Journal of the Minnesota Academy of Science

Volume 5 | Number 6 Article 8

4-1936

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The whey remaining after the removal of casein from the milk still contains the milk sugar which can be separated and converted into a marketable product.

High grade casein would find a ready market in the country. There is an abundance of skim milk available in the dairy states which could be diverted into the manufacture of casein which would bring in fine financial returns.

Many other wastes result from fruit orchards that might be converted into desirable and useful products. The citrous fruit growers found it worth while to manufacture citric acid, pectin, and essential oils from the cull fruit. Jerusalem artichokes may not be a farm waste but they are easily and cheaply grown and cultivated and might be an excellent means of income from farm operation. These artichokes contain large amounts of the sugar fructose which can be extracted. It is an important food, particularly for diabetics. Lack of familiarity with the products of different farms, and especially with the many varied waste materials coming from such farms, limits the consideration of other farm wastes. Moreover there are many more possible uses for these wastes than those discussed and which might suggest themselves.

As stated earlier this paper merely suggests the various possible uses of farm wastes. Research and further investigations alone will determine whether or not any one of these wastes can be utilized to make a process technically and economically feasible.

SCIENCE AND RUBBER TREES

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It takes a flat tire to make many of us realize our dependence on rubber. What good is an automobile without tires, and what good are tires without rubber, and what good are we without automobiles? Much of our modern transportation is based on rubber, and tires are only one of the hundreds of uses to which it is put.

Until 1910 almost all of the world's supply of rubber came from Brazil. In the 16th Century explorers had brought to Europe a new substance, called "Caoutchouc" by the Indians of the Amazon Valley. It was interesting because it came from the milky juice of a forest tree, *Hevea brasiliensis,* and had unusual resilience. But it was not important until 1770 when Priestley found that it would rub out pencil marks. And so it was christened "rubber." The Indians had smeared it on wounds and on their feet as a protectant. And so Macintosh, a Scotchman, smeared it on cloth and invented the "mackintosh" in 1823. But in hot weather the coat got sticky and in cold weather it got stiff. Nevertheless, the use of rubber for waterproofing continued under this handicap until Goodyear in 1839 found that when crude rubber was treated with sulfur and heat it retained its valuable properties and was more resistant to changes in temperature, to deterioration in air, and to mechanical wear and tear. This was the beginning of the modern process of vulcanization, without which the manifold uses to which rubber is now put would be impossible. Great improvements in rubber technology were made much later, but it is with the production phase that this paper is supposed to deal.

As late as 1905, even with the automobile on the threshold of its amazing development and the potentially enormously increased demand for rubber, 99.7 per cent of the world's supply came from wild trees, nearly all in Brazil. But the development of plantation rubber had begun, and by 1922 more than 93 per cent of the supply came from planted trees, not in Brazil. There were several reasons for this remarkable transition from wild rubber to cultivated rubber. The British India office became actively interested in attempting to develop the plantation rubber industry in India and Ceylon as early as 1873. Through the cooperation of the British Government and the Director of Kew Gardens, Henry Wickham, an Englishman who had written notes on rubber in Brazil in 1871, was commissioned to collect seeds of the para rubber plant, *Hevea brasiliensis,* in the Amazon Valley. After varying vicissitudes, seeds were obtained, seedlings were grown in Kew in 1876 and sent to Ceylon and Singapore. From these beginnings the plantation rubber industry developed, slowly at first, then with startling rapidity. The principal impetus was given when those in control of the Brazilian output forced the price from 61 cents to $1.50 a pound in 1905–1906 and from 72 cents to $3.06 a pound in 1909–1910. With prospects of huge profits, there came an era of feverish activity in planting rubber, especially in Ceylon and Malaya. And when procedures outstrip basic knowledge, mistakes are likely to be made.

The mistakes made in the early days of rubber culture illustrate clearly the imperative necessity of having a fund of scientific knowledge as a basis for agricultural procedures. They show, too, the importance of understanding basis principles in order best to develop sound practices.

One of the first questions that arose was which kind of tree to use. *Hevea brasiliensis* is not the only rubber-producing plant. There are many kinds of plants from which rubber can be, and has been, obtained commercially. Experiments were made with a considerable number, and opinions with respect to the most suitable varied considerably. Finally, however, the Para rubber tree, *Hevea brasiliensis,* was selected as being the best.

In the early days there were almost more ideas regarding the kind of soil most suitable for rubber than there were kinds of soil. Trees were planted in low, swampy lands, on flat lands, and on very hilly lands, depending on the prevailing notions. In many cases no provision was made for soil conservation on the hills; the plantations were clean cultivated, with the inevitable result that the tropical rains, often amounting to more than 100 inches a year, washed most of the soil away. This led to the use of cover crops, mostly legumes. But some of them were susceptible to the fungus causing white root rot of rubber trees, and the result was an aggravation of this destructive disease.

There was almost no information regarding the number of trees that should be planted per acre. Should it be 100 or 200, or more or less? And what was the optimum number for the final stand — 50, 75, 100, or more? For it was early recognized that not all the trees planted would grow, and, as the trees increased in size, on what basis and at what age should thinning be done? It was soon found that the trees in a plantation, coming as they did from seed of a cross-pollinated species, constituted a very heterogeneous population. Not only did they differ in size, branching habit, and other similar characters, but, far more important, in yielding ability also. The question then became acute as to the relative influence of heredity and environment on yielding ability. And could one tell by looking at a tree how much it would yield? Some said that the biggest and most robust trees yielded best; others maintained the opposite. Some planters and business men made the profound pronouncement that not until the function of late had been ascertained could this question be answered. And that answer just was not in the books.

The method of tapping furnished a fertile field for guess work. For the milk-like latex from which rubber is made is in the inner bark of the tree, and the bark had to be scratched, scraped, or gouged to make the "rubber milk" flow. The tree had to be milked, and how to milk it was an important question. At first a mallet and chisel were used, but about 1900 tapping knives came into use and a shallow cut was made. But should this cut be made on the herring bone pattern, should it be V shape, or spiral; on one-fourth or one-half circumference, or some other circumference? Many answers were given, and many were not right. Then, too, was it best to tap the trees every day for a while and then give them a rest, or was it better to tap them continuously every other day, every third day, or when and how should the tree be milked?

While these questions and many others were agitating the minds of the pioneer planters, new and still more serious problems arose. Diseases made their appearance: brown bast and white root rot and others. The most important characteristic of brown bast was that the tapping surface "went dry." And that was really something to worry about. Why did it "go dry" and what could be done to prevent it? No one knew. Root rot also got in its insidious work. Trees often looked healthy and promising, only to be blown over in a wind storm or to suddenly wilt and die, when it was found that the roots were rotted. So what? No one knew. Obviously, much was to be learned. So common sense and science were put to work.

Research, experimentation, and accurate observation have taken much of the guess work out of rubber production and put it on a substantial basis, although much still remains to be learned. The principles of plant growth apply to rubber trees as well as to other plants. Practices now are based more and more on these principles and less and less on supposititious assumptions. It is known that the trees thrive best on fertile, well-drained soil, that cover crops have their uses and limitations, depending on the kind used and the need for holding the soil. Artificial fertilization pays on some soils, and not on others. The optimum number of trees per acre depends on the size of the trees and the carrying capacity of the soil: there is no universally applicable optimum number. Thinning must be done on a common-sense basis. Obviously, suppressed, misshapen, or diseased trees should be removed early. Then selective thinning should be done after yield tests have been made, and technics have been devised for getting this information early. The exact shape of the tapping cut is unimportant, except with respect to economy of labor and flow of latex. The tapping interval is based on two considerations: economy of labor and uniformity of quality of latex, fairly regular tapping being more likely to assure the latter. Maintaining the health of the tapping surface is accomplished by obviously sensible procedures: avoidance of too deep tapping, periodic disinfection of the tapping surface to prevent the growth of injurious and troublesome fungi and bacteria, and avoidance of overtapping in order to prevent the development of brown bast. The ravages of root rot have not yet been eliminated, but many mycological myths in connection with it have been thrown into the limbo of the past, and progress has been made.

This is a remarkable record of achievement, but most remarkable of all is the improvement of the rubber tree itself. Under the best conditions seedling rubber plantations might yield as much as 600 pounds of dry rubber an acre a year. But most of them yielded far less. And there was tremendous variation in yield of individual trees within a plantation. Plant scientists studied the problem and found that this difference was largely due to inherited characters of the trees. Clearly, then, it would be possible to develop more uniform, high-yielding lines. Crosses could be made between known high-yielding trees, or individual high yielders could be self pollinated and the seed used to establish better lines. But it is not easy to "self" rubber. Then, too, the seed from high-yielding "mother trees" did not always produce high-yielding progeny, because the pollination was not always controlled. An easier way seemed to be to take buds from high-yielding trees and "graft" them on stocks of young seedling trees. Thus the development of budded clones began, and for several years this process has been used almost exclusively in the development of new plantations. The result is that acre yields have been doubled or even trebled, and the end may not yet be in sight. And thus has *Hevea brasilien-*

sis been tamed and converted from a heterogenous conglomeration of dissimilar trees, whose performance could not be predicted, into a number of pedigreed lines whose characters are known and whose performance can be predicted with reasonable accuracy. Amazing as this achievement is, it resulted merely from the application of known principles of plant breeding and plant propagation to the rubber tree. And still further improvement is possible.

Every improvement of the technics of rubber production and rubber technology is of vital interest to us in the United States. We use most of the world's rubber and produce almost none. Most of the rubber we use reaches us after an ocean voyage of approximately 10,000 miles. The supply easily could be cut off. Or the price easily could be raised. In 1922, for example, when we used about 75 per cent of the world's production of rubber and controlled none of it, an artificial restriction scheme forced the price from 14 cents a pound to $1.23 a pound. Every increase of one cent in price cost the American people approximately eight million dollars, and it is estimated that we paid about one and one-fourth billion dollars additional for our rubber because of this restriction scheme. This led a number of thoughtful people in the United States to consider the desirability and feasibility of growing some rubber under American auspices. Experiments were made by Edison in Florida in which it was demonstrated that rubber could be obtained from the giant sunflower. But the most successful attempt to produce rubber under American auspices has been made by the Firestone Plantations Company in Liberia, an independent negro republic on the west coast of Africa, over which the United States has exercised more or less a "moral protectorate." Beginning in 1926, the plantations have been steadily developed by modern scientific methods and easily could be expanded very greatly. Rubber from Liberia requires an ocean voyage of only a little more than 4,000 miles to reach the United States. That from the principal rubber producing countries at present must be brought approximately 10,000 miles. The economics of the situation is not the concern of this paper. But the scientific development of rubber production concerns us all.

It may be apparent from this brief sketch that soundest procedure in the development of agricultural enterprises must rest on a sound foundation of scientific facts. Possibly it is apparent also that the elucidation of botanical principles which can be applied to new crops and new situations is of paramount importance. Very often the most fundamental science is the most practical science. And is it not clear that one of the principal functions of science is to accumulate stores of facts and principles in order that they may be applied to new problems that may arise in future? More and more science should function in preparing for the future, not only in explaining the present and the past.

Published papers were edited by an Editorial Committee: L. M. Gould, J. G. Leach, W. M. Sandstrom, H. K. Wilson.