Copper Sulphate as A Yield Stimulant for Hevea brasiliensis II. Techniques for the Application of Copper Sulphate

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By using a light-weight petrol-driven drill, copper sulphate pellets and a sealing compound (Flintkote Type 7 Emulsion), it has been possible to employ a copper injection stimulation technique at a cost of 2.5 cents per tree and to avoid damage to the tree. The increase of copper in the field latex does not extend to latex concentrate, sheet rubber or cup lump crepe and is easily removed from skim crepe.

The stimulation of yield in *Hevea brasiliensis* by injecting copper sulphate into the tree has been reported by many workers: COMPAGNON AND TIXIER (1950) and TIXIER (1951) of Vietnam; BAPTIST AND DE JONGE (1955) of Malaya; and LEVANDOWSKY (1961) who studied a wide variety of clones in Liberia. The percentage increase in yield varies with the clone used, its nutritional status, the tapping intensity and the position of the tapping cut, and consequently it is not possible to make a precise comparison of reported increases in yield. However, an increase of over 20% has been reported for the clones BD 5, BD 10, Tjir 1 and PB 186 (Levandowsky) for seedlings (Baptiste and De Jonge) and for clones AVROS 49, 50 and 152 (Institut de Recherches sur le Caoutchouc au Viêt-Nam, 1959—63). Furthermore, copper sulphate has given additive stimulation when used in conjunction with 2,4-D or 2,4,5-T (MAINSTONE AND TAN, 1964). The above facts would suggest that copper sulphate could be used commercially as a yield stimulant; that this is not so, is mainly due to the hazards involved in injecting the chemical into the trees and the cost of the injections.

When a copper sulphate solution containing more than 0.1% copper comes into contact with the cambium the young bark undergoes complete necrosis, which means that a hole permitting this contact cannot be allowed in the vicinity of the tapping panel. The cost of making holes in the tree and injecting copper sulphate was also found to be time-consuming and expensive, even when no wound effects were evident.

Finally since copper has a catalytic effect on the oxidation scission of the rubber molecule, the levels of copper tolerated in rubber are set at 10 p.p.m. It is known that stimulation with 2,4-D or 2,4,5-T alone can increase the copper content in the latex, so that the use of copper sulphate as a stimulant in conjunction with 2,4-D or 2,4,5-T may raise the copper content above the accepted level, apart from the attendant possibility of accidental contamination in the field.

In Vietnam, where copper sulphate has been used as a stimulant on a semi-commercial scale for many years, some of the hazards have been overcome by protecting the bark and cambium around the hole by a polyethylene tube which is closed at the outer end with a screw plug (UNION FINANCIERE D'EXTREME ORIENT, 1961). Once the hole has been made and the polyethylene tube tapped home, 5 or 6 grams of copper sulphate crystals are poured into the hole and the tube sealed. The hole thus protected is then available for subsequent injections which are normally carried out every 6 or 12 months.

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Experimental work on the Dunlop estates over the past ten years has confirmed the finding of other workers (BAPTIST AND DE JONGE, 1955; INSTITUT DES RECHERCHES SUR LE CAOUTCHOUC AU VIET-NAM, 1959) that copper sulphate injected into the tree at half-yearly or yearly intervals gives repeated stimulation without any apparent harm to the tree or the latex. The Dunlop experiments for the period October 1954 to October 1963 are reported by MAINSTONE AND TAN (1964). These experiments show that Tjir 1 and AVROS 50 can be made to produce up to 50% more rubber per annum by using copper sulphate in conjunction with 2,4,5-T.

On the lateritic soils of Bukit Serampang Estate (Dunlop Malayan Estates Ltd) AVROS 50 responds to the application of 2,4,5-T grease below the tapping cut with a short flush yield lasting only four to six weeks. A simultaneous injection of copper sulphate and 2,4,5-T grease application gives a slightly better stimulation, and the enhanced yield is sustained for about four months. AVROS 49 and AVROS 152 respond much better to 2,4,5-T stimulation, but again copper injection increases the yield mainly by lengthening the period of enhanced yields. In view of the large acreages of the AVROS clones already planted, the use of a copper injection technique could be a commercial proposition. The following is an account of the development of a technique for copper sulphate stimulation.

TABLE 1. COSTS OF VIETNAM-TYPE TECHNIQUE, CENTS PER TREE

Labour: drilling holes etc.	3.4
Kerosene, petrol	0.7
Polythene tubes (lots of 20,000)	8.0
Copper sulphate	1.0
	13.1

TRIALS USING INJECTION TECHNIQUES

Trial 1

The first semi-commercial attempt at copper sulphate injection followed methods already used in Vietnam. The holes were made by heavy duty Wolf drills, two of which were driven by a portable Homelite motor. The holes were $\frac{11}{16}$ in. in diameter, 3 in. deep, made at an angle of about 45° from the vertical into the tree. The hole was lined with a polythene tube. Six grams of coarse crystals of copper sulphate was poured into the hole and the tube closed by a screw plug. The operation required a team of eleven people in all for the Homelite motor and two drills. The team averaged 600 trees in a working day and the cost was roughly 13 cents a tree (see *Table 1*).

Table 2 gives the results over a 3-month period recorded for this first experiment on AVROS 49, (S/2.d/3). The control trees yielded an average of 42 grams dry rubber per tree per tapping. The treatments were control (no treatment), stimulation with copper sulphate

TABLE 2. MEAN PERCENTAGE INCREASE IN YIELD OF DRY RUBBER OVER YIELD IN THE PRE-TREATMENT PERIOD

Treatment	1st Month	2nd Month	3rd Month
Control	8	8	7
2,4,5-T + Cu (Near the cut)	97	81	63
„ + Cu (base)	85	80	61
„ alone	80	59	41
Cu alone	32	32	30
	m.s.d.	*m.s.d.*	*m.s.d.*
P = 0.05	16	15	11
P = 0.01	25	23	17

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only, 2,4,5-T below the tapping cut only, 2,4,5-T plus copper injected close to the tapping cut, and 2,4,5-T plus copper injected at the base. Each treatment was replicated six times, and there were thirty-six trees in each replication. The 2,4,5-T was 1% acid equivalent in a palm oil Standard Vacuum Product 2295C grease mixture. The pre-treatment period lasted one month.

The point at which the copper sulphate is injected is clearly not critical and in all further work, injection took place at the base of the tree in order to minimise the fatigue of drilling.

Trial 2

In the second trial on AVROS 50 (S/2.d/3. 67 %) the treatments were copper stimulation for three months followed by 2,4,5-T stimulation, compared with no stimulation followed by 2,4,5-T stimulation. This system of successive stimulations was used because in any stimulation programme it would be difficult to combine the two techniques simultaneously for a large area. The results are given in *Table 3*.

Severe wintering set in during late January and this severely affected the yields in February, eliminating all signs of stimulation.

In both these experiments when the time came for a repetition of the treatments it was found that the increase in girth of the tree had created pressures on the polythene tube and in many instances had broken off the part holding the screw plug.

When two of the trees were felled and the injection area was examined, it was found that there was no apparent damage to the active cambium and that girthing was normal; but both the conducting and non-conducting wood contained a very high level of copper (100 p.p.m.) which had stained the tissue and from microscopic examination appeared in some areas to have blocked the tracheids. Cellulose and lignin are known to absorb copper ions (BLAND, 1963). It was thought that, even if the tubes had sufficed for more than one injection, the second dose of copper sulphate would have had difficulty in diffusing into the conductive xylem, and consequently would have been largely ineffective as a stimulant.*

Several compounds were tried as a means of plugging the hole and at the same time protecting the cambium; the compounds included putty, plasticene and plastic wood. The best was found to be the recommendation of Shell Chemicals Ltd—Flintkote Type 7 Emulsion. This has the consistency of wet modelling clay and sets hard in forty-eight hours. It was found to have no injurious effects on the bark and in many instances a veil of

* An experiment not reported here confirmed this premise. It therefore seemed preferable for a new hole to be made for each injection treatment.

TABLE 3. TRIAL 2. MEAN YIELDS IN POUNDS OF DRY RUBBER PER TAPPING PER TASK

Month	No stimulation (6 tasks of 250 trees)	Cu injected (6 tasks of 250 trees)
September	12.15 ± 1.75	15.2 ± 1.7
October	10.2 ± 1.35	16.2 ± 2.6
November	10.7 ± 1.75	16.5 ± 2.6
	2,4,5-T stimulation of all tasks at end of November	
December	13.6 ± 2.25	18.5 ± 2.7
January	11.8 ± 2.1	13.0 ± 1.6

cambium grew either through or behind the Flintkote plug.

Trial 3

In view of the promising results already obtained, a commercial trial was carried out on two fields of AVROS 50, one tapped 2S/2.d/2, the other 2S/2.d/3. Twelve tasks of 240 trees per treatment were treated as shown in *Table 4*.

Only 3 g of copper sulphate in the form of 1 g pellets were injected in each tree, since an experiment not reported here had indicated that there was little difference in stimulative effect between 3 and 6 g of copper sulphate. The hole was positioned near the ground either in the area of the stock, or at the junction of the two tapping panels. It was angled at 45° to the vertical and was 2½ in. deep. The hole was closed by a small plug of Flintkote and polythene tubes were omitted.

Since the Flintkote costing only 0.6 cents per tree replaced the polythene tubes (8 cents each, see *Table 1*) and simplified the whole operation, the costs were reduced to just under 6 cents per tree.

It must be borne in mind that a commercial trial is not quite the same as a controlled field experiment and the following circumstances of this particular trial should be noted:

(a) The area allocated was low yielding (about 12 lb per tapper on a double-cut tapping system).

(b) There could be no elimination of areas which, possibly because of a high water table and poor root development, failed to respond to any form of stimulation.

(c) There was no rotation of tappers.

There was an attempt to allocate tasks in order to even out the pre-treatment yields of each treatment and any bias was always in favour of the control treatment, but some changes in tappers occurred during the trial.

Under such circumstances it must be expected that the degree of stimulation would be more variable and not of the same magnitude as a field experiment on well yielding trees. Nevertheless the results are perhaps more valuable, from a practical point of view, in that they are obtained from a considerable number of trees under normal commercial tapping conditions.

Trial 4

Two further improvements to the technique were made. First the copper sulphate pellets

TABLE 4. TRIAL 3. MEAN YIELDS IN POUNDS OF DRY RUBBER PER TAPPING TASK

Treatment	Time of yield recording				
	Pre-treatment	Nov.	Dec.	Jan.	Feb.
Tapping system 2S/2.d/2					
Control (no stimulation)	14.8	13.3	13.5	12.8	10.6
3 g $CuSo_4$	11.7	15.3	16.6	14.5	13.0
Ready Rub*	12.1	16.2	16.5	14.4	11.5
Ready Rub + $CuSO_4$	10.9	16.8	19.0	17.0	12.7
Tapping system 2S/2.d/3					
Control (no stimulation)	11.9	11.6	13.5	13.5	10.5
3 g $CuSO_4$	11.2	12.7	15.5	15.0	12.0
Ready Rub	9.6	14.4	15.9	15.2	12.6
Ready Rub + $CuSO_4$	10.8	14.6	17.0	16.2	13.4

* a proprietory yield stimulant containing 2,4,5-T

manufactured by Dumex Ltd were changed to the 3 g size which reduced the cost of pellet making; and secondly the expansion of the market of light-weight portable petrol-driven motors for use as chain saws offered alternatives to the electric drill. A McCulloch MAC 35 engine was modified to take an auger of $\frac{9}{16}$ in. diameter (tapered shank) see *Figure 1*.

The whole weighed approximately the same as the electric drill and by eliminating the Homelite generator enabled the labour to be reduced to one adult driller, with two juveniles following along with pellets and Flintkote, or two adults who alternated driller and injection duties. The number of trees injected per day was raised to 1400, with the result that the cost of the injection technique was reduced to 2.5 cents per tree, see *Table 5*.

Figure 1. Operator boring hole for copper sulphate injection. The auger is driven by petrol engine.

TABLE 5. COSTS OF THE FINAL TECHNIQUE, CENTS PER TREE

Labour	1.2
Flintkote	0.5
Copper sulphate	0.5
Fuel	0.2
Depreciation	0.1
	2.5

The initial machine is now in its fourth year of service and will have drilled approximately 1,000,000 trees by the end of 1964. Depreciation has therefore been assumed as 0.1 cent. The work is strenuous but the adult driller earns about $8 a day (average of a 30-day month) in spite of a compulsory rest day every week which was enforced in order that the machine could be serviced.

Trial 5

A further trial of the improved technique was made using clone RRIM 612. On one estate, the RRIM 612, first tapped in 1960, shows a very slow recovery in yield after wintering, and the latex contains only 1.5 p.p.m. Cu in the rubber instead of the more normal 4—6 p.p.m. Five tasks of 500 trees were injected with 3 gram pellets of copper sulphate per tree and for three months showed a marked increase in yield in spite of the prevailing drought. Furthermore, the young wood was so easy to drill that the 2500 trees were completed in $6\frac{1}{2}$ hours. Clearly copper sulphate stimulation need not be confined to old rubber.

EFFECT OF STIMULATION ON COPPER CONTENT OF LATEX

Although the copper injection technique appears to be an economic possibility (2.5 cents as against 4 cents per tree for 2,4,5-T stimulation) there would be no advantage in using it unless one was absolutely sure that the copper was not contaminating the latex or producing a sub-standard latex product.

It was therefore essential to have adequate safeguards. Gross contamination of the latex

from the areas treated with copper sulphate was checked at the receiving factory by the following method:

To 10 g of latex was added 10 ml of 10% trichloroacetic acid and the serum filtered (approx. 15 ml). To 4 ml of serum was added 1 drop of phenolphthalein and this was then neutralised with 2% NH_3 (1 ml was usually enough). Then 0.5 ml EDTA/NH_4 citrate solution was added together with 0.5 ml 0.5% sodium dithiocarbamate and the volume made up to 10 ml with water.

Any colour darker than a pale yellow indicates a degree of copper contamination and an accurate determination would then be necessary. Such a latex would have to be coagulated separately and the rubber soaked in water containing EDTA, a copper chelating compound. However, on no occasion did gross contamination occur.

When yield is stimulated with either 2,4-D, 2,4,5-T or copper sulphate there is an increase in the copper content of the latex (DE JONGE, 1955). This was confirmed from bulk latex samples of each treatment in all the above experiments. The results from Trial 1 were as shown in *Table 6*.

During the first month of flush yields from the experiments the latex was processed into both sheet and concentrate and gave products which contained only slightly more copper than the control (see *Table 7*). The levels were well within the acceptable limits of 8 p.p.m.

The skim was coagulated with formic acid and tested for copper content. The results showed variations between 12 and 21 p.p.m. Cu and in general were 50% above control for all 2,4,5-T and copper stimulated treatments. When the skim was digested with pancreatic trypsin as for the Dunlop process (DUNLOP RUBBER CO. LTD, 1953) a considerable reduction in copper content of the resultant skim rubber was evident. Although the highest recorded level was 13 p.p.m. Cu, the blending of stimulated yield latex with latex from young rubber (as normally happens at the factory) produced a skim crepe within the limits for copper normally recorded for Dunlop trypsin-treated skim crepe.

Cup lump and tree scrap from the copper injected area was also regularly creped and tested for copper, but like the latex these products gave copper contents well within the limits of 8 p.p.m. Cu.

CONCLUSION

It is not claimed that copper injection will stimulate the yield of all clones and for several clones the degree of stimulation obtained will not warrant the expense of such a technique. For instance although LEVANDOWSKY (1961) reports a 20% increase in BD 5 with copper stimulation, the sparsely canopied BD 5 of Ladang Geddes Estate (Dunlop Malayan Estates Ltd) has given no marked response to stimulation. Stimulation seems to depend to a great extent on the nutritional status of the tree. This makes a pilot survey of areas suitable for copper stimulation essential. Similarly users of the copper injection technique must carry out their own control tests to safeguard their latex products from copper contamination.

With the further development of light-weight fuel engines it should be possible to improve on the number of trees that can be

TABLE 6. COPPER CONTENT (IN P.P.M.) OBTAINED FROM THE FIELD LATEX OF TRIAL 1

(Averages of three two-week periods)

Treatment	Period 1	Period 2	Period 3
Control latex	6.1	5.5	6.0
2,4,5-T + Cu (near the cut)	8.5	8.8	9.1
„ + Cu (base)	9.6	8.0	8.7
„ alone	7.4	7.7	8.6
Cu alone	7.9	7.9	8.2

TABLE 7. COPPER CONTENTS (P.P.M.) IN SHEET AND CONCENTRATE OBTAINED DURING TRIAL 1

(Averages of four one-week periods)

Treatment	Period 1	Period 2	Period 3	Period 4
	RSS 1 sheet			
Control	4.6	2.0	3.0	4.5
2,4,5-T + Cu (near the cut)	5.4	3.3	5.3	4.8
„ + Cu (base)	6.8	4.1	5.0	4.7
„ alone	4.9	4.1	4.7	4.3
Cu alone	4.7	3.1	4.0	4.5
	Latex concentrate			
Control	5.3	1.5	2.9	3.1
2,4,5-T + (near the cut)	5.9	2.4	2.5	3.6
„ + Cu (base)	6.3	2.2	3.5	4.0
„ alone	4.5	2.5	3.3	4.4
Cu alone	4.5	2.4	3.5	4.1

treated in a working day and so enable further reduction in cost of application. Some improvement on Flintkote for sealing the hole should also be possible.

By using a light-weight petrol driven drill, copper pellets and a sealing compound (Flintkote Type 7 Emulsion), it has been possible to employ the copper injection stimulation technique at an economic cost of 2.5 cents per tree. Assuming no gross contamination due to accident or deliberate mischief, the only latex product where the copper content is likely to be above the specified limits is in the skim blanket crepe (from the centrifuge process), but even here the copper can be effectively reduced by digestion of the skim with trypsin.

With adequate safeguard tests the technique presents no difficulties, and can give a good economic return in the form of increased yield.

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