Because if you say that it is a panacea and that chemicals are the disaster of the world … Manichaeism can work against you … we must avoid the duality between bioinputs and chemicals. Don't make (biocontrol) an exaggerated banner because you will gain many enemies who will find counterexamples of your Manichaeism.
>
> *(Interview, Buenos Aires, 11/10/2017)*

The chosen position is thus to "promote the use" of biological alternatives in a more neutral way, not to take sides with organic over chemical, and above all to dissociate technological questions from "political" or "ideological" questions. The latter would indeed risk making the promoters of biocontrol lose their objectivity, as says an official from the Environment Division of the Argentinean Ministry of Agriculture:

> We are not in favour of bio-inputs, we are not in favour of agrochemicals, we are in favour of sustainability. We are in favour of sustainability. We are in favour of continuing production… If you mix up the discussions, it generates a debate that does not end up moving forward. It ends up being a technical, ideological, political dispute, where models are confronted that in reality do not necessarily have to be confronted. But from the point of view of the development of the nation, they have to be compatible because there is room for everyone.
>
> *(Interview, Buenos Aires, 12/12/2016)*

In Brazil, a similar tone is used, seeking to bring the promotion of biocontrol and bioinputs back to higher, non-political or partisan issues. The Secretary of State for Family Agriculture in the Bolsonaro government thus justifies the National Bioinputs Programme as being institutionally supported under the banner of "innovation", understood here as being associated with more economic issues:

> It will be led by the innovation secretariat and, in our opinion, it is a relevant theme economically and in generating income for many communities, small producers.
>
> *(Communication event, Brasília, 09/05/2019)*

The first coordinator of the national programme also insists on this relationship with the notion of innovation, which acts as an umbrella term (Rip and Vos 2013) allowing for the inclusion of diverse and sometimes even divergent dynamics:

> Bio-inputs enters this logic of innovation, of seeing what possibilities there would be for these inputs that are still considered as if they were alternative inputs, and how these inputs now have the potential to actually innovate in the agricultural sector, gaining scale …, thus involving all these possibilities, all these potentials.
>
> *(Interview, Buenos Aires, 18/05/2015)*

Another umbrella term commonly used to situate bioinput initiatives is bioeconomy. At the time of the launch of the National Bioinputs Programme in 2020, the Brazilian Minister of Agriculture made bioinputs one of the flagship initiatives of this bioeconomy:[1]

> (The bioinputs programme) means we are entering the often-cited bioeconomy. The bioeconomy Brazilian agriculture is actually joining is based on what we expect from the agriculture of the future.
>
> *(Interview, Brasília, 11/04/2019)*

This desire to bring together and to depoliticise the different technological options available also applies to the public targeted by the development of bioinputs. While biocontrol has often been promoted in favour of agroecology and small-scale producers, as part of a more general alternative project to the agro-industrial regime, this time the project is intended to be inclusive. An Argentinean official, referring to the initiatives in favour of bioinputs, points out:

> The idea here is to make public policies that integrate the small with the big. Not that one of us is left out, not that we are left out, because the reality of the country is also like that.
>
> *(Interview, Buenos Aires, 11/10/2017)*

The president of a national network of large agricultural producers defending the use and production of biocontrol goes further regarding this inclusive position. He insists on the challenge of opening up to producers who are not necessarily opposed to the use of pesticides, but rather bearers of a certain pragmatism focused on the effectiveness of products. This would mean taking an interest in:

> conventional producers, that don't have, let's say, an ideological issue behind "I don't want pesticides" … No. These are people that have to be convinced of the efficiency of the process, of the success of the process.
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> *(Online workshop, 11/08/2020)*

Through semantic work on the category of bioinputs, but also through positions taken on the coexistence or even compatibility between pesticides and biocontrol, the latter is placed in a specific position. It is presented as a viable technological alternative for ensuring the health of cultivated plants, capable of performing functions similar to those of pesticides. But at the same time, officials, supported by farmers, refuse to condemn pesticides and to use the expansion of biocontrol as a lever to displace pesticides. This tension is reflected, as we have seen, in a choice of classification and categorisation (Bowker and Leigh Star 1999). The trajectory of biocontrol has been reoriented so that it joins that of bioinoculants, which are resolutely inscribed in the world of biotechnologies and in the regime of the pesticide-consuming agroindustry. Through this framing, biocontrol finds itself in a "technical package" that includes the technology it is supposed to help develop. It is installed in a logic of coexistence, which would make it possible to respond to societal warnings about the dangers of pesticides, without hindering the agro-industrial regime. No government would dare to condemn the latter, given that the foreign currency it generates is essential to state budgets (Richardson 2009). But to understand the form taken by this expansion of biocontrol, it is important to look beyond the state and public policy. It is also important to look at the shifts that have taken place on the side of the pesticide and biocontrol industry.

7.3 Industrial mergers and technological equivalence

Having shown how biocontrol has become part of a broader public policy category—bioinputs—let me now return more specifically to this set of biological alternatives to pesticides. In the early 2010s, when biocontrol began to attract public policy interest, the organisation of the industrial sector that designs and produces these technologies was still in its infancy. While the bioinoculant sector was already well organised—in Brazil, the National Association of Inoculant Producers and Importers (ANPII) was created in 2000—the Association of Biocontrol Companies (ABC Bio) was only created in 2007. However, these companies were not new. Brazilian companies emerged mainly in the 1980s and 1990s in the Campinas region of the State of São Paulo, southern Brazil. They were originally small and medium-sized companies, founded by entrepreneurs closely linked to the scientific and university sector, which rapidly became connected to the demand from the sugar cane sector. One of the leaders of ABC Bio says:

> When this biological control started, it came much more from the university, by post-graduate students, who ended up developing a project with the university. And then they created their own company. This was very common … these are companies that came with some knowledge from the university, or from the Biological Institute of Campinas. The Biological Institute of Campinas provided some strains—what we call—microorganisms; selections, and some companies … and it was a sector that developed a lot in the state of São Paulo by providing solutions for the sugarcane crop. Which today is one of the crops that most uses biological control in Brazil.
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> *(Interview, São Paulo, 15/06/2018)*

The ABCBio was originally formed around these companies, until the 2010s came to mark a turning point. It was at this time that large multinational companies in the agrochemical sector, in the same way as at the international level, began to take an interest in biocontrol and to invest in this sector through the acquisition of local companies. In Brazil, they invest in these companies in the south of the country and quickly join as members of ABCBio. The association's executive secretary mentioned this approach in 2018 and the change it generated in the association:

> I had several meetings with the agrochemical industries. Because I saw, outside Brazil, that they were already operating in this segment. So, I had several meetings with Bayer, BASF … which are traditionally agrochemical companies, but which were already carrying out research. And they were enthusiastic about this group of companies (ABCBio) and from there, it got stronger and we started to have a more operational team; bigger … They are now investing heavily in this technology. So, we have a Bayer, which is strongly active in the association; an FMC; a BASF; an Arysta.
>
> *(Interview, São Paulo, 15/06/2018)*

This rapprochement thus gave the association new capacity for action, which ended with the significant funding that the large multinationals could bring. It is also the developments made possible by these investments that finally convinced the historical companies of ABCBio, which initially did not like the arrival in their association of the agrochemical companies, of the benefit:

> So much so that some directors wanted to put in the statute the non-permission of companies that have agrochemicals as well, to participate in the board. But this ended up softening over time. Even today there are still some who are very reticent. But, on the other hand, they are seeing that innovation and development is being introduced … and it is a natural thing for the market.
>
> *(Interview, São Paulo, 15/06/2018)*

And, in fact, the association's position has become conciliatory vis-à-vis agrochemicals, with a discourse defending the complementarity between biological and chemical inputs:

> And we have no confrontation, for example. As we are still a very small segment in Brazil, the agrochemical industries, we practically act together. We don't have, for example, conflicts of interest. Mainly because today, these agrochemical companies are also acting in this segment. The idea is that the companies have options for the farmer, who will increasingly need agrochemicals, but will also need biological inputs. So, the idea is that these industries, they end up providing the solution for the farmer; a complete portfolio. Not just high toxicity products.
>
> *(Interview, São Paulo, 15/06/2018)*

This rapprochement of companies producing chemical and biological inputs within a single entity was concretely recorded at the institutional level in 2019. In Brasilia, at a ceremony organised in the presence of the Ministers of Agriculture and the Environment, CropLife Brasil was officially launched, a union bringing together industries producing four types of agricultural inputs: pesticides, biocontrol, seeds and biotechnologies. As in public policy, biocontrol is included in a set of technologies that combine technologies that are symbols of agribusiness, such as biotechnology. But above all, it is associated with synthetic pesticides, i.e., the technologies to which it was supposed to represent an alternative. On its website, Croplife Brasil refers to this association by linking it to the same banner term used in public policy, namely innovation. With this new organisation, the following would come together:

> In a single platform the experience and track record of associations that have led discussions on innovation in agriculture for decades.
>
> *(https://croplifebrasil.org/sobre-croplife/)*

And the executive secretary of ABC Bio, who has become the "Biological Director" at Croplife, again mentions the "non-competitive" place of biocontrol in this group of technologies and industrial players. The emergence of an alternative technology would not necessarily accompany or cause the decline of the dominant technology:

> We represent an efficient tool that can, when used properly, help reduce excessive pesticide consumption. But one technology is not going to replace the other.
>
> *(Interview, São Paulo, 15/06/2018)*

The argument of coexistence and complementarity between technologies is therefore put forward by the chemical and biological input industry as well as by public administration. This idea is obviously reflected in the composition of the new industrial alliances, such as CropLife Brasil, and in the positions taken by their leaders defending a unified approach to plant protection technologies. But the close connection between the two types of technologies and the two industrial sectors can also be seen in the individual trajectories of some individuals, such as entrepreneurs in the biocontrol sector. This is the case, for example, with one of the managers of an Argentinean company marketing biocontrol solutions, who returned to Buenos Aires in the early 2010s after working for many years in the pesticide industry in Brazil and the US. This shift from chemical to organic did not prevent him from maintaining activities in the pesticide sector, and from developing certain convictions about the importance of using both types of technology. He points out:

> I listen to all the bells. Then I decide what is best for me … Besides, I work as a consultant for many agrochemical companies. I don't think there is going to be a total disappearance of chemicals.
>
> *(Interview, Buenos Aires, 26/04/2017)*

The idea of a massive decline of pesticides and a generalised replacement by biocontrol is thus rejected as a utopia by these industrialists, pioneers of biocontrol without defining themselves as enemies of the pesticide industry. This utopia of substitution or decline is, in their eyes, carried by actors who basically do not understand the technical elements of the plant health issue. The secretary of ABC Bio explains:

> Our segment is seen positively as the solution to all problems. And this is very positive. However, when they talk about our segment, about bioinputs, there is a very big rejection with respect to agrochemicals, saying—"No. Bioinputs are going to be the solution to the problems"—and, in fact, we are one more tool within the integrated pest management.
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> *(Interview, São Paulo, 15/06/2018)*

Biocontrol and pesticides are both said to have virtues, as well as drawbacks. Those involved in the industrial alliance between biocontrol and pesticides insist on this point, thus making an equivalence between biological and chemical inputs. While pesticides are denounced for their environmental or health effects, some industrial players do not hesitate to point out the risks that biocontrol can generate, especially products based on micro-organisms. An Argentinean consultant supporting companies in the registration of chemical or biological inputs with the public regulator mentions this similarity between the two types of inputs:

> There are a lot of things that are natural, that are organic, in my vision, doesn't mean they are less toxic. Or that they can't bring some kind of trouble. So, I agree that perhaps the current regulation is too chemical or too complex and

> does not fit in with certain studies, but to say well, that this is not the case… we have to look for different methods of identity, we have to evaluate it … all are compounds that are applied. It's all an artificial thing you're going to apply to a crop. It's not water, it's not sun. Bioinputs also have their risks.
>
> *(Interview, Buenos Aires, 04/09/2017)*

The risks pointed out are obviously not of the same order as those induced by chemical molecules. It is the risk of dispersing micro-organisms such as bacteria or viruses into nature that is pointed out, when the selection or reproduction process is not controlled. This would be the case in particular when farmers venture to produce certain micro-organisms by themselves. But it is also the risk of poor agricultural practices, of farmers misusing biocontrol technologies, that is pointed out. This last risk is precisely the same as the one regularly identified by the pesticide industry to defend their products. Faced with accusations against their molecules and their dangerousness, the industry often argues that it is the misuse of products by farmers—overdosing, treatments in bad weather conditions—that is to be condemned, rather than the technologies themselves. This link between the product and its use is even recognised in the legislation of certain countries. In France, for example, it is not the commercial products alone that are approved, but the commercial products and their conditions of use (Pellissier 2021). As a result of these arguments and movements in the chemical and biological input industry, biocontrol is thus associated with and equated to the dominant technologies that are pesticides. While alternative technologies undoubtedly offer a breakthrough and a credible alternative to problematic technologies, they are not necessarily the levers of their decline. They can be involved in both the discontinuity and continuity of the regime developed around problematic technologies.

7.4 Conclusion

How does the emergence of alternative technologies contribute to the decline of incumbent technologies? This is the question I asked in the introduction to this chapter. To answer it, I looked at the Argentine and Brazilian cases of the development of biocontrol technologies, alternatives to chemical pesticides. More specifically, I considered the expansion stage of these technologies, i.e., a period in which existing technologies start to receive increasing interest from both public and private stakeholders. While they were a niche for decades, their market has been growing strongly for the last ten years, and they are the subject of dedicated public policies. Following on from the work done in both countries (Goulet 2021; Goulet and Hubert 2020), I have shown here that the development of these alternative technologies plays an ambiguous role in the decline of the technologies in place. The dilution of these alternative technologies into larger ensembles, including technologies essential to the functioning of the incumbent technological regime and even including the incriminated technologies, contributes to the idea of coexistence between technologies. The scientific, political and industrial spheres are at the heart of this dynamic, by incorporating these alternative technologies into their activity portfolios, and by defending a vision of coexistence or even complementarity between technologies. Alternative technologies are thus placed at the service of both technological continuity and discontinuity. This position obviously does not hide the fact that certain actors, historical defenders of alternative technologies and promoters of an explicit discontinuity, do not find their way in the direction taken by this expansion. This is the case, for example, of the promoters of agroecology or organic farming, for whom only the firm and definitive withdrawal of pesticides constitutes an acceptable outcome. But in our case study, marked by the joint support of the state and the input industries for the agro-industrial system based on the use of pesticides, the space for strategies of counter-framing alternative technologies remains slim. This raises the question of what would happen in other contexts, such as those of industrialised countries where society and consumers are becoming more aware of the risks associated with pesticides. Analysis of the development of biocontrol in France (Aulagnier and Goulet 2017), intervening in the framework of an ambitious pesticide reduction policy, seems however to show us that things are not different in the end. While political speeches in favour of a frank break are certainly formulated, biological alternatives remain, as in South America, one option among others to guarantee high levels of agricultural productivity in the long term.

Therefore, in the same way as in other sectors (Bergek et al. 2013; Kim and Park 2018; Goulet and Vinck 2022), agricultural technologies that have become problematic and are set to decline are thus associated with and attached to alternative technologies, within technological mixes. But once this conclusion has been reached, it is the question of the future of these mixes that should be of concern, and that of the balances or competitions that arise or shift over a longer period, beyond the expansion phase. In the case of the combination of bioinputs and pesticides, an Argentinean public servant does not hesitate to delegate the evolution of these balances to "natural" forces, which are related to the market or to the evolution of the efficiency of technologies:

> The technological paradigm shift will necessarily take place gradually, that is, these products will be introduced and show their potential, they will be adopted to the extent that farmers want to use them … If later one model proves to be more efficient, naturally one will win out over the other.
>
> *(Interview, Buenos Aires, 11/10/2017)*

Based on a short period marking the expansion of alternative technologies, this chapter has provided elements for a better understanding of the role of these alternatives in the decline of problematic technologies. The challenge now is to better characterise how this relationship can evolve over time, without relying on naturalistic explanations, and how they can be governed (see Stegmaier 2023). The three spheres considered here—political, scientific and industrial—offer important places to observe and consider these developments and their drivers.

Note

1 Bioinputs are currently handled by IICA within a "Bioeconomy and Productive Development Programme".

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