Sustainability **2012**, *4*, 3151-3157; doi:10.3390/su4113151

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Opinion

The Potential of the South American Leaf Blight as a Biological Agent

Oghenekome Onokpise * and Clifford Louime

Florida A&M University—College of Agriculture and Food Sciences, 204 Perry Paige, Tallahassee, FL 32307, USA; E-Mail: Clifford.Louime@famu.edu

* Author to whom correspondence should be addressed;
E-Mail: Oghenekome.Onokpise@famu.edu; Tel.: +1-850-561-2127; Fax: +1-850-561-7094.

Received: 17 October 2012; in revised form: 11 November 2012 / Accepted: 13 November 2012 / Published: 15 November 2012

Abstract: When asked by the Department of Homeland Security to create potential terrorism scenarios, even "Out of the Box Thinkers" initially failed to come up with the following scenario. Oil tankers, refineries, nuclear plants, *etc*., are obvious potential terrorists' targets, and adequate measures are being taken to protect them. However, what if the target were to be a non-food commodity product, such as natural rubber tree plantations located in places as remote as southeast Asian countries like Thailand or Indonesia? Would it be of concern? At first thought "maybe not", but think again. What could the release of a deadly microorganism (fungus/virus/bacteria) in a rubber tree plantation in Indonesia, Malaysia or Thailand possibly mean to you or the world economy?

Keywords: rubber; *Hevea brasiliensis*; South American Leaf Blight; national security

1. Introduction

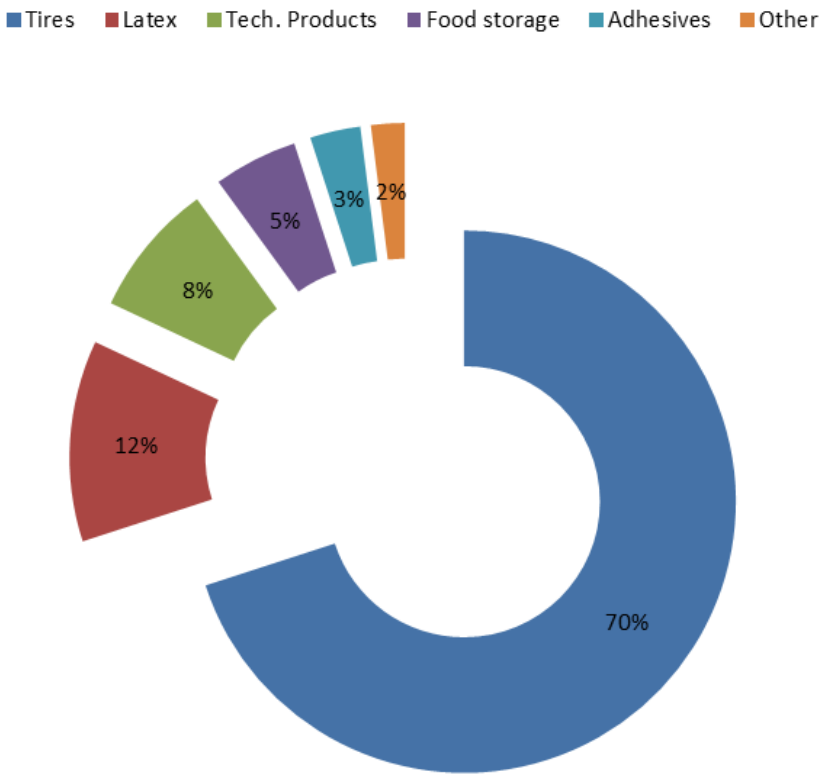
Natural Rubber tree (*Hevea brasiliensis*) is native to the Amazon Rainforest. Initially, the Northeast of Brazil was the only habitat in the world where *H. brasiliensis* could be found. Efforts to propagate *H. brasiliensis* outside of its natural environment remained unsuccessful for centuries. It was not until the late 1890s, that breeders in Malaysia managed to establish the first rubber tree plantation outside of Brazil [1]. Around that time, in an attempt to keep up with the Asian competition, rubber tree growers in Brazil decided to set up experiments to cultivate rubber in plantations in the Amazon [1]. This technique considerably increased the trees vulnerability to pest and diseases, such as the South

American leaf blight fungus [2]. In addition, latex extraction from natural rubber groves stayed low due partly to the high diversity of the natural forest. Consequently, rubber plantations in Asia outproduced Brazil and the production center was shifted from South America to Southeast Asia [1]. The blight managed to take over the entire South American continent and decimated most rubber tree plantations in the region [3]. Subsequent efforts to cultivate the tree in South America remained forever unsatisfactory. Nowadays, *H. brasiliensis* grows mainly as a plantation tree crop in Southeast Asia, which provides over 90% of the world's natural rubber supply [2–4].

Although decades of breeding have resulted in highly selective rubber tree cultivars, most commercial plantations around the world are descended from seeds originated from Brazil [5]. This narrow genetic background or variability makes rubber tree plantations particularly vulnerable to pest and diseases [6–7]. Over the years, rubber tree improvement has resulted in select varieties with traits that give the highest return, such as the quantity and quality of sap harvested [8]. However, selection processes have disturbed natural rubber balance and created a so-called genetic homogeneity. Crop genetic uniformities are usually welcomed, as most of them expand superior resistance to pest and diseases [6,7,9]. Nonetheless, over the centuries, pests have developed the capacity to overcome host resistance by genetically evolving and gaining access to larger uniformed crop base plantations where damages could be severe [10]. The concerns of genetic uniformity became apparent in 1970, when the spread of the Southern Corn Leaf Blight (*Helminthosporium maydis*) led to a 15% reduction in the U.S. corn crop [8]. This issue of genetic vulnerability is a broadly recognized problem affecting genetic resources globally. Consequently, significant efforts to collect and preserve genetic resources have been made by national and international institutions as an insurance policy against future disasters [6,9,10]. The recognition however, that *H. brasiliensis* plantations around the world originally stem from a single source raises new concerns that are global in scope [5].

Hevea brasiliensis is presently the only commercial source of natural rubber, making it a very important strategic commodity not only for the United States, but also for countries around the world [11]. *H. brasiliensis*' major economic importance lies in its sap-like extract, also known as latex, the primary source of natural rubber. Rubber has a widespread use, spanning from the manufacture of household over medical to industrial goods [4,11,12]. Rubber has been used as an intermediate or final component in the production stream of most rubber products (Figure 1), such as gloves, balloons, adhesives, hoses, *etc*. Tires and tubes make up rubber's largest market share. Other significant uses of rubber include the paper, carpet and textile industry, where rubber's low tenacity and oxidizing resistance limits its use in, for example, lightweight garments, substituting it thereby with Neoprene or synthetic rubber [11,12]. Natural rubber, however, due to its unusually high molecular weight, is far superior to synthetic rubber, and cannot be substituted for the manufacturing of many products, such as aircraft, space shuttle and heavy construction equipment tires like those of Caterpillar and Halliburton, which require 100% natural rubber [11].

Figure 1. Natural rubber consumption by industry.



Last year, worldwide production of natural rubber topped 10 million tons, of which more than 10% with a worth of almost $3.0 billion were exported to the U.S. [4,11,13]. China and the U.S.A. are the two leading importers of rubber, followed by EU and Japan. Thailand, Indonesia, Malaysia and India are the leading exporters of natural rubber in the world [4]. With the center of production located in Southeast Asia, natural rubber supply to the U.S. is constantly being threatened not only by social instability in the producing region, but also by environmentally related crop failures [11–13]. This vulnerability of the rubber market has prompted congress to mandate the development of new commercial sources of natural rubber [14–16]. However, to date, no new replacement sources or adequate substitution have been found, making natural rubber supply an international security issue, with the potential for destabilizing the world economy [15–16].

For example, a natural rubber shortage could easily result in a complete halt in the manufacturing of airplane tires. And with the aviation industry being a key driver of the world economy, such situation could be proven disastrous. In reality, this scenario is not far-fetched, considering the damaging potential of biological agents such as the South American Leaf Blight [17]. This fungal disease caused by the ascomycete *Microcyclus ulei*, single handedly managed to prevent natural rubber production on a commercial scale in South and Central America [17]. Although today, the spread of this pest is still limited to South America, the potential of an economic disaster increases with every transcontinental flight landing in Southeast Asia.

Imagine for a moment, a terrorist act involving the release of *Microcyclus* spores in a *H. brasiliensis* plantation in Thailand or Indonesia where 80% of the world rubber is produced! The pathogen can be easily isolated from infected rubber trees in Brazil and transported undetected across borders. Transfer can also occur through host (budwood, foliage, flowers, fruit and seeds, *in vitro* plants) and

non-host materials (contaminated goods) [18]. Depending on the material, the viability of conidia or spores could be compromised during transport [18]. However, considering the similarities in climatic and environmental conditions between Southeast Asia and the pathogen endemic region in Brazil, the likelihood of an invasion increases tremendously. There are also numerous published reports on non-technical fungus isolation and storage, where terrorists can take notes. While Goh [19] detailed the procedure for using glass needles in the manipulation of single fungal spores, Ho [20] was able to isolate and propagate fungal spores within 24 hours. Holliday and Junqueira also reported a special technique of isolating *M. ulei* [21,22]. Hyacinthe explores the potential misuse of print cartridges to diffuse lethal airborne substances to a massive population of computer users around the world, where common substances are mutated into very lethal weapons [23]. Quantanilla also demonstrated that fungal spores when stored dry in glass vials have the capacity to survive and germinate up to one month, while they will propagate after a year when stored on wet agar plates [24].

The need to develop control measures against the pest is an urgent task and must be carried out on an international scale. Although the South American Leaf Blight has been listed as a biological weapon by the United Nations, all control efforts taken so far since 1910 have resulted in miserable failures [25]. Over the years, pests control mechanisms, such as chemical (pesticides) or biological, including breeding and selection, which work well on providing disease resistance to most crops, have not proven successful on leaf blight of *H. brasiliensis* [25]. These failures were partly related to a lack of a cost-effective management tools; e.g. it is almost impractical and expensive to apply fungicides to trees of great height. In addition, pathogens with novel physiological potential will emerge capable of breaking down the resistance of new breeding lines. No rubber clones can therefore escape infection over the long term. Luckily, the pathogen did not establish during the introduction period, and nowadays, there are almost no direct flight connections between Brazil and Southeast Asia and freight shipments from South America usually undergo a stringent control. However, this could change any day.

Travel methods (sea or air) usually determine the entry potential of a pest. Although fungal spores will have a high level of survival if air-transported through fresh host materials such as leaves, the duration and environmental conditions of sea cargo would not promote survival and viability of the pathogen. At the port of entry, the probability of not being properly identified is enormously high, as pathogen detection through visual inspection alone is almost impossible. For example, if properly concealed, budwood has the potential to act as both a vector and a host. Once established, the pathogen can cause severe economic damages, as seen in Brazil, where affected plantations were completely abandoned in the past. Because of *M. ulei* invasion, rubber cultivation in Brazil were forced to move from its traditional state of Bahia to Sao Paulo and Mato Grosso where defoliation occurs during the dry season escaping *M. ulei* infection [18]. Apart from the direct impacts of the pathogen infection (yield reduction, shortage of material), this has also resulted in 30% loss of income in the state of Bahia and an increase in land prices in the already over populated state of Sao Paulo [18].

The very narrow genetic base of *H. brasiliensis* has made all clones in Southeast Asia extremely susceptible to Leaf Blight infection. Within a few years following invasion, all standing stock in the region will most likely be infected and destroyed, resulting in unforeseen direct and indirect economic and environmental consequences. A relatively widely spread infestation would require costly control measures, which in the long run would not be economically sustainable. An uncontrolled infestation on

the other end would result in trees dieback and concomitant loss of vast plantations, which will directly affect the livelihood of hundreds of smallholders and indirectly decimate the natural rubber industry. Economically, this could be translated as a loss of revenue in the amount of over $100 billion annually, significantly impacting both producing and importing countries alike and crippling the overall world economy!

2. Conclusions

Fortunately, in the history of humankind, there are only few reports of a global intentional biological invasion. The deliberate use of anthrax in 2001 was limited to the United States alone. Subsequently however, this incident resulted in a substantial increase in funding to counter the threat of bioterrorism the world over. Global initiatives to detect and respond to biological threats were suddenly becoming increasingly vital to most nations. Worldwide models and scenarios were constructed and consequently attacks potentially disruptive to global supply chains and human welfare, remain exceedingly low. In recent years, the dynamics have shifted between Indonesia (where "wildtype" rubber grown in mixed agroforests is the dominant production system) and Malaysia/Thailand where monocultural plantations still dominate. More importantly, new advances in science and technology have helped us gain ground against these threats. The challenges represented by *H. brasiliensis* however remain. Today, there is an immediate need to speed up the development and production of alternatives to *H. brasiliensis* through transnational research. Although guayule (*Parthenium argentatum*) and gutta-percha (*Palaquium gutta*) have been attracting attention as sources of hypoallergenic rubber for more than 50 years, their limited geographic range appears to restrict their expansion [26]. More research investments for example, could target these two crops including *Taraxacum kok-saghyz and T. megalorrhizon* as possible alternatives to *H. brasiliensis*, as many sectors recognize that when it comes to upstream planning and prevention efforts against bioterrorism, the benefits outweigh the costs.

Acknowledgments

We are grateful to B. Hyacinthe for fruitful discussions and inputs regarding the manuscript. We also would like to thank K. Simmonds, Director of the *Center for Global Security* and International Affairs at *Florida A&M* University for his insightful comments and suggestions.

References

1. Schultes, R.E. The history of taxonomic studies *Hevea. Bot. Rev*. **1970**, *36*, 197–276.
2. National Research Council. *Managing Global Genetic Resources: Agricultural Crop Issues and Policies*; The National Academies Press: Washington, DC, USA, 1993.
3. Lieberei, R. South American Leaf Blight of the rubber tree (*Hevea* spp.): New steps in plant domestication using physiological features and molecular markers. *Ann. Bot.* **2007**, *100*, 1125–1142.
4. U.S. Code. 7 USC Chapter 8A. Rubber and Other Critical Agricultural Materials. Available online: http://uscode.house.gov/download/pls/07C8A.txt (accessed on 10 February 2012).

5. Warren, D. *Brazil and the Struggle for Rubber: A Study in Environmental History*; Cambridge University Press: Cambridge, UK, 1987; p. 14.
6. Wilkes, G. Germplasm Conservation Towards the year 2000. Potential for New Crops and Enhancement of Present Crops. In *Plant Genetic Resources: A Conservation Imperative*; Yeatman, C., Kefton, D., Wilkes, G., Eds.; American Assoc. for the Advancement of Sciences: Washington, DC, USA, 1984.
7. Priyadarshan, P.M.; Jain, S.M. Breeding *Hevea* Rubber. In *Breeding Plantation Tree Crops: Tropical Species, Part III*; Springer: New York, NY, USA, 2009; pp. 469–522.
8. *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices. Global Invasive Species Programme*; Wittenberg, R., Cock, M.J.W., Eds.; CAB International: Wallingford, UK, 2001; p. 228.
9. Rantala, L. Rubber Plantation Performance in the Northeast and East of Thailand in Relation to Environmental Conditions. M.Sc. Thesis, University of Helsinki, Finland, 2006.
10. Montoro, P.; Carron, M.P.; Lardet, L.; Clément-Demange, A.; Leclercq, J. Biotechnologies in rubber tree (*Hevea brasiliensis*). *AsPac. J. Mol. Biol. Biotechnol.* **2010**, *18*, 81–83.
11. Cecil, J.; Mitchell, P. *Processing of Natural Rubber*; FAO, Food and Agriculture Organization of the United Nations: Rome, Italy, 2003.
12. Killmann, W. *Non-Forest Tree Plantations*; Forest Plantations Thematic Papers; Forest Products Division, FAO: Rome, Italy, 2001.
13. RMA. Rubber Manufacturer Association. Available online: http://www.rma.org/publications/market_information/index.cfm?PublicationID=11513 (accessed on 2 October 2012).
14. International Rubber Study Group (IRSG). Rubber Statistical Bulletin, 2010. Available online: www.rubberworld.com/RWmarket_report.asp?id=333 (accessed on 2 October 2012).
15. Finlay, M.R. Growing American Rubber: Strategic Plants and the Politics of National Security. In *Strategic Plants and the Politics of National Security*; Rutgers University Press: New Brunswick, Canada, 2009.
16. Morris, P.J.T. *The American Synthetic Rubber Research Program*; University of Pennsylvania Press: Philadelphia, PI, USA, 1989.
17. Tatum, L.A. The southern corn leaf blight epidemic. *Science* **1971**, *19*, 171.
18. Zhang, K.M.; Chee, K.H. Different sensitivity of physiologic races of *Microcyclus ulei* to fungicides. *J. Nat. Rubber Res*. **1986**, *1*, 25–29.
19. Goh, T.K. Single-spore isolation using a handmade glass needle. *Fungal Divers.* **1999**, *2*, 47–63.
20. Ho, W.C.; Ko, W.H. A simple method for obtaining single-spore isolates of fungi. *Bot. Bull. Acad. Sin*. **1996**, *38*, 41.
21. Holliday, P. South American Leaf Blight (*Microcyclus ulei*) of Hevea Brasiliensis. In *Phytopathological Papers*; Commonwealth Mycological Institute: Kew, UK, 1970; p. 31.
22. Junqueira, N.T.V.; Lieberei, R.; Kalil Filho, A.N.; Lima, M.I.P.M. Components of partial resistance in Hevea clones to rubber tree leaf blight, caused by *Microcyclus ulei*. *Fitopatologia Brasileira* **1990**, *15*, 211–214.

23. Hyacinthe, B.; Anglade, Y. Conceptual Design of a Microfluidics Suppressor to Protect against Potentially Lethal Printing Devices: A Scenario-Based Physical Cyber Security Measure. In *Proceedings of the 2nd International Conference on Information Warfare and Security*, Naval Post Graduate School, Monterey, CA, USA, 22 November 2007.
24. Quintanilla, L.; Amigo, J.; Pangua, E.; Pajarón, S. Effect of storage method on spore viability in five globally threatened Fern species. *Ann Bot*. **2002**, *90*, 461.
25. Chee, K.H. Management of South American leaf blight. *Planter Kuala Lumpur* **1980**, 56, 314–325.
26. van Beilen, J.; Poirier, Y.; Orts, B. *Alternative Sources of Natural Rubber*; Outputs from the EPOBIO Project; CPL Press: Berks, UK, 2006.