ESTABLISHING RUBBER DANDELIONS AND GUAYULE IN THE UNITED STATES VIA PREMIUM MARKETS TO SECURE ESSENTIAL SUPPLIES.

Katrina Cornish[*,**,***] FNAI, FAIMBE, FAAAS,
John Cardina[*], Jonathan Fresnedo[*] and Frederick C. Michel Jr. [**]

[*]Departments of Horticulture and Crop Science, and [**]Food Agricultural and Biological Engineering, College of Food, Agricultural and Environmental Engineering, The Ohio State University, Wooster, OH 44691

[***]EnergyEne Inc, Wooster, OH 44601

ABSTRACT

Natural rubber and latex are imported, critical, agricultural raw materials essential to all sectors of the US economy and cannot be replaced by unsustainable petroleum-derived synthetic rubbers due to their performance deficiencies. National security is seriously compromised by our lack of domestic production and dearth of domestic inventories and stockpiles. Scalability challenges US production because commodity markets, which require low prices and huge supplies, cannot be accessed by rubber or latex produced at pilot scale from small crop acreages[1]. Thus, premium markets with high profit margins must be identified and addressed to support initial production and commercialization which can lead to later entry into medium markets and eventually lead to large-scale production of rubber dandelion and guayule crops, processing at a commodity scale, and fully valorize co-and by-products.

Key words: Guayule, Latex, Natural Rubber, Rubber dandelion, Supply security

1. INTRODUCTION

In 2020, global natural rubber production declined by 10% (Fig. 1, 1.4 million tons (MT)) due to a combination of leaf drop fungal diseases affecting over 1 million acres of trees in seven countries, extreme weather events, and COVID-19 labor movement restrictions. US latex manufacturers are now experiencing supply disruptions and are attempting to move away from the "just-in-time" model prevalent in the US over the last 20+ years. Rubber stocks in producing countries are becoming exhausted as global demand recovers "post-COVID" and supply chain deficiencies are expected to now impact affect tire manufacturers and automotive tier one parts suppliers. About 2,500 plant species make natural rubber, a raw material vital to economic prosperity and security, but few have commercial prospects due to poor productivity or rubber quality[1]. **Rubber dandelion** and **guayule** ("why-YOO-lee") are the leading contenders for US production as field crops[2–5], and dandelion can also be produced intensively in indoor controlled environment vertical hydroponic or aeroponic farms[6]. As the world continues to develop, more and more rubber will be needed (Fig. 1), especially by the transportation and healthcare industries. Disruptions of global supply chains are making domestic natural rubber production for national security and defense increasingly important, even imperative. So far, latex supply lines are more adversely affected than solid rubber lines, partly due to burgeoning container ship costs and reluctance of overburdened shippers and truckers to handle liquid latex. COVID-19-induced new demand for latex (+1 million tons) is likely to enhance the prospects of both crops as latex sources. Successful exploitation in premium markets can fuel expansion of crop production and associated commercial-scale processing facilities, which do not yet exist in the US. Production, processing and manufacture must all be scaled concomitantly. The current sole commercial source, the tropically grown rubber tree (*Hevea brasiliensis*) cannot continue to expand to meet

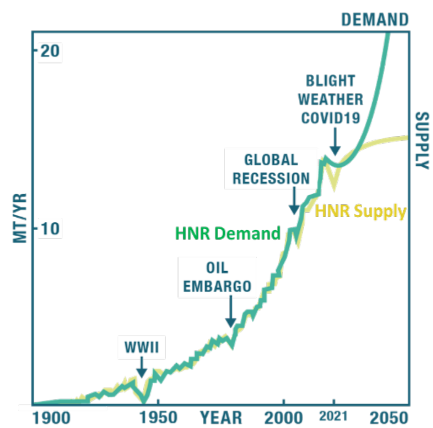

Figure 1*. Production (yellow) and consumption (green)) of natural rubber (HNR, Hevea natural rubber) to date, and future projections.*

ongoing increasing demand because of the global deforestation moratorium banning clear cutting of virgin tropical rain forests to plant more rubber trees. This means that additional demand must be met by alternative natural rubber crops, even if the rubber tree crop does not fail: the genetic uniformity of clonal rubber trees, does put this crop at extreme risk of massive crop failure. Also, the restrictive climatic requirements of rubber trees, and endemic fatal South American Leaf Blight in the Amazon region, largely limit large scale production to southeast Asia, although West Africa has significant production area. Geographical and biological diversity, and domestic production, are all vital to secure rubber and latex supplies.

2. PROSPECTS

2.1 Opportunities for rubber

In recent years, Cooper Tire & Rubber Company, Ohio and Continental Tire, Germany, have made excellent car tires from 100% guayule and dandelion rubber, respectively, proving that both alternatives meet required performance specifications. However, supplies are much too limited to produce tires, other than for some bicycles, and production costs prohibit manufacture of car and truck tires. Ford Automotive Company, with a Tier 1 company, has successfully tested guayule rubber in bushings and vibration dampening products and these may present a more accessible commercialization path for limited alternative NR supplies.

***Figure 2**. A field of rubber dandelion in Willard, Ohio (top), the OSU TNR extraction plant (middle), and a sample of TNR from the pilot plant before it is dried (bottom).*

Rubber dandelion rubber (TNR) in many respects is similar to tropical rubber, including the presence of Type I latex allergy cross-reactive proteins[7]. Nonetheless, it remains a very promising supplement of the current global supply. This industrial crop (Fig. 2, top) can be grown as an annual in the northern states, and as a winter crop in the hot southern states. Ohioan crops have been established by transplants and by direct seed. A high planting density (>1 million/acre) and a long growing season are currently required, and light soils foster growth of large roots[3]. Weed control is essential but was a real challenge because this crop grows more slowly than most weeds. Scientists at the Ohio State University (OSU) have established chemical herbicide application protocols effective against local weeds and have selected and developed improved and herbicide resistant germplasm currently being tested at Oregon State University and University of Nebraska. Commercially, Kultivat and Farmed Materials are two young US companies focused on dandelion rubber (TNR) production, while Ernst Conservation Seeds is tackling the issue of large scale seed production. OSU also has developed a wide range of germplasm resources and enabling technologies to accelerate the domestication and improvement of this new industrial crop[8] and operates an aqueous TNR extraction pilot plant[9] (Fig. 2, middle and bottom).

Guayule agronomics are well understood and are much more established than rubber dandelion agronomics: guayule can be reproducibly farmed as a crop (Fig. 3). Guayule can be used to produce solid rubber (GNR) either by (i) solvent extraction followed by precipitation to separate the GNR from the resin

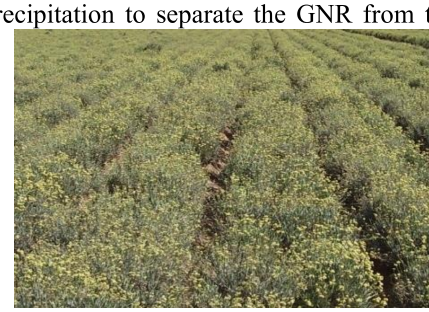

***Figure 3**. Guayule is a semi-arid crop in the southwestern U.S.*

and bagasse, as performed by Bridgestone Americas in its Mesa, AZ pilot plant, or (ii) coagulating guayule latex, as produced by EnergyEne, Inc. Cooper Tire developed and patented a process in which the latex can be coagulated and deresinated simultaneously to produce a tire-grade GNR (US2018/0230243A1).

2.2 Opportunities for latex.

Virtually all natural latex glove manufacture was off-shored from the US to southeast Asia in the 1990’s. The off-shoring of dipped products has exacerbated our supply woes because we depend on southeast Asia and China for raw rubber and latex *and* for finished gloves and other protective latex-containing personal protective equipment (PPE). Although synthetic gloves, dominated by nitrile, have gained significant market share in response to Type I latex allergy, their performance standards were perforce lowered by the FDA because they could not achieve the standards expected for natural latex gloves. Since then, nitrile glove quality has increased but the standards have not been readjusted, allowing poor quality gloves to remain in the marketplace. The causes of Type I latex allergy are well understood, and good manufacturing practices readily prevent distribution of gloves capable of sensitizing users with this life-threatening allergy (although they remain unsafe for the allergic people sensitized by exposure to other products with high levels of residual soluble proteins). Safety has been improved further by FDA’s ban of glove powder, preventing pervasive air borne latex protein allergens. The shortage of natural rubber latex is severely felt by markets for single use latex gloves and associated PPE, especially because COVID-19 has increased global glove demand from 300 to 600 billion/year. Increased nitrile glove manufacture has been able to produce about 100 billion additional gloves, but this has completely exhausted nitrile latex supplies and nitrile latex is fully allocated through the end of 2022. This means that about 1 MT of natural latex needs to be produced for the manufacture of 200 billion additional gloves.

Although soil grown dandelions make their rubber (TNR) in the form of latex (TNRL), like all other rubber-producing species, much of its latex coagulates in the roots during the life of the plant, possibly due to environmental stress, and so cannot be extracted in latex form. An emulsion can be reconstituted from solid rubber by dissolving the rubber in organic solvent followed by emulsification in aqueous surfactant and solvent stripping. However, a simpler approach is to produce the roots in intensive hydroponic or aeroponic farms (Fig. 4, right and center, respectively) in which the roots do not become stressed, and which can be harvested every two months (Fig. 4, top left). Automated indoor vertical farms are highly productive systems and could be rapidly expanded in case of a major rubber tree crop failure when no price would be too high to meet critical needs. The rubber particles remain in latex form in these systems, and the extracted latex ought to be suitable for glove manufacture, although this is not yet proven. OSU has produced the first quantities of dandelion TNRL and has begun glove formulation development and testing (Fig. 4 bottom left).

Figure 4. *Aeroponic (OnePointOne LLC, center) and hydroponic (American Sustainable Rubber LLC, right) production systems are high intensity, fully-automated systems, allow repeated bimonthly root harvests of the same plants (top left) and can be used to rapidly produce latex (bottom left) and rubber.*

Guayule rubber particles do not coagulate in the plant, if the crop remains hydrated, and can be extracted in the form of latex. The most efficient technology for this process is exclusively licensed by OSU to the start-up company, EnergyEne. Guayule latex (GNRL) films outperform all other natural and synthetic latices and are strong and very soft and stretchy, essentially preventing hand fatigue for glove users[10]. GNRL also is free of allergenic proteins which trigger Type I latex allergy[11] and can be formulated using accelerators (Robinson Brothers U.K.) which don’t cause the skin contact reactions commonly caused by residual chemicals in natural and synthetic latex products. Such products can be considered "*circumallergenic*" since they avoid both types of allergies. This allows entry into premium specialty markets and the first natural radiation attenuation medical glove is under development[12] (funded by USDA-SBIR Phase II). GNRL can be produced in ton quantities at the Wooster pilot plant co-owned and operated by OSU and EnergyEne. Over 2.5 tons of GNRL are currently in inventory. The natural rubber latex supply is experiencing more disruption than solid rubber partly because latex stabilized in ammonium hydroxide at pH 10 has a limited shelf life (up to six months) and this is not long enough for container shipping under today's mores. Some companies are using airfreight to import needed latex – a very expensive option. In addition to its unmatched physical properties, GNRL is very clean and is stabilized at pH 11 with KOH, allowing a much longer shelf (quality does not decline out to 10 years) and so GNRL stockpiles may prove possible. (Note: The same latex pilot plant can be used to extract and purify TNRL for aeroponic or hydroponic dandelion).

3. CONCLUSIONS

Rubber supply failures have converged with extensive technological improvement of alternative rubber crop germplasm and processing making it possible to create and sustain new domestic rubber industries. However, rapid expansion will require significant investment into germplasm development, farms and processing facilities – akin to what was earlier achieved to get bio-ethanol underway. The question that remains is not whether the United States has the ability to establish domestic rubber production but whether it has the will to do so.

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