IMPERIAL BUREAU OF HORTICULTURE AND PLANTATION CROPS

TECHNICAL COMMUNICATION No. 16

FURTHER WORK ON PLANT INJECTION FOR DIAGNOSTIC AND CURATIVE PURPOSES

W. A. ROACH and W. O. ROBERTS, East Malling Research Station.

August, 1945

Price 1/6

Reprinted by courtesy of the editors of the "Journal of Pomology and Horticultural Science," from J. Pomol., April 1945, Vol. XXI, pp. 108-119, and published by the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England, and obtainable from I.A.B., Central Sales Branch, Penglais, Aberystwyth.

FOREWORD

In 1938 Dr. Roach surveyed the whole field of plant injection work and gave details of the technique used by himself and others in Technical Communication No. 10.

Since then not only has there been a persistent and increasing demand for the T.C. and for relevant information, but also considerable advance in technique has been made by the workers in this field.

By now, therefore, under normal circumstances the bureau would have hoped to bring the whole subject up to date by a further comprehensive survey, but this the stress of war has prevented.

Hence, it has seemed reasonable to do the next best thing, namely, to offer the present paper by Dr. Roach and Mrs. Roberts, in which they describe the improvements in technique introduced by the East Malling team since 1938, as a useful addendum to the information given previously. The paper considered as an interim survey, should, it is thought, fill the gap until such time as a fuller survey is possible.

The Bureau is most grateful to the authors and to the Editors of the *Journal of Pomology* for permission to reprint the paper and make it readily available at a low price to those interested.



FURTHER WORK ON PLANT INJECTION FOR DIAGNOSTIC AND CURATIVE PURPOSES

By W. A. ROACH and W. O. ROBERTS

East Malling Research Station, Kent

This communication describes improvements made in plant injection methods since they were described in detail (Roach, 1938, 1939) and includes experience on a wider range of plants, both in this country and in South Africa. A brief note on the results obtained has already been published (Roach, 1940). The methods elaborated are now in use in many parts of the world, but the present is not a suitable time for making a comprehensive survey of the recent work of other investigators; this is deferred until after the war. The present account is written as an addendum to the earlier papers, to which page references are given.

I. INJECTION FOR DIAGNOSTIC PURPOSES.

Concentration of solutions.—Responses have been obtained on a number of different kinds of plants with the following solutions, but it may be necessary to modify them, e.g. when work is done on new kinds of plants.

N	1%	Urea.
P	0.5%	Sodium dihydrogen phosphate.
K	. 1%	Potassium chloride.
Ca	1%	Calcium chloride.
Mg	0.5%	Magnesium sulphate.
Fe	0.025%	Ferrous sulphate+0.025% (by volume) sulphuric acid.
Mn	0.025%	Manganese sulphate+0.025% (by volume) sulphuric acid.
Zn	0.025%	Zinc sulphate+0.025% (by volume) sulphuric acid.
Cu	0.025%	Copper sulphate+0.025% (by volume) sulphuric acid.
Ni	0.025%	Nickel sulphate+0.025% (by volume) sulphuric acid.
В	0.1%	Boric acid.

High grade chemical reagents are quite satisfactory. The sulphuric acid is added to the metallic trace element solutions to prevent all risk of precipitation by hydrolysis. This has been a serious inconvenience in respect to the ferrous sulphate solution.

A. Interveinal leaf injection (cf. Roach, 1938, p. 18; 1939, p. 168).

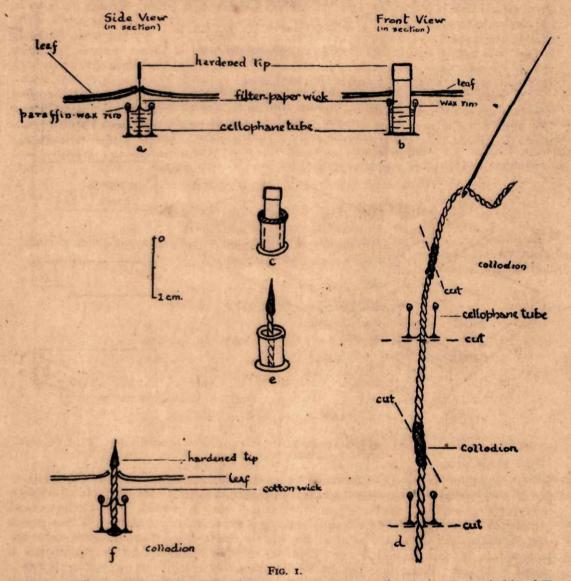
Further experience with this method has confirmed the conclusion that a response may be detected more rapidly by it than by any other method. In an experiment by B. N. Lal (1944) at Malling a response to iron was observed in the Soya bean two days after injection. The method as originally described has, however, two serious drawbacks: it calls for delicacy of manipulation and it cannot be used in windy weather.

manipulation and it cannot be used in windy weather.

The apparatus described below (Fig. 1) has made manipulation easier, has removed the tendency for the contrivance to fall before the absorption is complete, and has increased its resistance to wind. The improvements consist mainly in the replacement of the long, relatively heavy, glass tube by a short, light one, made of cellophane, and the use (in one method) of a chisel-ended scalpel to make an incision of exactly the right width, the lips of which consequently clip the filter paper wick and hold it firmly.

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Construction of the appliance.—The cups for holding the liquids to be injected are made from cellophane drinking straws (those without a decorative strip of tinsel). These are obtainable in several distinctive colours, which may if desirable be increased by marks in waterproof

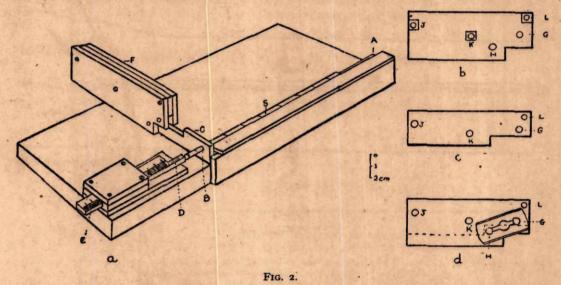


Apparatus for interveinal injection. Side and front sectional views of one form in use are seen in (a) and (b). It is drawn in the solid in (c). The manufacture of the other form is illustrated in (d). It is seen in the solid in (e), and (f) is a sectional view of it in use.

ink. If each colour or colour combination is used for a particular solution the little cups may be used a number of times without cleaning.

The straws are cut to the required length with the apparatus illustrated in Fig. 2. The straws are slid along the guide A, through the hole B in the vertical piece of box-wood C up against the stop D, which can be adjusted to give different lengths of straw, the length being

To lessen the tendency of the liquid to be drawn out by capillarity along the leaf surface when the underside is hairy, the rim of the cup is protected by a thin layer of paraffin wax (Fig. 1, a & b). The layer is applied by heating a little of the wax on a horizontal sheet of glass over a steam bath and dipping one end of each piece of tube into the thin layer of melted wax.



(a) Guillotine for cutting cellophane drinking straws into lengths suitable for injection cups. (b), (c), (d), details of F. For detailed description see text.

Discs to form the bottoms of the cups are cut from sheet cellophane with a leather-cutting punch of slightly greater diameter than that of the tube, a piece of card being placed between the cellophane and the brass block against which the cutter is pressed. Into the non-waxed end of each bit of cellophane tube is squeezed a drop of collodion* and the tube is then placed over one of the discs so that the collodion may seal the two together, thus closing the end of the piece of tube and forming a little cup. While the collodion is still liquid a filter paper wick is placed in the cup. When the cup is dry the tip of the wick is hardened by brushing it with a little dilute collodion. This soaks in and hardens about 2 mm. of the wick. Instead of a filter paper wick a cotton one may be used. For that purpose the cups are allowed to dry, ordinary unmercerized mending cotton is drawn up through the bottom of the cup with a very fine darning needle (Fig. 1, d, e, f). The cotton is cut off just below the bottom of the cup and a little longer than is necessary above. Collodion is squeezed over the bottom of the cup to secure the thread and seal the hole; it is also smeared over the protruding end of the thread, leaving about 2-3 mm. untreated above the rim of the tube. When quite dry, the hardened end is

^{*} An adhesive sold in convenient tubes and known as Durofix, is suitable for this purpose.

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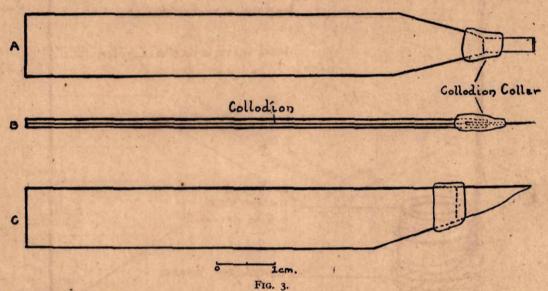
sharpened to a point by cutting slantwise with a razor blade, as shown in Fig. 1 (d), which also shows how several of such tubes may be provided with cotton wicks at one and the same time.

Both types of cup can be filled with the required liquids by using an ordinary dropping

bottle with a slender delivery tube.

The scalpels (Fig. 3, A and B) are made by breaking a suitable piece from a thin safety-razor blade of the Gillette type held in parallel-jawed pliers and cementing it between two flat wooden spills with collodion. A number may be clamped between boards to dry overnight, after which collodion is run around the joint between the blade and the wood to strengthen it.

For work in the field it has been found convenient to carry the various items of the apparatus in a box fitted so that each dropping bottle occupies its own compartment in a row and has opposite it two compartments, one for each type of its distinctively coloured injection cups.



Scalpels suitable for diagnostic injection. A, front, and B, side view of chisel-end scalpel for interveinal injection. C, front view of scalpel for leaf-stalk injection.

B. LEAF-STALK INJECTION (cf. Roach, 1938, p. 27; 1939, p. 180).

This is by far the most generally useful of all diagnostic injection methods. It is at present in routine use for testing the effect of essential elements singly and in combination, and many thousands of injections of this type have been done. Experience has proved the desirability of carrying out the test with each solution at least in quadruplicate. Usually about a dozen elements are involved, which entail about fifty injections. Water injections should also be included.

Construction of apparatus.—The apparatus found most convenient is shown in Fig. 4, A and B, and two methods of using it are illustrated in Fig. 5, A and B. Apparatus shown in Fig. 4, B is for use with smaller leaves.

For lightness, tubes are blown from the thinnest walled quill glass tubing. These are obtainable from Messrs. C. L. Muller, 6 Parton Street, Red Lion Square, London, W.C.I.

A suitable length of lead wire is held against the tube in a spring clothes peg. Collodion is applied to the bottom of the lead wire so as to stick it to the tube; a little more is applied to the wire near the open end of the tube. While the collodion is still liquid two turns are made round both ends of the tube with thread, which is then covered completely with a layer of

collodion. When dry the clothes peg is removed and collodion is applied along the whole length of lead wire in contact with the tube. In this way the exterior of the whole contrivance is left quite smooth and without projections which might scratch the leaves in a wind. Finally, a thin band of melted paraffin wax is painted round the inner rim of the tube. This tends to prevent the liquid from running out of the tube, even when it slopes mouth downwards.

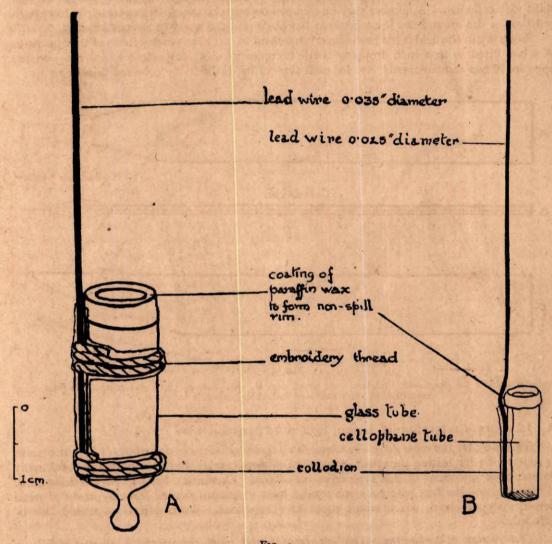


Fig. 4.

Cups for leaf-stalk injection. A for larger and B for smaller leaves.

For slender leaf-stalks the single coil of the wire shown in Fig. 5, A is sufficient to bend the stalk down. Stiff leaf-stalks can be bent down by using a piece of .025 in. diameter lead wire attached to the basal knob of the tube and with its other end coiled around the stem of the plant (Fig. 5, B). Both for maximum speed in working and for minimum damage to the plant the wire should be twisted as little as possible.

The type of scalpel found most convenient for leaf-stalk injections is shown in Fig. 3, C.

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It is easily held in the mouth, or even stuck to the moistened underlip, between operations, and its lightness is a distinct advantage in use.

As already pointed out (Roach, 1938, 1939), the reliability of a diagnosis made by the leaf-stalk injection method depends on how closely the distribution of the improvement (if any) in leaf colour (and sometimes the growth increase) corresponds with expectation based on experiments with dyes, and on the degree of likelihood of a similar distribution of colour variation occurring naturally. Hence before starting such injections on a fresh type of plant it is necessary to do a sufficient number of experiments with dyes and to make a survey of the naturally occurring

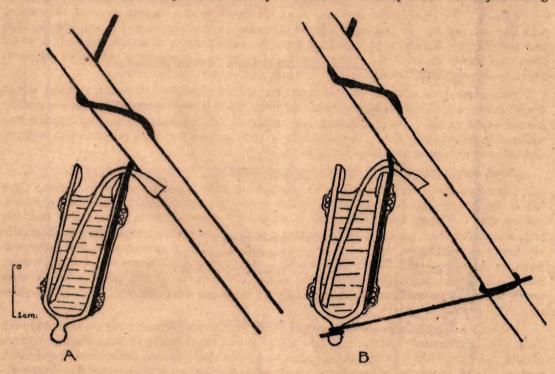


Fig. 5.

Method of attaching injection cups to the plant stem. The method shown in A is used unless the leaf-stalk is too stiff, when the method seen in B is used.

variations in colour and size which might be mistaken for the result of the experiment; shoots with leaves showing such variations must, of course, be avoided.

In such plants as the apple, the distribution of injected liquids may be predicted within narrow limits, and there are all stages between this type of material and the aubergine, in which the distribution is so variable as to make this type of injection useless for diagnosis. There are similar differences between species of plants in respect of the degree of variation in colour and size of the leaves. The degree of variation in the leaves of a given plant depends largely on the degree of uniformity of the soil.

C. SUMMARY OF EXPERIENCE WITH VARIOUS PLANTS.

Extensive injection work has been done for the most part on relatively few kinds of plants but enough has also been done on a number of other kinds to suggest the most hopeful methods to try on them. The following notes summarize our present knowledge. The plants are arranged alphabetically.

Apple.—Frequent references have been made to methods suitable for the apple (Roach, 1938, 1939). The leaf-stalk method is the most generally useful. The commonest type of distribution of injected substance has already been described (Roach, 1938, pp. 27-29; 1939, pp. 181-183). The only really commonly occurring divergence from this pattern is one in which the two leaves immediately above and below the injection point respectively do not become permeated. In a recent experiment with 1 per cent. acid fuchsin on the variety Lord Derby, in which 100 shoots were injected, the first leaf below the injection point in 10 shoots was free of dye, and in one shoot only were the leaf below and the leaf above this point free of dye.

Apricot.—The distribution resulting from the injection of a regular shoot of the apricot with dye solution by the leaf-stalk method is similar to that shown in Fig. 19, Roach, 1938 and text Fig. 17, Roach, 1939. Judging from the small number of shoots injected, it would seem that shoots in which the arrangement of the leaves is irregular is somewhat common. These must be avoided, because they give unpredictable injection patterns.

Aubergine.—Dye solution injected into the aubergine by the interveinal method moves freely, and even medium sized veins do not form definite barriers to permeation, but the method seemed worth trying. The plants used were unusually healthy, however, and no response was obtained to mineral injection. The distribution resulting from leaf-stalk injection was irregular and this method appeared useless for diagnosis.

Broad Bean.—See Hill and Roach, 1940, pp. 518-520.

Cape Gooseberry.—A few experiments carried out late in the season with vigorous Cape Gooseberry plants below deciduous fruit trees in the Western Cape Province, South Africa, suggest that this plant would lend itself to diagnosis by the leaf-stalk method, and that the first, second and third leaves above the injection point become permeated sufficiently unequally on their two sides to be useful for diagnosis. Strong colour responses and obvious growth increases were obtained. Shoots in which the arrangement of the leaves is not quite regular must be avoided. Although not of great commercial importance this plant is nevertheless worth testing as an indicator plant, especially for diagnosis when the fruit trees in the same plantation are not in growth.

Citrus.—A few experiments were carried out on orange trees between the seasons of growth flush. These suggested that the leaf-stalk method is well worth trying on trees making vigorous growth. An abnormal type of shoot common on trees between growth flushes must be avoided, because leaf-stalk injection of them results in a general distribution of the injected liquid throughout the whole shoot. These shoots are easily recognized because their leaves are small and become progressively smaller from the base of the current year's growth to the tip. The experiments done on normal shoots suggest that the distribution may be predicted with sufficient accuracy for diagnosis. The commonest type of distribution corresponds closely to that given by the pear (Roach, 1938, p. 33; 1939, p. 188). Citrus leaves often become bleached in sunlight and this must be borne in mind in making a diagnosis. No positive response was obtained in any of the few score injections of nutrients carried out during a visit to the Union of South Africa, but none of these was done under the best conditions for getting a response. Experiments under better conditions, i.e. when the trees are making vigorous growth, are therefore highly desirable.

Coffee.—See Roach, 1938, p. 35; 1939, p. 189. Currant.—See Roach, 1938, p. 33; 1939, p. 188. Gooseberry.—See Roach, 1938, p. 33.

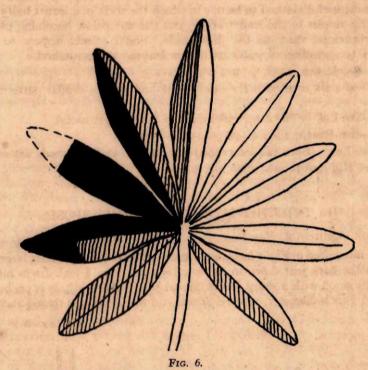
Gousblom (Arctotis).—Work was done on this plant (Compositae) because it is a self-sown cover crop commonly found in some of the orchards of the Western Cape Province and it is in vigorous growth when the fruit trees are leafless. The pattern resulting from leaf-stalk injection resembles that of the apple.

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Guava.—Experiments with dyes only have been done on this plant. Interveinal injection results in the permeation of the area without any dye crossing the bounding secondary veins. Leaf-stalk injection gives the same distribution as in coffee and the Hydrangea.

Hop .- See Roach, 1938, p. 35.

Japanese Plum.—The leaf-stalk method is the most useful one for this plant and it gives the same distribution as in the common plum. Care must be taken, however, not to use shoots developing from adventitious buds on old wood, because leaf-stalk injection on such shoots results in permeation of the leaves of practically the whole shoot; no leaves became permeated on one side of the midrib and not on the other.



The distribution of liquid resulting from the injection of a lupin leaf through a cut leaflet tip.

Loquat.—Experiments with dyes only have been done on this plant. The extreme hairiness of the loquat leaf does not interfere with interveinal injection because the hairs are not easily wetted. Dye solution injected through an interveinal incision permeates the interveinal area thoroughly, and, in addition, enters a band near the midrib nearly reaching the leaf tip. Comparison must therefore be made mainly between one side of the leaf and the other and not between contiguous interveinal areas. The effect of a high concentration may be seen by comparing the interveinal area containing the incision with the one on the opposite side of the leaf, and the effect of a lower concentration by comparing most of the injected half leaf with the other half. Leaf-stalk injection brings about the permeation of leaves of the whole shoot and can therefore be used for experiments in which a unit of this size is desired.

Lupin.—The leaflet-tip method of injection has been found to be applicable to a number of types of lupin grown as cover crops in South Africa and in gardens in this country. A typical result of injecting dye is shown in Fig. 6. The effect of injected nutrients is usually seen in the

shaded and black areas. Leaf-stalk injection tends to result in the second leaf above, the first and third leaves below, becoming permeated on the proximal but not on the distal side. Limited experience with this method suggested that it is worth trying as well as the leaflet-tip method. The leaf-stalk one is the easier to carry out.

Peach.—The leaf-stalk method of injection is the most useful and gives the same pattern as in the apple.

Pear.—See Roach, 1938, p. 33; 1939, p. 188.

Plum.—The leaf-stalk method of injection is the most useful and gives the same pattern as in the pear.

Potato.—Experience in the field since the publication of the paper by Hill and Roach, 1940, has proved the most useful method to be one in which the stalk of a leaflet halfway along a leaf is immersed. This results in the leaflet above and the one below becoming permeated, more heavily on the proximal than on the distal side. Slight effects appear to have resulted occasionally from the injection of water into a few leaves by this method.

Raspberry.—See Roach, 1938, p. 30; 1939, p. 185.

Rose.—The leaf-stalk method is the most useful and gives a similar pattern to that in the apple.

Soya bean.—See Lal. The interveinal method is the most useful.

Strawberry.—See Roach, 1938, p. 26; 1939, p. 179.

Tobacco.—See Lal. Both the interveinal and the leaf-stalk methods are useful.

Tomato.—See Hill and Roach, 1940, pp. 506-512.

II. INJECTION FOR CURATIVE PURPOSES.

A. INJECTION OF LIQUIDS (cf. Roach, 1938, p. 52-60).

The method illustrated in Fig. 7 has been found satisfactory for injecting large trees. A hole is bored through the bark just down to the wood with a sharp \(\frac{3}{8} \)-inch Irwin bit. The hole is continued into the wood with a sharp \(\frac{1}{4} \)-inch similar bit. Into this hole is pushed a cylindrical plug of hardwood \(\frac{3}{8} \)-inch diameter, tapered at one end to a little less than \(\frac{1}{4} \) inch and bored to

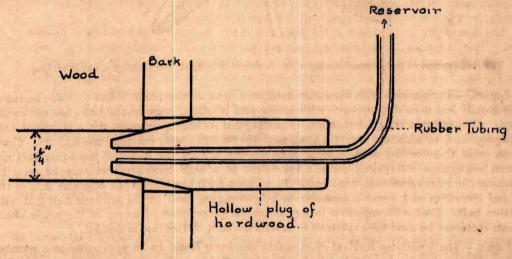


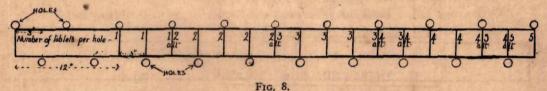
Fig. 7.

Method for leading liquid into the injection hole in the tree-trunk or branch to be injected.

take the narrow-bore rubber tubing (such as is used for bicycle tyre valves) leading to the reservoir. It is important that the boring be done by a genuine Irwin bit, kept clean and razor sharp, otherwise the cut edges will be ragged and a good joint with the plug will be impossible, nor will the hole heal rapidly and cleanly. The degree of plugging of the cells in the wood next to the bark is not found to slow up absorption appreciably except when there is only a thin ring of living wood, e.g. in a plum tree affected by Silver Leaf disease, when the method described earlier should be used (Roach, 1938, p. 53).

B. INJECTION OF SOLIDS (cf. Roach, 1938, p. 68; 1939, p. 217).

The advantages of injecting a solid instead of a liquid are that little apparatus is necessary, the handling of volumes of liquid comparable with those required for spraying is avoided, and the process is completed in one operation. The use of the solid method became essential when it was found that cherry trees commonly absorbed little or no liquid (Duggan, 1943). The most serious drawback to the solid method is the amount of mechanical damage done because of the necessity of having so many holes in the trunk. Thus, about ten times as much wood is removed in making the holes for solid, as is necessary for liquid injection. Bennett's (1931) recommendation amounts to a hole of $\frac{1}{2}$ -inch diameter every 3 inches of circumference of trunk or branch.



Calibrated rubber band for spacing holes for injecting a tree with substances in tablet form. The band is wrapped round the tree and the line nearest where the beginning overlaps the other end gives the number of tablets to be inserted into each hole.

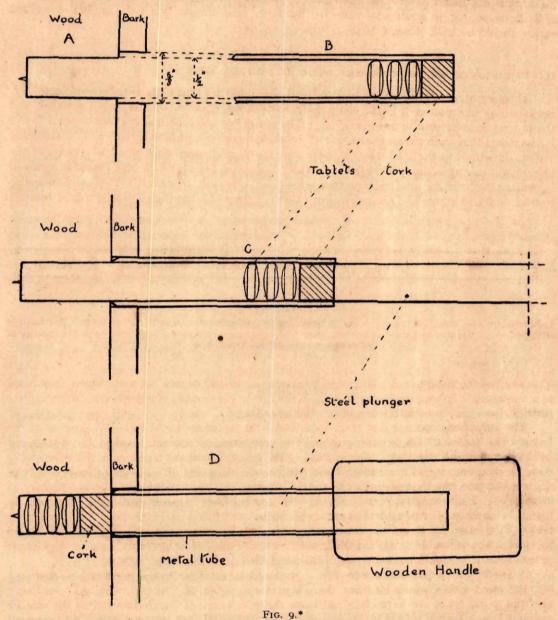
This exposes the wood to risk of invasion by disease-producing organisms, and it must be reduced to a minimum. It has been found that any reduction in the number of holes results in incomplete

distribution of the substance throughout the tree (Duggan, 1943).

The aim of the method now to be described is to encourage rapid and clean healing of the holes. The essentials are a clean cut and the prevention of contact between the introduced solid substance and the bark. The spacing of the holes around the trunk is most conveniently done by wrapping round it a rubber band (such as shown in Fig. 8) on which a mark has been made every 3 inches, first securing the end of it with a pin and stretching the band slightly, if necessary, to make the first mark coincide with another one. Against this latter mark will be found the number of grm. tablets of substance to be introduced into each hole. To save using tablets of smaller size to get the exact dosage for each hole when the amount comes to an odd half gm. it is permissible to use the whole number above and below alternately. It is important to note that if branches have died back the amounts injected must be reduced.

A hole of $\frac{5}{8}$ -inch diameter is bored through the bark just down to the wood and is continued into the wood with a $\frac{1}{2}$ -inch bit using the same centre (Fig. 9, A). As before, it has been found essential to use Irwin bits kept clean and razor sharp. A cork of $\frac{1}{2}$ -inch diameter at the smaller end and $\frac{1}{4}$ inch long is placed in the end of a metal tube of $\frac{1}{2}$ -inch internal and $\frac{5}{8}$ -inch external diameter, and externally bevelled at the other end. The solid is obtained in I grm. tablets (lighter ones for smaller trees) and the requisite number are placed in the tube (Fig. 9, B). The tube is now inserted into the hole in the bark until its bevelled mouth presses on the margin of the hole in the wood (Fig. 9, C). The end of a plunger provided with a handle is now placed

against the cork and pushed home, driving tablets and cork into the hole in the wood (Fig. 9, D). The length of the plunger protruding from the handle is exactly the same as the length of the tube measured along the inside wall. The outer end of the cork, therefore, lies flush with the surface of the wood and forms a platform over which healing takes place rapidly. Holes bored



Sectional drawings illustrating method for injecting a tree with substances in tablet form. A, Shows holes bored through bark and wood. B, Metal tube with cork and tablets in position. C, Tube inserted in hole in bark against the mouth of the hole into the wood. End of plunger ready to push cork and tablets into hole in wood. D, Cork and tablets pushed home into hole in wood.

^{*} The implement here described can be obtained from Edward Griffin, West Malling, Kent.

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in the winter or early spring heal during the succeeding summer and are barely visible by the autumn.*

Curative treatment has so far been done mainly on large trees. For small trees the size of the hole must be suitably reduced (see Bennett, 1931, p. 7, Table 3). For trees with soft bark the apparatus shown in Fig. 36 (Roach, 1938) makes the neatest holes.

SUMMARY.

Improvements in the appliances hitherto developed by one of the authors and his collaborators and used for plant injection with liquid for both diagnostic and therapeutic purposes and with solid materials for therapeutic purposes are described in detail and fully illustrated. They include the reduction in weight of the small containers employed for interveinal and leaf-stalk injection by the substitution of cellophane for glass. Special tools for making the cellophane cups are described and illustrated and the sources from which the requisite materials can be obtained are mentioned.

Brief notes are given on the experience gained both in this country and South Africa in the use of injection methods with twenty-five different kinds of plants, including fruit trees and bushes, some forage plants, hops, potatoes, tomatoes, tobacco and a few others. Paged references are given to information contained in previous papers on the subject.

In connection with injection for curative purposes, an improved method for the injection of solids into a tree is described and figured. It consists in drilling a small hole through the bark, continuing it at a slightly decreased diameter into the wood, introducing with the help of a metal tube and plunger the necessary chemicals in tablet form into the wood and sealing them there with a cork disc, over which the bark readily heals. By this method a minimum of mechanical damage is done to the tree.

ACKNOWLEDGMENTS.

Figs. 2, 3, 4, 5, 11 and 12 were kindly drawn by Miss M. E. Bunyard, to whom the writers are duly grateful.

REFERENCES.

- Bennett, J. P. (1931). The treatment of lime-induced chlorosis with iron salts. Univ. California Agr. Exp. Sta. Circ. 321.
- Duggan, J. B. (1943). A promising attempt to cure chlorosis due to manganese deficiency, in a commercial cherry orchard. J. Pomol., 20, 60-78.
- a commercial cherry orchard. J. Pomol., 20, 69-78.

 Hill, H., and Roach, W. A. (1940). Injection for the diagnosis of mineral deficiencies in the tomato, the potato, and the broad bean. Ann. Bot., N.S. 4, 505-522.
- Lal, B. N. Plant injection methods for the diagnosis of mineral deficiencies in tobacco and Soya bean. Annals of Botany. (In press.)
- Roach, W. A. (1938). Plant injection for diagnostic and curative purposes. Imp. Bur. of Hort. and Plant Crops, Tech. Comm. No. 10.
- —— (1939). Plant injection as a physiological method. Ann. Bot., N.S. 3, 155-226.
- (1940). Diagnosis of mineral deficiencies and excesses by systematic leaf injection and analysis. East Malling Res. Sta. Ann. Rpt. for 1939, 51-58.
- * Mr. C. R. Thompson, Assistant Advisory Officer in Commercial Fruit Growing to the Kent Education on Committee, has used an apparatus differing slightly from the one just described. A description of this has appeared in the *Market Grower* for Oct. 14, 1943, pp. 12-13 and for Oct. 21, p. 15, since this paper went to press.

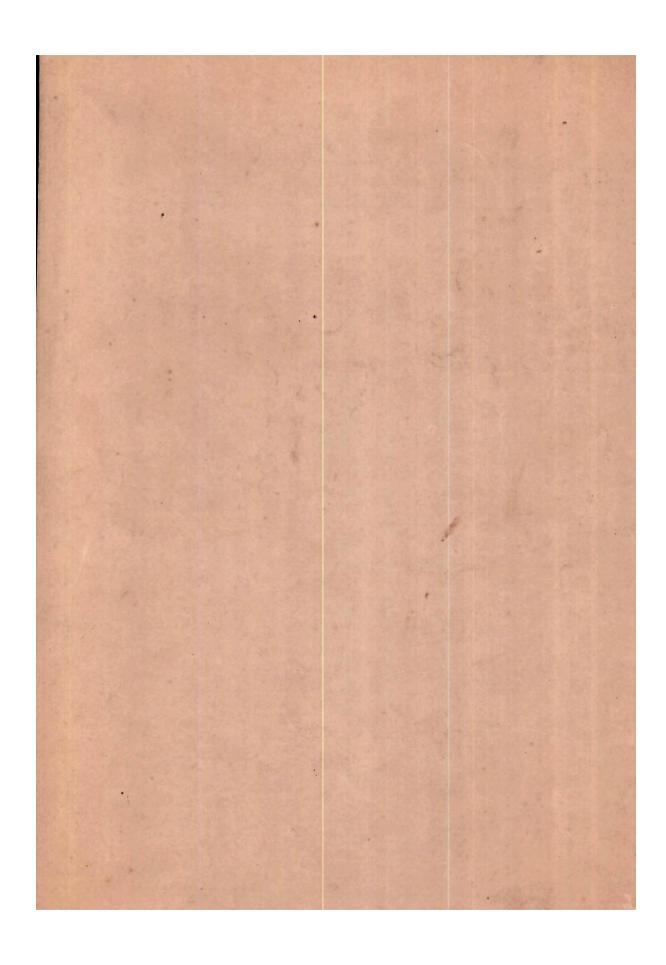
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FUTURE ELASTOMERS FOR INDIA



V. C. NANAVATI



TALK DELIVERED AT THE INSTITUTION OF THE RUBBER INDUSTRY (LONDON) - INDIAN SECTION - CALCUTTA, ON 30TH JULY, 1966.

The consumption of rubber in our country has been increasing at an average rate of 12% per annum over the last ten years. In spite of this, the per capita consumption of rubber in our country is some 0.35 lbs. as compared with some 21.6 lbs. for the U.S.A. This significantly illustrates the scope for increasing the consumption in the years to come.

Based on an estimated per capita income of Rs. 466/- per annum by 1970-71 (Rs. 363/- in 1964) and various other considerations of estimated demand for the finished products, it is now felt that the total new polymers required by the end of the 4th Plan may be some 1,50,000 tonnes. The quantity of reclaimed rubber might be around 20,000 tonnes. Table No. 1 shows the break-up of total polymer requirement by end products. As will be noted from the table, the production of tyres has been estimated at some 5 million units. Table No. 2 shows the detailed analysis of this requirement of tyres. Doubts have been expressed regarding the demand of tyres as some feeling exists that the requirement of tyres by that time may be around 7 million units. However, the present indications do not corroborate this figure and a production of five million tyres seems more logical. If it is granted that the new polymer requirement by 1970-71 will be some 1,50,000 tonnes, it is then necessary to analyse how this demand for new polymers can be met. Basically, we must consider the polymers which are widely used in some of the leading nations of the world. These polymers are Natural, SBR, Butyl, Polybutadiene and Polyisoprene. Obviously, the choice will be restricted to these polymers for our study.

NATURAL RUBBER:

The availability of natural rubber from indigenous source is visualised at some 75,000 tonnes, leaving a deficit of 75,000 tonnes to be met either fully by synthetic rubber or by a combination of natural and synthetic. Therefore, every effort should be made to fill the gap by local production of synthetic rubbers. It is now appropriate to examine each type of synthetic rubbers and conclude how best the synthetic rubber production be planned to meet the demand and at the same time ensure that no idle capacity exists.

SBR :

As is well known, this polymer has been called the workhorse of the industry the world over. Fortunately, a SBR plant with a capacity of 30,000 tonnes per annum exists, however, the fact that larger quantities of SBR can be used, consideration should be given to this aspect of increasing the availability of indigenous SBR.

Table No. 3 gives the estimated SBR consumption by end products from which it will be observed that a minimum of 50,000 tonnes of SBR or 33% of

the total new polymer can be used. The visualised percentage of SBR consumption is considered most realistic. We have already achieved a usage of some 25% and it is expected that during the year 1967 some 30% SBR usage can be established. In other words, the projected consumption of SBR is in fact based on the present pattern and should leave, therefore, no doubt regarding the possibility of 50,000 tonnes being consumed by 1971.

It is necessary to analyse whether this quantity can be produced. The requirement of Styrene for producing 50,000 tons of SBR will be approximately 13,000 tonnes. This quantity can be produced readily from Benzene that is expected to be available in larger quantities both from the coke ovens and petro-chemical sources. The Butadiene required will be approximately 35,000 tonnes and presently a capacity of 25,000 tonnes of Butadiene from alcohol sources already exists. The remaining 10,000 tonnes can be had from some of the proposed petro-chemical complexes.

This now leaves a net deficit of 25,000 tonnes which is to be filled in by the other three synthetic polymers stated above, viz., Butyl, Polybutadiene and Polyisoprene, and Special Purpose.

BUTYL:

The outlets for Butyl are many. However, judging from the present Butyl consumption the world over, it will be safe to confine the application of Butyl mainly to tubes and to a lesser extent for cables. The demand for polymer for automobile tubes may be around 7,500 tonnes whereas for bicycle tubes, some 4,000 tonnes.

As all the bicycle tube production cannot be converted to Butyl, it is estimated that only 2,000 tonnes of Butyl will be used for this application, making a total requirement of 9,500 tonnes. In spite of the fact that the raw materials for producing Butyl rubber, viz., Isobutylene and Isoprene will be available in sufficient quantities, a Butyl plant cannot be justified in view of the limited demand. Therefore, the logical approach to meet the Butyl requirement will be to import this product. The Butyl manufacturing capacity the world over is utilised only upto 65% and if imports are considered, the requirement will be only to the tune of some 5,000 tonnes per annum, as the remaining requirement for manufacturing tubes can be met by other polymers.

POLYBUTADIENE:

Table No. 3 shows the estimated consumption of Polybutadiene by end products.

The introduction of PB as a stereo rubber had a very interesting history and based on the data now available, it appears reasonably certain that the various difficulties encountered with the use of PB have been largely overcome and that with the passage of time, the quality of PB can also be improved. It

is interesting now to study the various important features of PB before accepting the fact that this polymer can be used in our country. As shown in the table based on the present world pattern of PB consumption, some 90 to 95% of the PB produced in India will be used in tyres and the remaining quantity for non-tyre applications.

The relative merits and demerits of PB are certainly warranted at this stage and hence the following analysis:-

Amongst the outstanding advantages of PB are:— (i) High Resilience, (ii) Improved Crack Resistance, (iii) Improved Wear, (iv) Mileage at High Speed, (v) Resistance to the Effect of Oxygen, (vi) High Filler/Oil Loading.

On the question of demerits, we have the problems of :— (i) Low Tack, (ii) Low Wet Traction, (iii) Cutting and Chipping, (iv) Difficult Processing.

The details on the above are listed below from which it will be observed that by and large, the problems encountered with in the use of PB have been overcome.

The raw material required for producing PB is basically Butadiene and for a 20,000 tonnes plant, a similar quantity of Butadiene is required. Sufficient quantity of Butadiene or Butane will be available from petrochemical sources to support this production.

Critical Analysis of PB:

The consumption of PB, particularly in U.S.A., U.K., France, Canada, and Japan has been increasing rapidly. The significant increase in the PB consumption has been in U.S.A., whereby in 1965, some 1,30,000 tonnes were consumed and it is estimated that by 1970, the consumption may reach 3,70,000 tonnes. It is therefore, evident that PB has now come to stay as an important polymer all over the world and its merits have been recognised. Of great importance from the tyre point of view are the following merits which deserve special attention:

1. Improved Wear:

The most significant property of this stereo rubber has been the excellent wear resistance. Indoor as well as fleet tests have established that the tread wear for a 50:50 blend of PB/NR is some 25 to 30% less as against a 100% NR tread taken as control. A higher wear index is obtained with PB treads even in cases of severe road conditions, particularly where the wear rate is higher due to impact. The following table illustrates the point:

Tread Compounding	Abrasion Index	Average Wear Index	Miles/ Mileage
100% Natural Rubber	100	100	99
70/30 Natural Rubber/Polybutadiene	140	116	117
50/50 Natural Rubber/Polybutadiene	153	136	134
30/70 Natural Rubber/Polybutadiene	127	128	128
100% Polybutadiene	145	142	139

It was also noted that as severity increased because of high speeds, cornering, hilly terrain and more stops and starts movements, the superiority of treads containing PB was more pronounced.

2. High Resilience:

The following table gives comparative figures on resilience, dynamic modulus and heat build-up. Trials were conducted using various blends of PB and NR or SBR in truck tyres and the following data illustrates the details:

amile quantity of Baradiene is required. Sufficient	NR	SBR (1500)	PB
Rebound % Raw Polymer @ 73°F Cured Gum Stock Rebound %	73	59	77
@ 73°F @ 212°F	78 90	65 71	84 84
Dynamic Modulus PSI	57	83	103

The following data illustrates trials with various blends of NR or SBR and PB in truck tyres:-

Indoor Testing		Shoulder Temp. °F
Control (100% Natural Rubbe	r) is the water to meet to	199
50/50 Polybutadiene/Natural R	ubber Tread	190
25/75 Polybutadiene/Natural R	ubber Tread and Body	185
High Speed Testing	High Speed Failure	Cont. air @ 95 mph
Control (100% NR)	0.1 hr. @ 100 mph	200°F
50/50 Polybutadiene/SBR	owal AN BY Jo bush o	197°F
Tread	0.4 hr. @ 105 mph	197°F
50/50 Polybutadiene/\$BR Tread & 35% PB in Body.	1.9 hr. @ 100 mph	agmi diger and a

Fleet Testing	Shoulder Temp. °F.
Control (100% NR)	Par
50/50 Polybutadiene/Natural Rubber Tread	4°F cooler
75/25 Polybutadiene/Natural Rubber Tread	7°F cooler
40/60 Polybutadiene/Natural Rubber Tread	2½°F cooler

The above fleet tests were conducted with size 9.00-20 tyres fitted to the rear wheels. The tests were carried out in Texas at the speed of 55 miles per hour and at 15% over-loading. The indoor tests were on sizes 9.00-20 and 10.00-20. For high speed testing, the passenger car size 6.00-13 was chosen.

3. Improved Crack Resistance:

During the experiments performed with blends of PB and NR in truck tyres on Texas highway, it was observed that inclusion of PB in tread polymer improved crack resistance to a considerable extent.

Indoor Crown Break	Cracking
Control	Crown Break @ 2 hrs. @ 75 mph.
50/50 PB/NR Tread	No failure @ 4 hrs. @ 75 mph.
25/75 PB/NR Tread & Body	-do-
Same Tread 40/60 Body	-do-
Indoor Endurance Test: (around 2	20,000 miles run)
Control (100% Natural Rubber)	Severe
50/50 PB/NR Tread	Slight
25/75 PB/NR Tread & Body	Slight
	2.0

4. Mileage at High Speeds:

This is one of the important considerations in designing tyres and choosing polymers for car tyres, as mileage is a function of rolling resistance. The popularity gained by radial tyres in Europe and now in the U.S.A., is due to their low rolling resistance. PB when blended with SBR was found to improve these properties and hence 50/50 blend of SBR/PB was found ideal for the passenger car treads. Results cited earlier indicate that high speed performance was improved 4 times when 50 parts of PB were blended with 50 parts of SBR in tread. Gasoline consumption of 35.1 miles per gallon was registered as against a figure of 33.6 using a blend of 25 parts PB and 75 parts of oil extended SBR.

5. High Filler/Oil Compounds:

PB gives good results with high loading of black and oil. Of course, at every high levels the compounds register a fall in optimum properties. Compounds can be designed with loadings of 80 to 100 parts of blacks like HAF with corresponding oil levels of 50 to 70 parts. Such compounds are used for products like camelback. In U.S.A. such compounds find application in second and third line passenger tyres.

6. Effect of Oxygen:

The most important effect on a polymer is the chain scission due to action of oxygen present in the atmosphere. The effect is of particular importance in tropical countries where the reaction proceeds with a greater speed. SBR tends to cross link while NR and PI degrades, as a result of chain scission. The effect studied by measuring intermittent stress relaxation indicates that when the effect on PB under standard conditions of testing is plus 25 units, SBR (1500) is affected to an extent of plus 190 units and NR minus 130 units.

7. Low Temperature Performance:

PB has a much lower glass transition temperature than SBR or NR and therefore, the lively properties of rubber are maintained at lower temperatures. The addition of PB either to NR or SBR improves the low temperature performance of these polymers. Following table shows the Bell Brittle Points of various combinations of NR, PB and SBR, and PB:-

	Bell	Brittle Poi	nt °C (30'	@ 300°F)	
Natural Rubber	100	75	50	25	0
Polybutadiene	0	25	50	75	100
Inglie To	- 59	- 68	- 85	- 98	- 100
SBR	100	75	50	25	0
Polybutadiene	0	25	50	75	100
	-70	- 90	- 94	94	- 95

Demerits :

PB in its early stage of development could not make a good headway in tyre treads. The important reasons for this are as follows:-

1. Low Tack :

PB is known not to possess any tack. This made it impossible to find application in body stocks and also limited its application in tread compounds.

Due to lack of tack, the time required to build the green tyre also increased, thus affecting the productivity. Tyres containing PB in bead stocks were found to sag and thus separating from beads. Though 60/40, NR/PB compounds could be considered as border line for adequate building tack, to improve on the slowing up of the tyre building, a recipe of 75/25, NR/PB is often preferred today.

2. Low Wet Traction:

Treads containing more than 50% PB tend to make the tyres slippery on wet pavement. This wet skidding was noted to be very poor both on concrete and asphalt road surfaces even though this was later on corrected by increasing cured hardness and by giving higher carbon black loadings and also by bringing about changes in tread designs. Good results were obtained with high molecular weight oil extended polymer (Ameripol CB 441). But in spite of this the percentage of PB was limited and in many cases SBR percentage in tread was required to be higher than 50%. Though 50/50, SBR/PB tread has given good performance in tyre tests, because of the desire to have maximum wet traction resistance, most manufacturers reduced the PB content to 40/85 and in some types of tyres to as low as 25%.

3. Chipping & Chunking:

This is the loss of small flakes or particles of tread or segments of the ribs of the tread. This problem has now been minimised particularly with cobalt catalysed, high-cis-content PB and through improved compounding techniques.

4. Difficult Processing:

It is difficult to process PB without blending it with other suitable polymer.

World Pattern :

With various difficulties as mentioned above, the use of PB had been limited to certain levels only, even though it has some excellent useful properties. As a result of constant research, both in tyre techniques and polymer chemistry, quite a number of problems have now been solved. For example, chunking was one of the greatest handicaps in the use of PB in treads, but recent experiments of testing several American and Yugoslavian truck tyres under severe road conditions have indicated that chunking is no longer a problem with PB. The following table describes the performance of four types of tyres with combinations of NR and PB in the tread:-

hand was day	Final Mileage	Wear (Miles/Mil)	Cut-Cracking inches	Chipping	Tyre Conditions
100% PB	12,350	66.3	17.00	Slight	ок
30/70-PB/NR	12,317	72.2	27.50	Nil	OK
60/40-PB/NR	12,360	59.7	21.00	Slight	OK
100% NR	. 4,017	49.5	20.50	Nil	(Crown Brake Failed)

The suitability of PB as a tread material has thus been proved beyond doubts. It is interesting to note the comments of some experts on the PB usage in tyres in various countries of the world:

U.S.A. :

When the price of NR was 35 cents a pound, there was a great incentive to use PB in truck tyres to replace NR. In passenger car tyres where heat is not such a severe problem as in truck tyres, SBR had replaced all NR, except that amount necessary for processing and building. Because of the outstanding performance of PB/SBR blends for abrasion and tread cracking resistance, PB found use in passenger car tyres as a replacement for SBR in spite of the cost disadvantage in many cases, probably the largest tyre use of PB is still in passenger car tyres.

Japan:

PB is mostly used for passenger cars and light trucks. The PB demand for heavy-duty trucks, though negligible at present, is expected to grow significantly in future.

U.K. :

Concerning the present pattern on the usage of stereo-specific rubbers in the U.K., our feeling is that the use of PB by the tyre manufacturers in U.K. has developed mainly because of the manufacture of this polymer by the Rubber Consortium in England (ISRC).

France :

Consumption of PB is relatively small in truck tyres although there is now a tendency to increase.

The summary of successful trace of PB in truck and passenger car tyres by some important companies of the world is given in the following:

PB USAGE IN TRUCKS & CAR TYRE COMPONENTS (1965)

Country	Tread	Truck Side Wall	Body Body	Tread	Car Side Wall	Body
U.S.A.	50/50	50/50	25/75	50/50	50/50	40/60
	PB/NR	PB/NR	PB/NR	PB/NR	PB/NR	PB/NR
Japan	10/90	10/90	-/100	30/70	10/90	-/100
right od	PB/NR	PB/NR	-/NR	The second second	PB/SBR	-/SBR/NR
Canada	50/50	10/90	10/90			
	PB/NR	PB/NR	PB/NR			
U.K.	30/70	-/100	15/85	35/65	-/100	15/85
	PB/NR	-/SBR	PB/NR	PB/SBR		PB/NR/SBR

From the discussion of various properties of PB given above, it is safe to say that PB will be a preferred polymer for both truck and passenger car tyres. Because of the processing difficulties alone, the usage in tread is restricted to a maximum of 50%.

In regard to the non-tyre products, we believe that cables and belting can use upto 10% of PB. Another important application is in the manufacture of High-impact Polystyrene and considering the future possibilities of Polystyrene, some 500 to 700 tonnes can be used in the country.

POLYISOPRENE :

Table No. 5 shows the estimated usage of PI by end products.

The present consumption of PI the world over presents a relatively hazy picture. Despite the properties of this product being comparable to NR, the usage has been restricted. It will be, therefore, desirable to compare PI Vs. NR. The following considerations need careful study when comparing NR with PI:-

- 1. The Structural Purity.
- 2. The Distribution of Non-cis Material.
- 3. The Average Molecular Weight.
- 4. The Molecular Distribution.
- 5. The Gel Content.

6. The Presence and the Type of Non-rubber Constituents.

The infra-red spectra of PI, NR and Balata indicated that PI was different from NR in regard to its total cis content. The PI produced by two major companies, viz., Shell and Goodyear differs in chemical structure. It is, interesting not only to analyse the similarities between PI and NR, but also equally important to know the specific differences. This is very aptly described by saying—"In fact, the characteristics of synthetic and natural polyisoprenes are very similar and there is an understandable temptation to treat them as identical. However, this should be resisted, for the greater the similarities, the more important becomes the differences and these differences must be appreciated if the true merits of the synthetic cis polyisoprene are to be realised".

The following table gives the physical properties of NR and PI gum compounds containing 50 parts of HAF:-

	I	п	Ш	IV
area of PE garm above, 1817-181	squar morter	No sometime	l, salamari	
Polyisoprene *	Cattle of Land	100	Bound	100
Natural Rubber	100	10 to	100	on has
Stearic Acid	3	3	3	3
Zinc Oxide	Suber 5	5	5	5
PBNA	us roqui indio	m/_ HI do	1801 cities	Bu-neo-
MBTS	ancioble no. 1 bin	a prestaleyla	of the principle	WH W
Lecithin/TEA	bette od ner is	neor ber o	901 same	000000
DPG	-	0.5		-
Sulphur	2	2	2	2
BLE 25	-	carry - A	ar angue	1
Agerite-HP	nian booment as	one combe ?	0.2	0.2
HAF Black	- 1	-	50	50
Dutrex R	on 19 do no	ogioue mon	BONG SOFT	3
Santocure	b 36 cor <u>ing</u> o	ng sub_ing	of. opini	a good
Modulus at 300% psi	How at _ Long	MAL INS	2,330	1,975
Modulus at 500% psi	510	510	NR Ihr	27.13
Tensile Strength, psi	3,400	3,945	4,045	3,580
Elongation at break, %	820	870.	480	520
Yerzley resilience, %	90	96	78	70
Tear Strength (ASTM angle), p	si 315	385	O all D	_
Heat build up (above 378°C), of		_	24	. 27
Shore hardness	edgis# when	erage Mole	65	65
Abrasion index,				05
Akron-Croydon (15° angle)	- normalism	olecular Di	87	85
The sin Croyage (12 angle)		touten 3 b	2 400	. 65

From the above table it will be observed that PI matches most of the physical properties of NR both in the gum compound and the compound loaded with fine black. However, it is interesting to analyse why PI consumption has not shown any significant increase in the last few years:

- 1. The PI prepared even from high purity monomer does not have green strength comparable to NR. It is observed that uncured PI compounds are comparatively soft and the low green strength in some cases results in difficulties in take-off from calender and collapse of extruded tubes.
- 2. In spite of good tack, attempts to use higher than 50% of PI have not been successful since the separation from the bead occurs on standing due to the plastic flow of uncured compounds.
- 3. In regard to the processing, it is observed that when mixing in an internal mixer, the compounded rubber is discharged in a gum form unless of course short break-down cycles are used.
- 4. The gum compounds of PI for which a considerable application exists in non-tyre products, show a tendency to reverse when over cured, which possibly can be attributed to the absence of natural based proteinous material found in natural rubber.

Judging from the present trends, the non-tyre applications of PI are far more promising because -

- 1. PI has excellent initial colour and has a good stability even on exposure to ultra-violet light.
- 2. High degree of chemical purity and freedom from contamination is obtainable.
- 3. Easy processing on open mills.
- 4. Excellent mould flow properties.

PI, therefore, has found large applications in non-tyre products.

Polyisoprene Production:

The primary raw material required for producing PI is Isoprene. At the present time, three processes are available for producing Isoprene based on different starting raw materials. However, IFP and the SD processes appear to be more prevalent.

The IFP process is based on Isobutylene and Formaldehyde, whereas the SD process is based on Propylene. Both, Isobutylene and Propylene, are expected to be available in very large quantities from the Petrochemical Complexes and to this extent either of the two processes can be used depending upon the know-how.

Summary & Conclusion:

From the above discussions, it will be evident that we have confined our scope to only NR, SBR, Butyl, PB, PI and Special Purpose Oil-resistant rubbers. The Indian conditions are different from the average world pattern in two respects — (a) Predominance of truck tyres, (b) Availability of NR from indigenous sources. It is, therefore, in this context that future polymers for India have to be carefully selected, and obtain a judicious balance of all polymers whereby the entire indigenous production can be used keeping in mind the prerequisites for specific end products. In order to arrive at final decision on the subject, some broad considerations are necessary:

- (a) Assessment of the total polymer requirement
- (b) Availability of polymers based on present sources
- (c) Selection of new polymers
- (d) Cost of producing new polymers
- (e) Inter-influence of one polymer on another

(a) Assessment of the total polymer requirement :

As stated earlier, the total polymer requirement is conditioned by many unforeseen factors. However, for the purpose of this paper, a total new polymer requirement of 1,50,000/1,55,000 tonnes by 1970-71 has been estimated. It is possible that this requirement may change depending upon the various circumstances and particularly after the 4th 5-year Plan is firmly established.

(b) Availability of polymers based on present sources:

The NR production in India by the end of the 4th Plan is estimated to be 75,000 tonnes. As stated earlier, the requirement for SBR can be some 50,000 tonnes and therefore, consideration should be given to increase the capacity of the existing plant from 30,000 tonnes to 50,000 tonnes. Assuming that it is possible to achieve the estimated NR and SBR productions, the deficit will be some 25,000/30,000 tonnes. The import of Butyl, if continued as visualised in this paper, will be around 5,000 tonnes and a similar figure for special purpose rubbers is also estimated. This, therefore, leaves a net deficit of 15,000 to 20,000 tonnes which has to be filled in by a new polymer which can be either PB or PI.

(c) Selection of New Polymers:

As stated earlier, there will be a shortfall of some 20,000 tonnes which can be met either by import of NR or a local production facility, either of PB or PI. The various considerations which go to establish a new polymer have been discussed earlier and it is our belief that, considering the economics of producing PB and the salient features of this polymer, this should be the preferred polymer for future.

(d) Cost of Producing New Polymers:

Another important aspect in selecting a suitable polymer will be the cost consideration. It is of course essential that the cost of a locally produced new polymer should not be prohibitive which would inhibit the use the product. In view of the Petro-chemical Complexes planned during the 4th Plan, the raw materials for producing practically all the synthetic polymers discussed in this paper will be available. It is, of course, difficult to foresee the cost of such raw materials from petro-chemical sources as a considerable change in the cost of these complexes has already taken place after devaluation. It will be erroneous to compare cost of producing such raw materials from petro-chemical sources in India with other countries, as after all, conditions are not comparable particularly in respect of capital cost of the project.

(e) Inter-influence of one polymer on another:

In order to analyse this aspect, it is necessary to establish the details of the polymers which will be used concurrently. Depending upon whether PB or PI is produced in the country, the pattern of consumption of polymers by end products will vary. Tables No. 6 & 7 give a detailed breakup by end products where 75,000 tonnes of NR. 50,000 tonnes of SBR and 20,000/25,000 tonnes of PB and PI respectively. It is realised that depending upon the final polymers selected for production in India, the pattern of consumption of a given polymer between tyre and non-tyre products will vary. For example, PB will have a greater scope for application in tyres whereas PI will have a much greater application in non-tyre products. SBR, for instance, will have the flexibility of being used both in tyres and non-tyres. However, the present consumption pattern of SBR will change considerably depending upon the new polymer selected for production in India. Insofar as NR is concerned, the application in tyres will certainly be a very major one and it might amount to using NR on a selective basis, as after all, the quantity available is restricted.

An attempt has been made in this paper to analyse the future polymers for India keeping in mind the various considerations. It is evident that decisions have to be taken in the very near future in respect of ensuring an availability of 50,000 tonnes of SBR and an added facility for producing either PB or PI to the tune of some 20,000/25,000 tonnes. It is necessary to point out that some of the newer manufacturing plants the world over have the desired flexibility for producing PB or PI with almost identical equipments and insofar as the raw materials are concerned, we do not foresee any difficulty in obtaining the same for producing any of the polymers listed above in requisite quantity. It is realised that the consumption of PB or PI in India in the past has been very limited. Depending upon the decision taken to produce the various polymers, it is equally important to ensure that the new polymers have a ready outlet and that the consuming industry is not faced with technical difficulty, either in regard to the use of new polymers or the availability of other corresponding matching raw materials.

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TABLE 1
ESTIMATED RUBBER CONSUMPTION BY END PRODUCTS BY 1970-71
(NEW RUBBERS PLUS RECLAIM)

Product	Estimated Production Nos.	Polymer per unit kg.	Total Polymer m.t.
Tyres-Truck:	CONTROL SANCES	A SECTION AND	Mary Mary
7.00-20 Size	55,000	12	665
7.50-20 ,,	1,10,000	17	1,880
8.25-20 ,,	8,00,000	20	16,400
9.00-20 "	14,70,000	22	32,400
10.00-20 ,,	2,30,000	28	6,425
11.00-20 & above	55,000	31	1,720
Passenger Car/Jeep	10,35,000	4.5	4,600
M/Cycle & Scooter	3,90,000	1.9	740
A.D.V.	2,50,000	6.5	1,625
Tractor-Front	55,000	5.0	275
Tractor-Rear	1,00,000	28.0	2,800
Aero & off-the-road	50,000	-	1,500
Tyres for export	4,00,000	ter to the state of	7,000
Sub-total, tyres	50,00,000		78,030
Tubes for the above	50,00,000	1.5	7,500
Flaps	22,00,000	1.5	3,300
Camelback	16,000 m/t	60%	9,600
Bicycle Tyres	3,00,00,000	0.3	9,000
Bicycle Tubes	3,00,00,000	0.13	3,900
Footwear	7,00,00,000 pairs	MARKET PROPERTY	19,000
Cables	22,50,00,000 mtrs.	NO. IL MUTEU	2,500
Waterproofing	1,50,00,000 mtrs.		1,160
Ebonites	400 m/t	The second second	200
Hoses-Handbuilt	A CONTRACTOR OF THE PARTY OF TH		0.00
Hoses-lead pressed/extruded	and the Market	1 warning is	8,000
Mechanical Belting		Market Area	7,500
Mechanical Non-Belting	same of the parties	THE PERSON NAMED IN	7,500
Battery Boxes		1	3,000
Latex		The state of the s	4,500
Others	The state of the state of the state of	2165 277	4,000
TOTAL			1,68,690

SUMMARY OF TOTAL TYRE PRODUCTION IN INDIA BY 1970-71

TABLE 3
ESTIMATED SBR CONSUMPTION BY END PRODUCTS BY 1970-71
(Based on present consumption pattern)

Product	Estimated Production Nos.	Polymer per unit kg.	Total SBR m.t.	
Tyres-Truck:				
7.00-20 Size	55,000	12	480	
7.50-20 "	1,00,000	17	1,060	
8.25-20 "	8,00,000	20	3,950	
9.00-20 ,,	14,70,000	22	8,100	
10.00-20 ,,	2,30,000	28	500	
11.00-20 & above	55,000	31	140	
Passenger Car/Jeep	10,35,000	4.5	3,520	
M/Cycle & Scooter	3,90,000	1.9	570	
A.D.V.	2,50,000	6.5	1,250	
Tractor-Front	55,000	5.0	210	
Tractor-Rear	1,00,000	28.0	2,000	
Aero & off-the-road	50,000	-	-	
Tyres for export	4,00,000	- 1-3 al	2,100	
Sub-total, tyres	50,00,000		23,880	
Tubes for the above	50,00,000	1.5		
Flaps	22,00,000	1.5	660	
Camelback	16,000 m/t	60%	9,600	
Bicycle Tyres	3,00,00,000	0.3	2,700	
Bicycle Tubes	3,00,00,000	0.13	1,150	
Footwear	7,00,00,000 pairs	_	4,750	
Cables	22,00,00,000 mtrs.	一 一 列州	625	
Waterproofing	1,50,00,000 mtrs,	4 34 31 31	600	
Ebonites	400 m/t	-	100	
Hoses-Handbuilt Hoses-lead pressed/extruded	A STATE OF THE STA	_	2,000	
Mechanical Belting	14 5 1 1 1 1 1 1 1	100		
Mechanical Non-Belting		100	2,250	
Battery Boxes		123	300	
			48,615	

TABLE 4
ESTIMATED POLYBUTADIENE CONSUMPTION BY
END PRODUCTS BY 1970-71

Polyment County	foremitted		
Product	Estimated	Polymer	Total
	Production Nos.	per unit	Poly- butadiene
-	CAA 22	kg.	m.t.
POS (2 5 7 1	707.72		20.015
Tyres-Truck	000,01,1		7.50-20 ,,
7.00-20 Size	55,000	12	115
7.50-20 ,,	1,10,000	17	390
8.25-20 ,,	8,00,000	20	3,520
9.00-20 ,,	14,70,000	22	8,580
10.00-20 ,,	2,30,000	28	290
11.00-20 & above	55,000	31	90
Passenger Car/Jeep	10,35,000	4.5	1,540
M/Cycle & Scooter	3,90,000	1.9	245
A.D.V.	2,50,000	6.5	505
Tractor-Front	55,000	5.0	60
Tractor-Rear	1,00,000	28.0	250
Aero & off-the-road	50,000	_	R. M. C. LO.
Tyres for export	4,00,000	-	1,400
Sub-total, tyres	50,00,000		16,985
Tubes for the above	50,00,000	1.5	inden
Flaps	22,00,000	1.5	total Pales
Camelback	16,000 m/t	60%	4,800
Bicycle Tyres	3,00,00,000	0.3	-
Bicycle Tubes	3,00,00,000	0.13	
Footwear	7,00,00,000 pairs		1,900
Cables	22,50,00,000 mtrs.		250
Waterproofing	1,50,00,000 mtrs.		tologida
Ebonites	400 m/t	Sitt of the last o	Howa-Hanton
Hoses-Handbuilt)	mann from / Dodg	Hoses-lead pu
Hoses-lead pressed/extruded	}	Sunta	Mechanical B
Mechanical Belting		annied-nol	Mechanical N
Mechanical Non-Belting			Battery Boxes
Battery Boxes		-	750
105 86			24,685
- DOLLA	The state of the s	01	say 25,000

TABLE 5
ESTIMATED POLYISOPRENE CONSUMPTION BY END
PRODUCTS BY 1970-71

Product	Estimated Production Nos.	Polymer per unit kg.	Total Polyisoprene m.t.	
Tyres-Truck	344			
7.00-20 Size	55,000	12	100	
7.50-20 "	1,10,000	17	300	
8.25-20 ,,	8,00,000	20	2,950	
9.00-20 "	14,70,000	22	5,610	
10.00-20 "	2,30,000	28	515	
11.00-20 & above	55,000	31	140	
Passenger Car/Jeep	10,35,000 -	4.5	135	
M/Cycle & Scooter	3,90,000	1.9	75	
A.D.V.	2,50,000	6.5	310	
Tractor-Front	55,000	5.0	10	
Tractor-Rear	1,00,000	28.0	140	
Aero & off-the-road	50,000		The special of	
Tyres for export	4,00,000	-	1,400	
Sub-total, tyres	50,00,000		11,685	
Tubes for the above	50,00,000	1.5		
Flaps	22,00,000	1.5	SORT ARRESTMEN	
Camelback	16,000 m/t.	60%	Ser or mi-	
Bicycle Tyres	3,00,00,000	0.3	100	
Bicycle Tubes	3,00,00,000	0.13	Indiane	
Footwear	7,00,00,000 prs.		7,600	
Cables	22,50,00,000 mts.		1,250	
Waterproofing	1,50,00,000 mts.		. 700	
Ebonites	400 m/t.		- A360/E	
Hoses-Handbuilt Hoses-lead pressed/extruded	} an ook		seriorites	
Mechanical Belting			3,750	
Mechanical Non-Belting			Mechanical pro	
Battery Boxes			mechanical M	
Latex		Ser	Carles Descri	
Others			1,000	
TOTAL			25,985	

TABLE 6

ESTIMATED POLYMER BREAK-UP BY END PRODUCTS (NATURAL RUBBER, STYRENE BUTADIENE RUBBER AND POLYBUTADIENE) BY 1970-71

Product	Estimated Production Nos.	to He had a second	Reclaim Natural Rubber m.t.	Styrene Butadiene Rubber m.t.	Poly- butadiene m.t.	Total Polymer m.t.
Tyres-Truck						
7.00-20 Size	55,000		185	365	115	665
7.50-20 ,,	1,10,000		820	670	390	1,880
8.25-20 ,,	8,00,000		12,450	430	3,520	16,400
9.00-20 ,,	14,70,000		23,820		8,580	32,400
10.00-20 ,,	2,30,000		5,925	210	290	6,425
11.00-20 & above	55,000		1,580	50	90	1,720
Passenger Car/Jeep	10,35,000		1,080	1,980	1,540	4,600
M/Cycle & Scooter	3,90,000		170	325	245	740
A. D. V.	2,50,000		375	745	505	1,625
Tractor-Front	55,000		65	150	60	275
Tractor-Rear	1,00,000		800	1,750	250	2,800
Aero & off-the-road	50,000		1,500		-	1,500
Tyres for export	4,00,000		4,900	700	1,400	7,000
Sub-total, tyres	50,00,000		53,670	7,375	16,985	78,030
Tubes for the above	50,00,000		1,250	1,250	(5,000 But	yl) 7,500
Flaps	22,00,000		1,320	1,980	2006 211 10	3,300
Camelback	16,000	m/t	THE REAL PROPERTY.	8,600	1,000	9,600
Bicycle Tyres	3,00,00,000		3,600	5,400	- A M	9,000
Bicycle Tubes	3,00,00,000		2,750	1,150	_	3,900
Footwear	7,00,00,000		8,200	9,400	1,400	19,000
Cables	22,50,00,000	mtrs.	1,875	625	250	2,500
Waterproofing	1,50,00,000	**	560	600	-	1,160
Ebonites	400	m/t	as tipi	200	_	200
Hoses-Handbuilt	1					
Hoses-lead pressed extruded	and the same		4,000	4,000	bearing has	8,000
Mechanical Belting			6,650	500	750	7,500
Mechanical Non-belting			1;500	1,500		3,000
Battery Boxes			3,000	4,500	- widt	7,500
Latex			3,500	1,000	_	4,500
Others			3,000	1,000	-	4,000
TOTAL	SELECT SELECT		94,875	49,080	19,735	1,68,690

TABLE 7

ESTIMATED POLYMER BREAK-UP BY END PRODUCTS (NATURAL RUBBER, STYRENE BUTADIENE RUBBER AND POLYISOPRENE) BY 1970-71

Product		Estimated Production Nos.	Natural Rubber Reclaim m.t.	Styrene Butadiene Rubber m.t.	Poly- isoprene m.t.	Total Polymer m.t.
Tyres-Truck	int	790 3 700	ne neck			ner la great
7.00-20 Size		55,000	185	380	100	665
7 50 00		1,10,000	820	760	300	1,880
9 05 90		8,00,000	9,500	3,950	2,950	16,400
0.00.00		14,70,000	18,690	8,100	5,610	32,400
10.00.00		2,30,000	5,410	500	515	6,42
10.00-20 ,, 11.00-20 & above		55,000	1,440	140	140	1,72
Passenger Car/Jeep		10,35,000	965	3,500	135	4,600
M/Cycle & Scooter		3,90,000	110	555	75	740
A. D. V.		2,50,000	115	1,200	310	1,625
Tractor-Front	ART.	55,000	55	210	10	27
Tractor-Rear		1,00,000	860	1,800	140	2,80
Aero & Off-the-road	7	50,000	1,500		barring	1,50
Tyres for export		4,00,000	3,850	1,750	1,400	7,00
Sub-total, tyres	110	50,00,000	43,500	22,845	11,685	78,03
Tubes for the above	NUSA LONG	50,00,000	2,500	1,067	(5,000 B	Sutyl) 7,50
Flaps		22,00,000	2,800	500		3,30
Camelback		16,000 m/	t -	9,500	_	9,60
Bicycle Tyres		3,00,00,000	7,000	2,000	1	9,00
Bicycle Tubes		3,00,00,000	2,750	1,150	100	3,90
Footwear		7,00,00,000 prs		1,400	7,600	19,00
Cables		22,50,00,000 mts	625	625	1,250	2,50
Waterproofing		1,50,00,000 mts	s 460		700	1,16
Ebonites		400 m/	t ***	200	_	20
Hoses-Handbuilt	1					
Hoses-lead pressed extruded	}	S S S S S S S S S S S S S S S S S S S	5,000	3,000	breeze	8,00
Mechanical Belting	18th		3,750	-	3,750	7,50
Mechanical Non-beltin	ng		3,000		Modern At.	7,50
Battery Boxes	BER		2,000			3,00
Latex			3,500			4,50
Others			2,000		1,000	4,00
TOTAL	DED	D 270 M.	88,885	48,820	25,985	1.68,69