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HOW CAN WE MOST RAPIDLY INCREASE THE PRODUCTION OF NATURAL RUBBER

James Bonner
(*California Institute of Technology, Pasadena, California 91125, USA.*)

We have gathered to celebrate history — the history of the rubber tree. Professor Schultes has told us about the botanical origins of the tree. We have heard about Sir Henry Wickham's removal of rubber tree seeds from their native Brazil to Kew Gardens and then to Sri Lanka. We have seen the original seedlings in the botanic gardens of Sri Lanka and we know how the seeds from these trees and other trees as well were distributed throughout Ceylon, Indonesia, Malaysia, Thailand and India, and how beginning with the first tapping of such a tree (an original mother tree) in approximately 1909 the rubber industry has advanced to a total production of about 3×10^6 tonnes of natural rubber per year. This has made possible the worldwide transition to rapid wheeled travel during the last 50 years.

The rapid development of the rubber industry has depended upon the application of my own two favourite sciences, genetics and chemistry. Plant breeding and clonal selection and propagation were started by the Dutch before 1920 and brought to its highest level by The Rubber Research Institute of Malaysia during the years 1925 to date. Selection alone has resulted in an increase of between 4 and 6-fold in rubber productivity per acre during the years 1940 to 1970. Chemistry has made possible the processing of rubber into pure and purer rubber culminating in the technically specified block rubber system of commercial presentation started by The Rubber Research Institute of Malaysia in 1965. For this important development the industry owes a great debt to Dr. B. C. Sekhar who, no doubt, will not in his own talk tell us that we owe a lot to him.

I will attempt to divide then the history of rubber into eras, analagous to the Chinese dynasties. These are : pre 1876 : Discovery and recognition of rubber as a plant and rubber as a product of the wild rubber plant ; 1876 to 1910 : Dissemination of the seeds and seedlings and beginning of the penetration of rubber from cultivated rubber trees into the rubber market, thus, stealing the rubber market away from rubber produced in nature, principally in Brazil and Colombia and from the Mexican guayule, which produced a substantial proportion of all rubber used in the United States until 1910 ; 1915 to 1940 : The era of plant breeding, agronomy and ever expanding productivity. When I was a postdoctoral fellow in the middle 1930's at the Swiss Federal Institute of Technology, a retired rubber breeder from Sumatra was working in the same laboratory with me. He had worked on clonal selection and it was his advice that one should never plant a pure stand of one clone because there might be something wrong with that clone. "Let us mix 2 or 3 clones in the same stand on the chance that one will be productive," he said. We have come a long way since that era of plant selection and breeding. It was an extremely productive one even so, and laid the basis for our future rapid increases in rubber productivity. The next era is that from 1945 to 1960 : Plant breeding, of course, continued and produced ever more productive clones in Malaysia. During this period the discovery of the path of rubber biogenesis was worked out in detail. The initial steps of rubber biogenesis are identical to the stages in the path of biogenesis of our own steroid hormones, our own vitamin A and the carotenoids of plants. Finally, the era 1960 to date : The discovery of yield stimulation first by 2, 4D and copper sulphate and then the recognition that both of these agents work through causing production in the tree of ethylene and, thus, the discovery of ethylene as a yield stimulant. Yield stimulation works by prolonging the flow of rubber latex from the tree and thence exploitation of a greater portion of the trunk than is possible, without use of the yield stimulant. This period brought also the age of technically specified block rubber and the development of the *Hevea* crumb process. It also marked sociologically the emergence of the small holder as a majority producer. So much for history. I will not dwell on it any further. I will confine myself on two topics : The first is, what can be done to increase the world's output of natural rubber — the output of which our world needs, wants and indeed demands ? This demand is projected to rise by 2-fold from today's 3×10^6 metric tonnes per year to double this amount by the early 1980. The second topic is, to what extent can technical innovation and improvement of the rubber plant and its crop management continue in the future as it has in the past ?

The answer to the first question is simple. If all rubber acreage now in use were planted to high yielding clones and subjected to optimal crop management, world production would be increased instantly, I calculate, by at least 2-fold were these measures taken and ethylene also used optimally the increase would be about 4-fold. Application of the knowledge we already have is all that is required to increase world rubber production quite significantly. I realize that really applying today's knowledge is easy to call for but hard to do. It takes capital, replanting schemes, fertilizer, pesticides, saturating advisor service. It takes new rubber processing plants, technically specified rubber and probably *Hevea* crumb rubber to start with. Nonetheless, rubber is economically such a profitable crop with such a bright long-term future that I have no doubt that a great deal of application of present knowledge to the production and cultivation of rubber will happen in the next several years. It would seem to me important that if the rubber industry of Sri Lanka implement application of all new knowledge, rubber could be a major source of Sri Lanka's foreign exchange.

The second question relates to what innovations in rubber practice can one foresee for the longer-range future ? Classical plant breeding and selection have done an immense amount of good for *Hevea*. It may still do some good by way of conferring more disease resistance, *etc.* upon our favourite plant. The dwarfing root stock is an idea whose time has not yet come; although, there is an obvious need for such a root stock. Innovations in control of fungal diseases are quite advanced over a range of pathogens. In many cases; the pathogen carries on its surface an elicitor which causes the host plant to produce a fungal toxin, called a phytoalexin. In one case the nature of the elicitor is known and it can be synthesized readily since it is a simple trisaccharide. The elicitor is a potent fungicide. We know enough about the biochemistry of disease resistance to exploit it in great depth in the next few years and to be able to cope with such serious diseases of *Oidium* in Sri Lanka, and perhaps even South American Leaf Blight, should it ever invade our territory.

We know enough about the biochemistry of latex flow and latex flocculation to be able to control, that is, to lengthen latex flow to a considerable extent by ethylene treatment. We will no doubt gain still more control over latex flow in future. As labour costs become more important as an item in the cost of rubber production we can still further increase the latex harvested per individual tapper per day. For example, short cuts coupled with ethylene treatment can yield more rubber per tree per tapper and still make it possible for the tapper to tap more trees than is possible by current procedures.

One of the ways in which we can improve rubber yield per acre per year is, of course, by better agronomy, that is, shortening the time in the field between the time of transplant of the seedling to the field and time of opening. It has already been shown by The Rubber Research Institute of Malaysia that the length of the immature period in the field can be shortened from the conventional 7 or 8 years to about 3 to 3½ years by the use of advanced planting material and by the simple strategy of watering the plants when they are planted.

Nonetheless, it seems to me that we may well be coming to an end of the good things we can do for rubber by conventional genetics and biochemistry. There is, however, a new genetics called molecular genetics and a new biochemistry called molecular biology, whose application to plants is just beginning. Indeed, the application to animals is just beginning also. The new genetics starts with the knowledge that the genetic material of all plants and animals is DNA, gigantic long molecules made of 4 kinds of building blocks fastened together in linear array. It is in the order of the 4 kinds of building blocks that the genetic information is encoded. We do not know the size of the *Hevea* genome, that is, we do not know how much DNA is contained in it ; although, I hope to find out soon. There is much to do in this field so far as rubber is concerned. In any case, the DNA is divided into several pieces called chromosomes. The DNA of each chromosome consists of sequential segments each about 1000 — 2000 building blocks long and called genes. Each gene codes for the production of a specific individual species of enzyme molecule. Although all the same genes are contained in each cell of each and every kind of specialized cell, only a few genes express themselves in any particular kind of specialized cell. For example, the genes for making the enzymes for making rubber are turned on and expressed only in the nuclei of the latex vessels and they are turned off in all other kinds of cells of the rubber tree.

The techniques of molecular biology have made it possible to isolate specific individual genes and to insert these genes into the chromosomes of hosts species quite different from those of the donor of the gene. Thus several groups in the U.K. and in the U.S. have isolated the genes responsible for nitrogen fixation in certain kinds of bacteria and transferred these genes to other kinds of bacteria. It is not too much to hope for that it will be possible to remove the genes for nitrogen fixation from microorganisms and to insert these genes for nitrogen fixation into the genome of the rubber tree and, thus, make the rubber tree independent with respect to nitrogen supply. I would expect that a major development in *Hevea* within the next 5 — 10 years will be the transfer of the genes for nitrogen fixation from, say, azotobacter to *Hevea*, thus freeing us from the need for nitrogenous fertilizer. No doubt genes for specific kinds of disease resistance could be transferred from one species to another in this same roundabout way.

Nature has also arranged it so that all creatures are divided into species which cannot in general mate with one another. For example, the cross of human by mouse has not been recorded. On the level of the cell, however, anything goes. Place human cells and mouse cells together in the same culture and they fuse and form cells containing all the genetic materials of human and of mouse. Such cells can multiply. The same appears to be the case with plant cells. Cell fusion may provide us with another way to transfer the genes for nitrogen fixation or disease resistance from the required and desirable donor to the recipient *Hevea* cells in tissue culture. The new biology opens the door to a whole new world of agricultural development. Want a rubber tree that will thrive on low rainfall ? Cross it with a pineapple which by virtue of its special mode of photosynthesis thrives on little water (about 1/10 as much water per unit of dry weight produced as is true of conventional crops). We do not yet know and can hardly guess where our new found tools will take us and what we can do with them.

It is my overall summary then, that for the short range we can increase the production of rubber merely by doing the things we know how to do already — replanting our rubber acres with high yielding clones, providing them with lots of fertilizer, and treating them with ethylene to maximize productivity per tree. In the longer run we can make dwarf trees. We can plant our trees under better conditions so that the time between planting and opening is lessened. In the still longer range we can create rubber trees which grow short and fat instead of skinny and tall (put the energy into making productive bark rather than a very tall unproductive trunk), and at the same time we can hope to make rubber trees that are more independent of outside resources and more dependent on their own internal resources; able to fix nitrogen, to repel insects and fungi, and to produce more rubber at less cost.