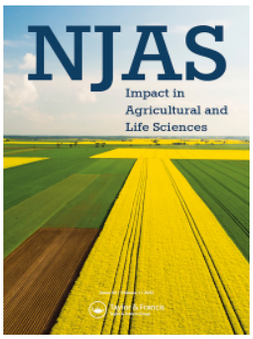

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The control of transboundary plant diseases and the problem of the public good: Lessons from Fusarium wilt in banana

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ABSTRACT

Many plant diseases and pests cannot be controlled on-farm as they spread from one field or region to another. This opens up a series of interconnected social, political, and economic questions besides the common technical questions about the spread, impact and management of the disease or pest. A new genotype of the soil-born fungus Fusarium, called Tropical Race 4, is extremely virulent, widely destroying banana crops destined for domestic and international markets, and spreading rapidly in Southeast Asia and recently to other countries in the Middle East, Africa, and Latin America. It threatens both staple food production and the export of bananas. The international research and policy-making communities on bananas have been alarmed and are calling for concerted action to control this disease. This paper supports the idea that Fusarium wilt control has to be regarded as a public good but also finds that the public good is being conceptualized in divergent ways. It raises the question as to what gaps exist in the current understanding of providing that public good. The paper identifies a set of key problems, including the problem of anticipation by governments, a neglect of histories of political economic oppositions in the banana sector, the strictures of sovereignty-thinking in multilateral responses, and the aversion that neo-liberal models of governance develop to the public good.

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KEYWORD Public action; sociology of agricultural pest management; regulation; disease governance; anticipation

1. Introduction

Epidemics of plant diseases with a transboundary movement of the pathogen generate questions about who should respond to it and what appropriate collective action is. Scientists, farmer associations, and regulators in many

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countries have articulated a deep concern about a new epidemic of Fusarium wilt in banana (sometimes called Panama Disease), which is caused by a new genotype of the fungus *Fusarium oxysporum* f. sp. *cubense* (hereafter Fusarium and Fusarium wilt for the disease and *Foc* for the pathogen), commonly known as *Foc* Tropical Race 4 (hereafter TR4). Fusarium has already destroyed many plantations in Southeast Asia and is spreading to other countries; diseases do not recognize borders.[1] *Foc* is a soil borne fungus that can spread through infected planting material, footwear and hoofs, tools, and water (e.g. irrigation and flooding) (Drenth & Kema, 2021; Ploetz & Churchill, 2011). No effective cultural or chemical methods for control exist yet (Ploetz, 2015) and chlamydospores may persist in the soil for a very long time (Stover, 1962). The widely planted Cavendish variety is resistant to other *Foc* genotypes, including the one that caused a previous pandemic – collectively called Race 1 – in plantations with the Gros Michel variety in Latin America in the first half of the twentieth century. However, like many other banana varieties, Cavendish – the most planted banana globally, both for export and local consumption – turned out to be highly susceptible to TR4. The concern about the disease is widespread, including countries where the disease is not yet present (Altendorf, 2019; EFSA-PLH, 2022; Pocasangre et al., 2011).

Historical studies have revealed the multiple interactions between plant disease epidemics, the reorganization of landscapes, changing agrarian structures and differentiation between forms of production, and the nature and effect of policy decisions (for example, for potato Whelan, 1995; for banana; Soluri, 2005; for strawberry; Guthman, 2019). Pest and disease control is typically an issue that requires action at a higher level than the field or farm, both in spatial terms and social and political terms (collective action, including public action by the state). An example is the discussions around area-wide integrated pest management, which is supposed to be knowledge intensive (Morse & Buhler, 1997; Toleubayev et al., 2011), to involve a "community" of different actors (Nowierski & Meyer, 2008), and to require a long-term perspective and a concept of total pathogen population management based on ecological theory (Elliott et al., 2008; Toleubayev et al., 2007). The latter implies control strategies adapted to population dynamics in heterogeneous environments with spatial and temporal variability, rather than opting for a uniformly effective control strategy (Levins, 1969). An example of a pest that has been eradicated from larger areas by developing detailed knowledge of its biology and collective, public action of different

[1]At the time of writing, *Foc* TR4 infestation had been confirmed in Taiwan, mainland China, Indonesia, Malaysia, Philippines, Australia, Jordan, Oman, Mozambique, Pakistan and Lebanon (Ordoñez et al., 2015, 2018), Vietnam (Hung et al., 2018), Laos (Chittarath et al., 2018), Israel (Maymon et al., 2018), India (Damodaran et al., 2019), Colombia (García-Bastidas et al., 2020), Peru (Acuña et al., 2021), and the Island of Mayotte (Aguayo et al., 2021).

states is the screwworm (*Cochliomyia hominivorax*). This parasite of livestock has been eradicated from the USA, Mexico and Central America through a multiple technique, multi-country strategy (Mastrangelo & Welch, 2012). It is unlikely that *Foc* will be eradicated through the control strategies applied in the screwworm case. However, drawing on known successes of transnational collective pest and disease control, it could be argued that successful Fusarium control goes necessarily beyond the field/farm level and single, universal technologies but instead, will be a matter of transnational, knowledge intensive, and ecosystem adapted action. The transboundary nature of Fusarium wilt brings up the question as to how current approaches to study *Foc* and Fusarium and to develop control measures provide the necessary public goods for transboundary disease control. To address this, we have to elaborate what is a public good in this context.

The problem of organizing collective action for pest and plant disease control is often framed as a "tragedy of the commons" dilemma or an incentive dilemma (e.g. Brewer & Goodell, 2011). Although this framing of the problem relates to our discussion below of the "underprovision of public goods", it falls short in understanding wider political and sociological forms of cooperation and analysing historically and place specific political and economic structuring of people's actions and thinking. In contrast to what the "tragedy of the commons" assumes, the underprovision of public goods is not just the outcome of a neutral, universal game between independent individuals, disconnected from time and space. Instead, the provision of the public good depends upon how institutions (sets of rules and social norms) operate and shape and bear pressure upon individual behaviour. The popularity of the tragedy of the commons thesis dovetails with the dominance of neoliberal thinking over the last decade, which looks suspiciously upon or dismisses collective action to deliver public goods, and which, in its most radical form, bets completely on individualized approaches. In the case of area-wide disease problems and transboundary spreading of the disease, however, the need for collective action obtrudes so starkly that most authors would at least argue for some form of public intervention to foster control programmes, expenditure of public funds on knowledge generation, and regulation (such as quarantine) (de la Cruz, 2020).

Several initiatives at the international level have approached Fusarium control from a public interest perspective, including FAO-related actions and the CGIAR institute Bioversity. CGIAR institutes have always been considered to deliver global public goods (Gardner & Lesser, 2003). Bioversity has been involved in several Fusarium research networks. The Food and Agriculture Organization of the United Nations (FAO) has called for an integrated global response to the Fusarium wilt TR4 epidemic (FAO, 2014) in order to provide solutions on a large scale and to mobilize and coordinate resources and expertise (for risk assessment and emergency prevention).

Through the International Plant Protection Convention (IPPC), contracting parties (184 as of October 2022) have agreed upon quarantine issues, reporting, and communicating about regulatory action. The Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases, facilitated by the FAO, may coordinate responses to large-scale emergencies resulting from transboundary pests (as against outbreaks of the Desert Locust). Despite these global arrangements, however, many actors in the banana sector have uttered the wish that governments, international organizations like the FAO, and global networks of expertise should do more to tackle the spread of the disease. It is implied that current management practices in the field, available alternatives, and quarantine practices are yet inadequate; in theoretical terms, there is an underprovision of public goods. The disease is spreading despite the international and national efforts to contain the epidemic. This brings us to the question addressed in this article: How to conceptualize Fusarium wilt control as a public good, and what gaps do we observe in the current understanding of providing that public good? We approach this question by critically reflecting on the current research lines and global arrangements that address Fusarium wilt in bananas. We will argue that current thinking about disease control as public good is severely limited and needs improvement in four different domains.

In the next section, we discuss first why plant disease control, at least in cases like Fusarium wilt, can (and should) be seen as a public good or better as a set of public goods. The third section identifies and discusses different research strategies that aim to contribute to Fusarium control and considers how these relate to a public good perspective. In the fourth section, we will discuss the perspectives on governance, collective action, and private–public relationships.

2. Conceptualizing plant disease control as a public good

2.1. Different ways to conceptualize the public good and its relevance for agricultural science

Unlike private goods, public goods, as defined in the economic literature, are non-excludable and non-rivalrous (i.e. non-exclusive) in consumption (e.g. Kaul, 2012; Kaul et al., 2003; Sandler, 2013). In other words, they are "freely available to all" and "not diminished by use" (Dalrymple, 2008). Consider the example of a farmer who reads on a website a report of a scientific study that shows how creating specific soil conditions helps to control Fusarium wilt. When this farmer applies this knowledge, it would not reduce its availability to others nor does its public character prevent people from using it. The term "goods" is not only used for things but also for services, conditions (e.g. microclimates related to landscapes), legal frameworks, scientific knowledge, and so on. Classical examples of publicly provided public goods are roads and energy infrastructure (though

these have often been subjected to privatization processes in many countries); these are things (material objects). Newer public goods are often intangible (Kaul et al., 2003, p. 15), for example, knowledge about disease control is more a condition than a concrete thing. Provision of intangible public goods is "difficult to monitor and verify". In the common definition of public good, "good" does not necessarily refer to the normative "good": public goods can be bad. Fusarium wilt itself is a bad public good: every farmer in an affected region potentially suffers from an epidemic (non-excludable and non-rivalrous).

The dominant economic interpretation of public goods provided above is just one way to define them. Sekera (2015, 2016) develops a systematic critique of the economic literature behind this definition of public goods and unravels its insistence on government incompetence and market failure as the only plausible justification for delivering (some) public goods. Sekera (2016) proposes to build a new theory of the public non-market economy that delivers public goods. This literature identifies the destructive effects of market mimicry: de-democratization, the perversion of seeing revenue raising as a goal, the problem of converting citizens into "customers", and the hollowing-out of government among others. Foucault (2008) was an early observer of how contemporary neo-liberalism is to be seen as a new constellation, not just as the continuation of the process of ever-expanding markets. Foucault was concerned about how the exercise of political power becomes increasingly modelled on the principles of a market economy and how the principles of a market economy are projected on to the general art of government (cf. Córdoba et al., 2014; Lemke, 2001). In this context, Sekera's call for rethinking the non-market economy is not just an appeal to old forms of government but instead concerns a project to find new routes to imagine and produce public goods. Distinct from the technical definition of public goods in economics (the non-excludability and non-rivalry characteristics resulting from emerging properties of a good seen from the perspective of the market), Sekera (2015), following Wuyts (1992), proposes a more comprehensive definition of the public good that recognizes non-market, public production, "created through collective choice, paid for collectively, and supplied without charge (or below cost) to recipients". Delivery of public goods is not just a technical-economic matter but an outcome of complex political processes and results from public action. In the context of Covid-19, Ghosh and Qadeer (2020) see public health as a public good in itself, not because of a technical definition of whether or not it is non-rivalrous or non-excludable, but by showing that cooperation and collaboration, needed for disease control, is not possible without a strong public good perspective. These authors point at the shared gains from a shared good, inextricably linked to equality and justice.[2] A more

[2]Kallhoff (2014) also provides a social justice argument for reconsidering the technical definition of public goods that mostly informs calls for substituting them by private goods. She argues that the production of public goods builds solidarity, promotes connectivity in communities, and strengthens

profound critique of the economistic interpretation of the public good is provided by Anton (2000) who introduces the concept of "commonstock", which is "logically and temporally prior to the economist's notion of a public good". Most actions, even neoliberal market institutions, are based on social rules and to some extent parasitic upon the commonstock, i.e. nonmarket values, social rules, nonexclusionary forms of property, noncommodified labour (care), shared knowledge, and so on. To only allow public goods that are non-excludable and non-rivalrous would be far too limited as such pure public goods hardly exist. This second perspective on public goods (Anton, 2000; Sekera, 2015) broadens our thinking about publicly funded agricultural research and private interests by going beyond the narrow idea of the public good in the economistic interpretation. Our perspective on the public good is in line with this second approach. Some ideas of the first approach are still relevant though, such as the distinctions between different types of public goods, which will be used below to characterize elements of Fusarium control.

Different views on the public good have in common a general concern for the underprovision of public goods. Kaul (2012) summarizes the factors that contribute to underprovision of global public goods (GPG), including 1) the publicness of consumption leads to free-riding and other collective action problems, 2) lack of process fairness and mutuality of benefits depresses willingness of countries to cooperate, 3) the complexity of provision with very different organizations involved each with their own constraints break down the provision path, 4) the divergent preferences of different organizations, networks and countries for particular public goods or how to provide them leads to issue avoidance or lack of action, and 5) the path-dependency of existing technological trajectories and organizations that are reluctant to change may lead to a lack of effective policy responses. Most of these factors play a role in constraining global efforts to improve Fusarium wilt control.

Several reasons have been given for the underprovision of problem-solving agricultural science in different types of literature. The first two discussed below follow more conventional views on the public good, while the third reason illustrates the more critical perspective in the line of Sekera and Anton. The first reason is the lack of global resource mobilization. Examples are lack of investment in R&D on communicable diseases (Smith & MacKellar, 2007) or a reduction of development aid funding for international agricultural research (Dalrymple, 2008; World Bank, 1998). Some of these calls are not more than opportunistic concerns about declining research funding made by organizations that at the same time engage with private research and seem to adapt likewise their research agenda and views on intellectual property rights to those concerns (for examples and debate,

a shared sense of citizenship. As this is not a prime goal for, nor outcome of Fusarium wilt control, other public goods would probably serve better such functions; we will not discuss this further.

see Lele et al., 1999; Dalrymple, 2008, and, on banana R&D; Persley & George, 1999). We have heard such kind of references to public goods in Fusarium wilt-related workshops and conferences but will not further discuss it given its minor relevance for further reflexivity on this topic.

A second reason for underprovision is experienced when scientifically well-defined measures cannot be implemented due to the realities of the neoliberal global governance model. As has been previously pointed out, international trade has exacerbated the problem of invasive species, but at the same time WTO rules may obstruct the internalization of the costs of such invasion "externalities" within the international trade framework (Perrings et al., 2005; Perrings, 2016). For example, the Secretariat of the International Plant Protection Convention, housed within the FAO, cannot proactively act until a disease is denominated as a quarantine pest. Denominating a particular plant disease as a quarantine pest allows it to be regulated by the IPPC and permits countries to impose phytosanitary sanctions without running afoul of WTO rules. However, this denomination requires that countries disclose the presence of the disease within their territorial jurisdictions – a requirement that, in the case of TR4, has been made complex by unevenness in technical expertise and diagnostic capacities, underdeveloped notification procedures, weak links between expert scientific communities and national governments within countries, and lack of transparency. But because classifying a plant pest as a quarantine pest effectively creates a trade barrier, the hoops to jump through are kept high and doubt is resolved against regulation, quarantine and collective action.

The third reason is not so much of the underfunding but the shifting nature of public agricultural research as an effect of privatization or a roll-back of the state's agricultural research, leading to overlooking and undervaluing the provision of public goods (e.g. Glenna et al., 2015). Due to a declining public goods perspective, the goal-setting of agricultural research changes. Glenna et al. (2015) argue that public funding of public-private research alliances shifts agricultural innovations towards private goods (excludable either technically as in hybrid seed and/or via patents) resulting not only in the underprovision of public goods but also in the demeaning of the value of the public good.[3] This "roll-out neoliberalism" (the increasing use of public resources for private interest) is not universal; their data suggest, for example, differences between the USA or UK, on the one hand, and Germany, on the other hand. Stengel et al. (2009) likewise criticize the privatization of agricultural research, but nevertheless argue that commercialization of

[3]Brooks (2011) analyses how reframing the role of CGIAR as a public good provider (cf. Dalrymple, 2008), was not just a discursive strategy to attract new research money, for example from the Bill and Melinda Gates Foundation, but also reinforced generic technology strategies based on "silver bullet" expectations, such as singling out genetic improvement as main strategy, to the detriment of more site-specific approaches based on a recognition of diversity.

science and the public good "need not be incompatible" (p. 289). They argue that it is impossible to go back to the image of an independent science, as historically "science cannot be easily separated from the market (or other social/cultural practise. (..) (P)lant science has historically developed through long-standing collaborations with growers" (p.293, see also Maat, 2001).[4] This also counts for banana research R&D (Córdoba & Jansen, 2014). It is not necessarily a problem when applied banana research addresses specific local productive needs of growers, but an unbalanced influence of private actors on research priorities that address broader public interest questions, such as a transboundary disease like Fusarium wilt, might be problematic.

The different perspectives on the public good identified above inform different views on what the shortcomings of current agricultural research are in delivering the needed public good of transboundary disease control. However, the question remains open whether transboundary disease control is a public good and in what terms. As an example, we will discuss Fusarium wilt control.

2.2. In what terms is Fusarium wilt control a public good?

In what sense can Fusarium wilt control be seen as a public good? Firstly, we have to realize that banana production as an economic activity is a collective effort. Although the banana commodity chain may appear as a pure private business endeavour, it can only exist so far as public action creates the conditions: pesticide use is being regulated, large-scale infrastructure (e.g. ports and roads) has to be put in place, quarantine regulations for international trade are being formulated, agricultural colleges educate engineers

[4]In their effort to develop frameworks for science that move beyond distinctions like public/private Stengel et al. (2009) follow Callon (1994), arguing that "public good science should not be based on ideas of insulation or protection from the market but, alternatively, on ideas of ensuring and promoting diversity in a science that is diversely networked with an appropriately democratic diversity of social articulations of needs, imagined ends of knowledge, 'stakeholders', and interpreters" (p. 296). Callon (1994) introduces three normative notions to decide about the publicness of research: freedom of association, freedom of extension, and fight against irreversibility. Taking examples from Fusarium wilt control these conditions can be explained as follows. *Freedom of association* refers to the absence of obstacles to connect with external technologies or knowledge partners. Examples of obstacles are patents, publication restrictions or control on the selection of research partners. The circulation of materials, creative ideas and techniques should be amplified. Include farmers or environmental movements in the network and one gets other research questions and statements. *Freedom of extension* means that Fusarium wilt researchers must have the means to create technical compatibility with other situations and to adapt production to expectations. This means building international connections for future experimentation and adaptation. The third notion —*freedom of irreversibility*— however, draws attention to the likelihood of extended networks simply perpetuating themselves and neglecting alternative potential opportunities. Science becomes private science and reduces variety. To fight irreversibility, emergent or new collectives that seek other solutions should be supported. These concepts may help to reflect on divergent proposals through which researchers and funding agencies seek solutions to Fusarium wilt. Although these three notions add sociological and anthropological insights to the economic definition of public goods, they seem to celebrate diversity and, consequently, provide little clues on what to decide about different, clashing technological options or the distribution of resources over different, competing research trajectories.

and technicians, and so on. Furthermore, public spending and the mobilization of resources (e.g. whether through taxes, levies, fees, or import/export tariffs) for disease control require the formulation of needs through collective decision-making and the identification of and choice between or among particular disease control strategies. The issue is then whether the short-term profit maximizing interests of individual producer/market actors prevail or whether there is adequate exploration of societal needs that goes beyond these private priorities.

In the literature we find several observations that the control of pest and diseases which easily move across state boundaries is hindered by typical problems in the delivery of public goods, for example, of rinderpest (WDR, 2007) and locust (Toleubayev et al., 2007, 2010). The fact that mobile pathogens do not recognize borders makes their control a regional or global issue. If compared with, for example, the restoration of soil fertility, the latter is generally much more a local issue to be handled at the field level. The transboundary character of Fusarium wilt implies that a focus on national provision of public goods will be insufficient. Instead, Fusarium wilt control is to be seen as a global public good, which involves the extra challenges resulting from differences between nations and ambiguity about what actors besides nation states should be involved (Desai, 2003; Sandler, 2013). Possible underprovision of Fusarium wilt control at the national level should therefore be looked upon together with an understanding of the problems of international co-operation, as well as the tension between national sovereignty and strategic self-interest, and acquiescence to international agreements and global actions that restrict state prerogatives.

Differences in disease control between countries may be problematic due to the "weakest-link" character of Fusarium wilt control, whereby "the socially available amount is the minimum of the quantities individually provided" (Hirshleifer, 1983; for an ecological example, see Perrings et al., 2002). In other words, disease transmission will increase if one producer or one country does not control its borders on pathogen mobility (despite intensive control by others). This is not a pure weakest-link situation, as border controls may always help, but if in a region one country does not control for the spread of Fusarium wilt it may easily spread further from there. Hence, with regard to quarantine aspects, international cooperation requires due consideration. Another public good characteristic of Fusarium wilt control is that it is not just a single, well-defined public good as pictured in theories of the public good. In fact, a more profound identification of Fusarium wilt control reveals the composite character of the problem at hand and the conjuncture in which it emerges. Several public goods play a role in Fusarium wilt control. Firstly, new knowledge and technologies (both artefacts such as resistant varieties and practices such as soil tillage) have to be made available. The privatization of such knowledge and technologies, confined to the control of a limited number of companies, would

not enhance disease control, as marginalized farmers or nations would persist in spreading the disease. Secondly, effective quarantine regulations and their implementation are a public good. However, they become more, and maybe only, effective if many nations take such quarantine measures. Thirdly, international research and innovation networks should function properly to produce new knowledge on *Foc*, disease epidemiology, control technologies, and so on. It is unlikely that investments driven by private interests will sustain such complex research networks by themselves.

Researchers could argue, however, that Fusarium wilt control is not necessarily a weakest-link public good as defined in classical public goods terminology. Instead, one good invention by a research network may be helpful in Fusarium wilt control, i.e. a "best-shot" character (defined as "the socially available amount is the maximum of the individual quantities"; Hirshleifer, 1983).[5] In general, however, it may be expected that durable technological solutions are not of such a "silver-bullet type". Another type of public good, besides the weakest-link and best-shot, is also present in Fusarium wilt control, assuming the condition stated below is present: "provision through summation" (Kaul, 2012). Only several approaches together, working synergistically or at least complementarily, such as agroecological adaptations, more resistant varieties, and appropriate phytosanitary measures, may provide the desired public good, whereby each individual technology contributes to a reduction of disease pressure. Recently, research that presents grand expectations of biotech-supported plant breeding makes reference to the importance of combining it with increasing biodiversity in banana fields and research into this (e.g. Zorrilla-Fontanesi et al., 2020). One condition for summation is the recognition of diversity in technological views on addressing plant diseases, particularly where contexts differ, and recognition of other approaches with paradigmatic differences in methods and thinking about banana systems and diseases. This means that the approaches should not compete with each other. In short, when we disentangle Fusarium wilt control, we discover various types of public goods (seen as "dimensions" by Barrett, 2007).

With these insights we gradually move away from the axiomatic Samuelsonian definition of public goods (yet labelled as collective consumption goods in Samuelson, 1954) as used in literature that focuses purely on the non-excludability and non-rivalrous character of plant disease control (e.g. Oude Lansink et al., 2018), to a more real-world based approach to public goods that analyses the construction of public or private solutions in relation to preferences and democratic formulation of needs and the effectiveness of public action in generating desired outcomes (e.g. Desai, 2003; Kaul et al.,

[5]The implication of a weakest-link expectation would be that it is a prerequisite to involve all relevant actors in participating, developing or using the public good, while a best-shot expectation would find it less urgent to include all actors.

2003; Orchard & Stretton, 1997; Sekera, 2016; Wuyts, 1992).[6] As illustrated with the point of multiple technological solutions, the desired public good is a matter of choice and thus social and political. This idea does not alter the fact that the nature of a disease sets conditions. A plant disease that can be controlled by on-farm spraying (e.g. Sigatoka) can be seen as less "public" than a disease whose only control, at the moment, is containment of pathogen movement. Furthermore, an increase in the hazardousness of an epidemic may shift an issue from private to public. In short, the public good character of Fusarium wilt control is not a single, a-historical, and given notion, but depends on what aspect of disease control we are talking about, the preferences of relevant actors, and the perspectives on the role of the public sector and other actors. In other words, conceptualizing Fusarium wilt control or elements thereof as a public good is not just a technical issue but highly political.

Mobilization of resources for collective action and public action by the state on Fusarium wilt control is hindered because of the problems of invisibility and anticipation. Effective plant disease control becomes "invisible" when successfully produced and provided (Sekera, 2016). For the wider public, it is difficult to be concerned about (and thus support policies) for something that does not happen because of public action (such as quarantine control). Moreover, political decision-making is not good in anticipation, as Arhin-Tenkorang and Conceição (2003, p. 486) argue: "Under the initial international arrangements for communicable disease control, action tended to follow crises". The relative public invisibility when anticipatory disease control would be successful may even reinforce a disinterest in anticipatory policymaking and contribute to the underprovision of Fusarium wilt control.

3. Coming full circle: Recurring research strategies and public-private connections

Starting from the premise that knowledge building for Fusarium wilt control is a public good, we explore in this section how banana research over time related to private interests. Historical accounts reveal close connections between a fragmentary development of scientific knowledge, agronomic problems in banana fields, trading interests, and the nature of plant diseases. In particular, the spreading of diseases due to expanding plantation agriculture (i.e. monocultures, see Scheffer, 1997, Soluri, 2000). We first elaborate on the invaluable historical study by Marquardt (2001), which describes the

[6]Desai (2003, p. 72) discusses the "Samuelson fiction of pure nonexcludable goods". "There are few goods like that, and the allocation of public funds for them is often the least difficult problem. Most public goods are excludable and have externalities but are genuinely beneficial to many people. They are also rivalrous in the sense that one has to choose among them as well as determine the quantity and quality of the provision of those chosen".

United Fruit Corporation's (UFCo) responses to the previous Fusarium wilt epidemic (Tropical Race 1) and how these altered the Central American landscape. The dominance of UFCo in the international banana trade, with its concomitant dominance in banana research, in the first half of the twentieth century, sowed the seeds for the later view among funders of international agricultural research that banana research did not deserve public investment compared to smallholder food crops such as rice (cf. Buddenhagen, 1993). The initial growth of UFCo's banana operations happened without building in-house agronomic knowledge; during the first two decades of the twentieth century bananas cultivation was mostly based on the knowledge and skills of its workers (Marquardt, 2001).[7] This changed with the production crisis resulting from the first Fusarium wilt epidemic in Central America, leading to abandonment of plantations and their life expectancy dropping from 15 to 20 years to 5 years, which pushed for systematic intensification.[8] In 1916, UFCo hired the soil scientist Prescott to do a survey, which was based on an agro-ecological premise: "the fungus was an opportunistic agent, taking advantage of weak plants in poorly sited, exhausted, or otherwise 'unhealthy' plantations" (Marquardt, p.62). This view was partly based on observations that Fusarium wilt was much less expressed in some fungus-infected fields than in other fields, for unknown reasons. Prescott's study focused on soil conditions, fertilization and drainage and incited the idea that banana production needed a more scientific basis. After Prescott's survey, the company also spent resources on finding Fusarium resistant germplasm. In the early 1920s, Dunlap, another contracted researcher, conducted field trials with over 150 different varieties. Interestingly, this included the Cavendish, which was found to be resistant but not economically profitable as being too delicate in transport. UFCo would stick to the highly susceptible Gros Michel variety, seen as the only option in the market.[9] Pressed by the expanding disease, UFCo consolidated its research efforts in La Lima in Honduras, as of 1924. The research station focused on the relationship between soils and the spread of the disease. Since then, agronomy and science in general would command plantation management. UFCo invested ambitiously in flood-fallowing (submerging fields for a long period) between 1945 and 1955, but these attempts proved futile. In 1959, UFCo resumed the abandoned search for finding resistant germplasm and added a "Plant Breeding and Genetics" department to its

[7]Division managers at that time were not trained agronomists. In that period more than 60% of UFCo's trade was sourced from local planters, thus not from UFCo's own plantations; by 1930 75% was sourced from UFCo's own plantations.

[8]Until then, treatments – mostly ineffective – differed between UFCo's plantations (adding lime, digging out infected rhizomes and liming around them, burning or bleaching disease areas, mulching or adding manure) as the company hardly engaged in supervision of agricultural practices.

[9]As late as 1962, Stover reproduces this view in his review published in 1962 (p.104), around the time that even UFCo was giving up Gros Michel and shifted to Cavendish.

research division (Soluri, 2005). However, apart from generating much knowledge about soil management, fertilization, and germplasm, research could not sustain the export production of the favoured Gros Michel. UFCo shifted to Cavendish in the early 1960s (Soluri, 2005), years later than its competitors, who were expanding to the detriment of UFCo.

After the Second World War, banana research at public institutes would gain relatively in importance, in particular since the UFCo handed over its research facilities in Honduras to FHIA – a non-profit, publicly funded foundation – in 1980 (Marquardt, 2001). With international aid funding, the breeding programme in La Lima could be more or less continued. Globally, public entities in Belgium, Brazil, France, Taiwan, India, and Australia, among others, have also developed research on Fusarium wilt. Most work continued in the line of Stover who considered in 1959 that banana breeding was "the only hopeful long-term approach" to Fusarium wilt (Soluri, 2005, p. 180). The breakthrough of molecular biology and willingness to invest in gene conservation in the second half of the twentieth century shaped the imagination of finding a resistant variety as the optimal technological response to epidemic plant diseases. We can distinguish three strategies within this line of thinking and will contrast those below with two other strategies.

The three positions that focus on genetic solutions are voiced by researchers who expect the solution from a genetically modified (GMO) banana, researchers who expect most from somaclones, and less vocal researchers targeting new forms of breeding (using seed-based production of hybrids). The first position considers that the GMO banana is the only solution for disease control of the difficult to breed banana, which has become the opening trope of many publications for about three decades now (see, for example, contributions to INIBAP, 1993; Persley & George, 1999). A basic assumption is that conventional breeding with Cavendish is practically impossible. Proponents time and again express a strong optimism that a GMO banana can be launched into the market in the short term (e.g. Godfray et al., 2010 predict five to ten years; Dale personal communication, 2014: six years; Crouch et al., in 1998: "A new transgenic banana cultivar may be released to the market within six years").[10] This narrative of optimism underlines the strong belief in and the felt need to defend this best-shot option. The second position claims it already has a way to construct resistant Cavendish through a selection of mutations in tissue culture bananas in Taiwan, the so-called Giant Cavendish Somaclonal Variants or GCTCVs (Hwang & Ko, 2004). A difference in opinion between the first two positions has emerged around the nature of "resistance" of GCTCVs and the applicability of the GMO alternative; the nature of this contention can be illustrated with a closer look at

[10]For reviews of biotechnology research in banana in different periods, see INIBAP (1993), Crouch et al. (1998), Sági et al. (1998), Ortiz and Swennen (2014), Zorrilla-Fontanesi et al. (2020), and Kema et al. (2021).

a discussion in a ProMusa blog (Vézina, 2015). One researcher (Dita) argues that the somaclonal varieties have no "true resistance" but only quantitative resistance (moderate resistance). Greenhouse trials, needed to overcome the limitations from field trials, show that with high inoculum levels these somaclones do not display true resistance. Planting them, it is argued, will keep the infested banana field as a source of inoculum for the further spread of the disease. In a reply to the blog, another researcher (Molina) defends the utility of somaclones for the situation of the Philippines where smallholders (who cannot shift production to non-infested land) can keep harvesting and make a livelihood with the somaclones. Molina differs from Dita in his assessment of the relative importance of field testing and greenhouse trials, emphasizing that what counts is what happens in the field. The somaclone argument emphasizes the widespread availability of somaclones, the selection among thousands of plants in the field, and the possibility to reproduce the method easily. The GMO argument emphasizes that somaclones are genetically not stable.[11] This controversy, partially rooted in different disciplinary views and contexts of research and development work, is an example of how the search for technical solutions to a disease problem may lead to contrasting strategies for addressing the disease and become hardened in competing research coalitions. When such science in competition has to inform policy making for addressing a risk, it may increase uncertainty rather than reduce it.[12]

The third position points at the manifold possibilities of conventional (non-transgenic) breeding, not in contrast to modern biotechnology but made possible by it. Already produced hybrids, resistant to Black Sigatoka, prove that crossbreeding for disease resistance is possible. Genetic engineering and biotechnology in general is seen as complementary to banana breeders (Ortiz & Swennen, 2014) although scepticism was already voice at an early stage: Rowe (1998), for example, questions the value of molecular markers in the case of bananas. Buddenhagen has argued that genetic engineering is seen as only necessary for Cavendish: "All the other banana classes should be bred conventionally since they are now proving so easy to breed" (Buddenhagen, 1993, p. 25). But even this claim is disputed: Aguilar Morán (2013) argues that even Cavendish, assumed to be female sterile, can produce seed with laborious work and thus be crossbred conventionally.[13]

[11] Is not yet exactly clear what happens at the genomic level in somaclonal variation: it has been suggested that stable genetic change has not been introduced but only some type of epigenetic modification (a heritable change that does not affect the DNA sequence but results in a change in gene expression) (Sorensen in www.youtube.com/watch?v=YE7mmCYels8).

[12] This does not mean, however, that such competition and confrontation hampers innovation: instead it may amplify the number of options and stimulate inventive research (Richards, 2004). Over time, competing strategies may be framed as complementary (e.g. Staver et al., 2020).

[13] Aguilar Morán (2013) suggests that crossbreeding will increase the genetic diversity, while an eventual successful transgenic Cavendish would again make the banana industry dependent on a single clone.

These first three germplasm-focussed strategies – GMOs (including the recent experimentation with CRISPR/Cas9-based genome-editing, Maxmen, 2019; Tripathi et al., 2020), somaclones, and conventional hybrids – are, in fact, presented as best-shot public goods. That would mean that key centres or research networks have to produce them. Resources and efforts have to be concentrated and not to be spread, thus go to the institute(s) or networks best-equipped and with the best researchers as the quickest route to produce the wanted public good. However, besides these first three germplasm-focussed approaches other strategies exist, which focus much more on the complexities of agro-ecological dynamics. Solutions may be more regional or local (field) specific.

Agro-ecology, the fourth strategy, can focus on introducing new products or on managing field conditions. The first seeks products that strengthen or induce banana's tolerance to infestation (e.g. endophytic fungi, (Caballero Hernández et al., 2014; Cosoveanu et al., 2016) for biocontrol agents in general, Bubici et al., 2019). A second line of research explores disease-supressing soil conditions, including abiotic factors. Segura-Mena et al. (2021) retake a research line of the 1950s that studied the influence of soil management on Fusarium wilt, showing that soil pH and nitrogen level in interaction influence disease expression and thus identifying a potential to deal with the disease (cf. Orr et al., 2022; Segura et al., 2022; Teixeira et al., 2022). The underlying idea of such research is a stronger emphasis on increasing biodiversity (not least soil biodiversity) in the field. The limited number of publications on this fourth strategy, if compared with the literature on the first three strategies, suggests that much less funding is available for researching agro-ecological interactions, though evidence for the relative distribution of research funding is unavailable. Knowledge on improved soil management is not directly applicable everywhere and is based on an approach of living with *Foc*, working on suppressive soils, and regulating growth conditions so that the disease does not manifest itself in a severe way. In this sense, Guthman (2019) speaks of repair approaches versus topological approaches. It could be argued that the genomics-oriented approaches lead to repairing problems in the monocrop plantation system without changing the production system. Cavendish was a repair for TR1 in Gros Michel plantations, and now this approach looks for a repair of the repair. As Guthman says: "Repair connotes the work of maintaining a system in the face of constant change – and sometimes crisis" (2019: 16). Topological approaches, instead, try to understand the conditions of production. Rather than centralizing underproduction they problematize overproduction, ways of producing that pass the limits of what is ecologically sustainable. In a topological understanding of disease, the attention would shift from the idea that Fusarium wilt is caused by a pathogen to the idea that states of disease are imminent in a situation and emerge as an effect of relationships and processes between multiple agents. A situation with genetic uniformity and little biodiversity

(e.g. in soil life) together with other factors produces then the disease. Even though recent literature may have shifted from a pure precision breeding focus to a combination with agroecosystem diversification (e.g. Dita et al., 2018; Zorrilla-Fontanesi et al., 2020), the distinction between repair and topological approaches can stimulate discussion to what extent this emerging broader view really is a paradigmatic shift in thinking.

The fifth strategy concerns a set of measures to cope with the epidemic, either seen as complementary measures until resistant varieties have been produced (the first three strategies) or as a crucial element of learning to live with the disease (a combination with strategy four). First are containment/exclusion strategies and eradication in cases of infestation in single fields or small regions. Many of the currently proposed measures (e.g. in Dita et al., 2018; Molina et al., 2010; Ploetz, 2015) were already explored in the first half of the twentieth century as discussed by Stover (1962): locating soils non-favourable to wilt (e.g. due to lower acidity) for planting, use of disease-free planting material, application of disinfectants to tools and shoes, quarantine measures (reduce movement of plant material, and of humans, animals and flood water) both at field level and at region or country border level, and eradication or sanitation. The latter consists of eradicating plants (including the rhizomes) around an infested banana, destroying the banana mat and burning the residues. In 1916 in Honduras the infested spot and adjacent healthy mats were "fenced off, cut down, covered with wood and the diseased tissue burnt over the rhizomes *in situ* with the aid of crude oil" (Stover, 1962, p. 87). Recently in the Philippines it is recommended to burn a pile of rice husk, assuming that the heating will kill the pathogen (Ploetz, 2015). Historically, larger companies have responded to Fusarium wilt by relocating plantations to new, disease-free land (Jansen, 2006; Marquardt, 2001; Soluri, 2000; Stover, 1962). Such relocation is a contemporary practice in the Philippines (de la Cruz & Jansen, 2018).[14] All these measures are supposed to slow the spread of the disease until a resistant variety appears which is also marketable. A second view on this point is that such measures combined with the fourth strategy could support another more agroecological or organic, small-holder driven agriculture based on the argument that in smallholder agriculture with high biodiversity, farmers are able to live with the disease (Scheffer, 1997; Soluri, 2000).[15] Although abandoning large-scale

[14]Reclaiming new land for banana has led to a growth in banana production in Mindanao in the 2010s, in a time that growers increasingly face damage from Fusarium wilt. Hence, national production figures have not been a good indication of the severity of the epidemic. The possibility for relocation can be considered an expression of the power of companies vis-à-vis land reform cooperatives and small farmers who cannot move when Fusarium wilt damages their plantations (de la Cruz & Jansen, 2018). The development of Fusarium detection tools has much less value for smallholders who cannot shift their plantations than for large companies who have to decide about where to start a new plantation.

[15]However, a situation with intensive smallholder cultivation on contiguous plots is still to be seen as a monoculture from an epidemiological perspective.

monocropping may be an unlikely strategy for the time being, the point reveals a crucial opposition between two views: the agroecological view in which diseases will always be present but whose impact have to be reduced through good practices based on ecological dynamics and high biodiversity versus a view that considers full control of diseases possible in monocultures under innovation strategies that only target the most limiting factor at a particular moment.

Several issues come full circle over time, that is, emerge, disappear and re-emerge. We see in different times different expectations regarding the relative importance given to finding or constructing a resistant variety versus agro-ecological solutions for disease management. Germplasm selection was hot around the 1920s, the 1960s and the late twentieth and early twenty-first century. The most recent upsurge is related to molecular biology. However, initial expectations are increasingly seen as inflated. The question is now if this opens up more space for other strategies. We also see a coming and going of Fusarium as an international concern. It became strong with the growth of international trade in the early twentieth century, weakened with the advent of Cavendish in Latin America and the spreading of Yellow and Black Sigatoka, still considered the most threatening disease for export bananas in the 1990s, and back on the top list of diseases with the TR4 epidemic. What we also see is that the shifting threats of plant diseases interact with shifts in contractual arrangements between international companies, domestic traders, and local producers. After sourcing mainly from local planters in the early twentieth century, the increasing reliance on scientifically managed plantations as a response to Fusarium supported the shift to UFCo-owned plantations. Towards the end of the twentieth century, international banana companies shift more and more from production companies to marketeers who source bananas from contract farmers. Plant diseases and disease control have relevant and divergent effects on different forms of production; it changes the conditions of production which may be more disadvantageous to some type of growers than to others. Finally, between assumptions about the lack of innovation observed in technical publications, we occasionally find casual statements suggesting that the lack of collaboration between social actors is the core problem. Stover (1962, p. 91), for example, writes: "To prevent [unrestricted movement of planting stock] requires complete co-operation among growers, growers' organizations, and Government. This is frequently the most difficult aspect of any disease control programme". Hence, besides demands for funding research that will provide the future solutions, we also find some recognition that issues of human behaviour, in particular co-operation, have to be addressed. However, while the possibilities and the constraints of the former are

often reviewed and discussed, the latter is addressed with little more than anecdotal evidence and no systematic debate.

4. Governance, regulatory responses, and the problem of the public good

Plant scientists meet the social world when they recommend how people should behave in order to reduce the movement of the pathogen. Claims are made that people should co-operate, work together and – as a one-directional view on communication – become aware of the scientific knowledge about how the disease spreads. What is proposed, perhaps unknowingly, are particular visions on the public good. Implicitly, scientists frame what institutions are needed to address the epidemic and who should provide public goods. Research networks have discussed the menace of Tropical Race 4 at international conferences and in dialogue with government officials in Latin America (e.g. Pocasangre et al., 2011), Africa (AC4TR4, 2014), and Asia. These have led to action plans (AC4TR4, 2014; Dita Rodríguez et al., 2013; Ploetz, 2004), which subsequently inspired a proposal for a global programme to prevent Fusarium wilt (FAO, 2014). The action plans differ somewhat but the list of actions composed by Ploetz (2004) gives an impression of what is being proposed: a survey of quarantine measures that are in place in the various countries and ports of entry, increasing awareness among stake-holders of the nature and seriousness of the TR4 threat, training of quarantine personnel and producers on ways in which TR4 could move, and producers on diagnosing TR4, developing diagnostic techniques with which TR4 incursions could be quickly and accurately identified, developing a database on populations of *Foc*, and developing eradication protocols.

These action plans, however, hardly analyse the political and regulatory context, which so often conditions what is possible. Below we discuss four issues that would need further study and to be resolved as a condition for developing adequate public action in the domain of transboundary disease control. Together they outline the contours of what could be interpreted as the problem of the public good. Based on social science insights, they increase the reflexivity on the difficulties of transboundary disease control. At the same time, they may be received reluctantly as no concrete solutions have yet been formulated; current thinking on these issues is yet preliminary and have to be seen as a call for further research and action.

Firstly, public action requires political will and some sort of social consensus to put topics on the political agenda. This may be limited for Fusarium control. It is difficult for governments to take anticipatory action (Gupta et al., 2020). The Fusarium case shows that most governments as well as multilateral agencies respond reactively rather than anticipatory in general. Although some countries took quarantine measures before the disease had

arrived there, e.g. Costa Rica and Colombia, this does not renounce the widespread experience within the banana research community of a lack of regulatory action and little anticipation in disease governance. Most governments have not yet given sufficient priority to the threat of TR4 according to different experts, although it has improved in recent years. National governments seem restricted in taking anticipatory action that could curb the spread of the disease, even when they have been informed about the technical likelihood of the spread and the potential economic impact or impact on the livelihoods of their farmers. Anticipation is difficult when experts still disagree about the presence and spread of the disease and possible solutions (scientific unknowns, uncertainty, and ambiguity). It is easier for governments to address risks (one knows the harms and the probability) than to address uncertainties (one may know possible harm-effects but does not know probabilities) (cf. Stirling & Scoones, 2009). It is difficult to justify investment of public resources when a disaster of a new kind has not yet taken place. Fusarium wilt is not yet a priority for countries without a strong presence of the disease. Anticipation is a weak legitimation for such spending.

It is not only uncertainty, though, which limits anticipatory action. Various competing needs may also keep a particular disease low on the priority list. It is difficult to legitimize expenditures when other disastersin particular, those that are already damaging livelihoods, have a higher priority. Individual countries may face more urgent problems, for example, already present problems such as HIV/AIDS, Covid-19, or bacterial wilt in banana, rather than spending resources on a potential but yet absent problem. Despite the construction of urgency by banana researchers and some journalists, not all actors prioritize Fusarium wilt as the major threat. In East Africa, for example, the epidemic of Bacterial wilt (*Xanthomonas campestris* pv. *Musacearum*) is "considered as the biggest threat to banana production" (Namukwaya et al., 2012; see also Staver & Capra, 2017). Furthermore, although banana is not a minor crop, other crops may be considered relatively more important than banana, and of more primary concern to government agencies. Moreover, governments and international agencies may consider that, because of the presence of large companies in an export-oriented commodity chain, the banana business should themselves take all the responsibility for addressing the disease. This implies that improvement of disease control is seen as a private issue and not a public good. Finally, governments too would likely support a reductionist approach which addresses disease control not as a governance issue, with potential risks of politicization, but as a technical issue to be addressed with technological solutions.

The observed lack of state action towards transboundary disease control opens up a second theme for further study as to whether current forms of

global governance could fill the governance gap. In the early 2010s, most countries still considered TR4 control an issue of individual affected countries. International action as far as it existed was based on national, particular interests (and hence, quasi-private), and not necessarily "in line with global exigencies and goals" (Kaul, 2012, p. 737). Experts at international fora such as the IPPC and FAO recognized the importance of the disease and the potential negative impact but were tied to international agreements, formal procedures, and sovereignty rulings that put the start of action in the hands of designated authorities of individual countries who sometimes did not yet act in terms of pursuing the public goal. For example, when *Foc* TR4 was detected in their country but not reported to the IPPC, which limits the Convention's options to act. It took until 2021 to establish an Implementation and Capacity Development Committee Team on Fusarium TR4. The FAO and Bioversity (a CGIAR institute) have organized a series of activities, such as workshops, on Tropical Race 4 and the epidemic has become an issue within the World Banana Forum (a network of producers, civil society organizations and researchers, hosted by the FAO). Three types of limitation merit more reflection. 1) Within the current initiatives, institutes and networks, the predominance of agronomists and plant scientists may explain that its focus of attention is predominantly the fungus-plant level with little in-depth analysis of the dynamics of human behaviour and societies. 2) The institutions in place that are supposedly contributing to a global action are not global but at best multilateral institutions. It means that national interests and country member sovereignty drive construction and implementation of new governance measures. For example, declaring a transboundary disease as an emergency risk depends on individual countries reporting and thus decision-making. The urgency should first be proven before measures can be taken and money be spent on the problem (this is a condition for the IPPC and EMPRES to act). Global action by international agencies is not supra-national as it is organized through and restricted by the principle of sovereignty. As earlier stated, the IPPC can only take action once designated national authorities (of one of the contracting parties) have reported the presence of a Fusarium wilt disaster. This accounts for the inordinate length of time between reports by experts on the presence of TR4 and the action taken by the IPPC. Hence, before a contagious disease can be contained it should first have spread, its spread being reported, and then be declared an emergency. This has delayed international collective action on Fusarium wilt, and it could be discussed whether anticipatory governance, already a difficulty for national governments, fares better at the multilateral level.

The third issue that invites for further discussion is the difficulty to develop a public good in a context of competing political-economic interests that inform different views on measures to be taken and prioritized. National governments as well as multilateral institutions may be

badly equipped for dealing with the political economy of agrarian structures that involve struggles between a diversity of producer types: corporations, smallholders, co-operatives, and so on. The situation in the Philippines is an exemplary case, as large businesses and smallholders (individual as well as organized in land reform co-operatives) are both present in the banana sector and blame each other for obstructing or hindering technical and political solutions to the disease problem (de la Cruz & Jansen, 2018). Different government agencies may side with different groups in society, whereby clashing mandates, contradictory interests, and decision-making stalemates hinder the development of regulations that restrict behaviour. Different producer types may have contrasting perspectives of what autonomy in the market and vis-à-vis the state entails (Jansen et al., 2022). Even at the level of large agribusiness competing and changing interests impact on governance processes, but how they do so has hardly been studied (Jansen, 2004, 2017). The term "public good" may conceal socioeconomic disparities and the highly differentiated framing of problems and solutions.

The final point for further discussion concerns the uncritical approach towards the boundaries between the public and the private and a lack of redefinition of those boundaries. For many involved scientists, it is quite obvious that the risk of transboundary movement of (plant) diseases requires collective action, with public action by states in particular, to deliver the public good of disease control. However, the notion of public good is often misused as a flag to persuade public funders to support research that in fact creates an open resource pool, the elements of which can easily be appropriated by private interests. In research for developing resistant varieties, we see signs of a growing presence of private interests, with a goal of patenting new resistant varieties or biotechnologies to arrive at such varieties. This raises the question whether more actors seem to be involved in the search for new hybrids than in improving quarantine systems or developing better cropping systems with increased biodiversity and better plant health and soil health management. There may be a technical justification for this: the hope that new varieties and the knowledge to construct new varieties faster may help to win the battle between disease epidemics and crop production. But this does not rule out the possibility of an economic motive for a privatized road to new varieties: the hope of increased profits by controlling knowledge. Whether this private control of knowledge (making it rivalrous and excludable) fosters or hinders the development of disease control and whether it is private business that helps with providing needed access goods (e.g. experiments that validate new varieties) or private business that appropriates publicly funded knowledge are difficult to answer questions.

That said, even within core neoliberal arrangements, space has been created to accommodate public intervention. An example is the WTO's SPS

Agreement (WTO, 1994), which can be seen as *a recognition* of public action, of the need for public goods, even though one of its main concerns is that phytosanitary measures could be erected as a trade barrier. At the same time, however, it also *intervenes*, as an agreement between states, in how to think about public goods in a rather limited way. A basic assumption is that the public good should not hinder and be in competition with the private good. In the context of an epidemic, however, even the staunchest neoliberal policymakers may find it hard to argue against the state and collective action. To date, the most elaborate public response against the new epidemic of Tropical Race 4 has been by the public-private "shared responsibility" model in Australia, after the detection of an infestation with Tropical Race 4 on a banana farm in Northern Queensland. Immediately the banana industry body held meetings with growers to prepare actions, and the government was willing to devote resources to disease control and containment, surveillance to delimit the extent of the disease, preventing further disease spread, research, and education, awareness raising and capacity building (de la Cruz, 2020). Many policy instruments as well as proposals by plant disease experts imply a sort of compromise between, on the one hand, a recognition that private actors and the market are in general not sufficient for the provision of adequate plant disease control, and, on the other hand, the idea that states, global agencies, or other forms of organized collective action should not constrain individual action. In fact, the idea of the provision of the public good is still mostly approached from a very individualistic perspective (reducing the state to another individual actor rather than a collective entity), with little creative and constructive thinking about how the collective should provide the public good. In that sense, we might even speak of a "neoliberal public good". Although a neoliberal public good prioritizes "concerted action" between individuals, it still refuses to think in terms of collectivity and solidarity and steering individuals to other, more desired behaviour, such as a transition to very different and more sustainable agricultural production systems, thereby restricting private actor forms of extractive agriculture.

5. Conclusions

The discussion above suggests that Fusarium wilt control, like the control of many other plant diseases, is not just a technical question and a grower practice in the field but requires thinking in terms of a public good ensemble. Fusarium wilt itself, and in particular the TR4 epidemic, is a public good (in the form of a public harm) because of its non-rivalrous and non-excludable character. Fusarium wilt *control* is also to be considered as a public good, in particular, because of the common-stock elements: it requires public action, states, free knowledge, and so on, because of the properties of the disease

(strong potential for transboundary – field, region, country, continent – infections), the importance of quarantine measures to be enforced by public authority, and the knowledge intensive and collaborative character of generating new control methods (e.g. increasing genetic variety and resistant varieties). In several of these aspects it is even a *global* public good. The notion of public good is a useful perspective to increase reflexivity of disease epidemics and their control. This implies that any meaningful science to improve disease control will have to reflect and act upon this public good character. Going beyond pure agronomy, issues of institutions, power, social relationships, and the larger political economic context come to the fore (thus requiring integrated approaches).

The argument that Fusarium wilt control should be treated as a public good is not a road to easy solutions but instead introduces new complicated issues: 1) the problem of divergent theoretical perspectives on the public good and 2) the presence of very different types of public good that have to be distinguished and among which choices have to be made. We have observed that the social science literature on the public good opens up a debate with different perspectives on how to theorize the public good and understand the underprovision of the public good. The more economistic definitions conceptualize the public good in terms of properties and behaviour in the market (the non-excludable and non-rivalrous aspects). The more social and political conceptualizations draw our attention to who is allowed to take decisions, issues of governance, power, and values. Either of these perspectives would probably support our observation that Fusarium wilt control as a public good encompasses, in fact, an ensemble of public goods. Some forms of disease control imply a weakest link public good, while others are best shot public goods or require provision through summation. This diversity points at the complicated nature of disease control. Although our preliminary review does not provide conclusive answers, it opens up a field of debate and further research beyond just agronomic research. Choices about what public good to pursue depend partly on the theoretical perspective taken and partly on the material complexities of the disease and disease control. Once it is accepted that disease control requires a perspective on the public good, the next step is to identify the contemporary constraints that make it so difficult to work collectively on public goods.

As a small contribution to this huge task, we argue that four topics of importance seem to be neglected in the literature on Fusarium control. First, aside from the commonly observed phenomenon of lack of capacity, we need to better understand the difficulty of anticipatory governance in a context of uncertainty, alternative priorities, or lack of political will. Second, we need to move the topic of "interests" from the coffee table to serious research and surface the constraining effects of diverse and contrasting political economic oppositions in the banana sector or

between banana exporting countries that may generate diverging views on what the desired public good could be. Third, observing a lack of knowledge about how global initiatives address the governance gap often experienced, we need to problematize the issue of sovereignty in multilateral responses, specifically how national decision-making, thus national politics, complicates thinking and decision-making about global public goods. Finally, we observed that statements about the public good and the roles of public and private actors do not go beyond conventional notions of the private and the public as seen through the lens of neoliberal ideology. Maybe unknowingly, this may lead to an unreflective acceptance of private appropriation of publicly funded knowledge development or an implicit prioritization of certain technological trajectories over others. We consider that these four tasks contribute to the more sociological and political science approaches in public good theory and thereby close important gaps in economistic approaches. They will stimulate a deeper reflection on the control of transboundary plant disease.

Besides contributing to the knowledge about transboundary plant disease, a more developed perspective of the public good may also contribute to investigating and reflecting on other types of "public bads", such as the COVID-19 pandemic. Not only is the COVID-19 pandemic the clearest and most recent illustration of how the various characteristics of public goods can converge – "weakest link" speaks to how the areas with weak surveillance and containment strategies affect neighbouring areas, "silver bullet" speaks to the vaccine strategy, and the "provision through summation" speak to the complementarity of strategies (quarantine, individual behaviour shifts, travel restrictions) – it clearly highlights the moral dimensions of collective action.

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