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RECENT PROGRESS IN FUNGICIDE APPLICATION TECHNOLOGY
FOR RUBBER LEAF DISEASE CONTROL (1)

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ABSTRACT

To reduce the damage caused by South American Leaf Blight and other major leaf diseases, protective fungicide treatment with the appropriate equipment for speed and economy constitutes an essential part of plantation practices in Brazil. Apart from spraying with helicopters, ground methods of applying fungicides in water or oil, at medium to very low volume rates, are reported to be effective. For water-based fungicides, portable motorised mist-blowers, modified for medium-volume application, are usable on smallholdings for trees up to 6-7 years old. Tractor-mounted high to medium volume mist-blowers, with extension lances, are recommended for larger plantations where the terrains permit.

More recently, thermal fogging machines such as Pulsfog K 20/0 and Leco 120D, were introduced for use. On the latter machine, several improvements were effected, by way of better temperature and pressure control, suitable angle of lance and a switch to gas fuel. Besides mineral oil, locally available vegetable oils such as palm oil and soya bean oil were used with apparently good effect.

Field evaluation of these machines in Amazonas and Rondonia in 1984 confirmed that Hatsuta TP, Jacto AJ-400, Jacto PJ-600 (modified) and Mist-blower PL-45 sprayers, and Leco 120D and Pulsfog K20/0 fogging machines, were efficient in controlling SALB, especially at increased dosages of the fungicides and where the weather and plantation conditions allowed.

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INTRODUCTION

South American Leaf Blight (SALB) caused by *Microcyclus ulei*, the most destructive of the rubber diseases, remains today a major constraint to the rapid growth of a viable rubber industry in the New World. In the Amazon Basin, apart from SALB, target leaf spot caused by *Thanatephorus cucumeris* and more recently, black crust caused by *Catacauma huberi* (Lim *et al* 1984; Silva & Lim 1984) also assumed increasing virulence as agents causing pre-mature leaf fall. In the principal rubber growing areas in south Bahia, Phytophthora leaf wither has since the 1960s occurred in epidemic scale and could be as serious as SALB in some years. In São Paulo, the rubber planted in the valleys near the Atlantic coast is susceptible to SALB epidemic attacks.

Historically in Brazil, SALB has been directly linked with the successful development or otherwise of her rubber industry. In the early days, lack of know-how, combined with non-existence of an appropriate technology for protective fungicidal treatment against SALB, the first plantations established by Ford Motor Tyre Company in Fordlandia and Belterra in Pará, Amazonia, during the 1920-30s, were a total failure. In south Bahia and around Belém, Pará, subsequent new plantations established with locally bred, more SALB - tolerant materials in the 1950s were also severely infected by SALB. With many of them on the verge of being abandoned by the 1960s, it was only following introduction of the wide use of fungicides, effectively applied from suitable equipment that these plantations were saved from a total destruction.

Several effective fungicides were available quite early on for use against SALB but non-availability then of spray equipment that could reach the increasing height of maturing rubber tree (15-25m) or effect rapid coverage over large areas, hindered efficient control of SALB. In south Bahia, most of the plantations were on hilly to steep terrains inaccessible to wheel-drawn powerful conventional sprayers. It was for this reason that from the early 1970s, fix-winged aircrafts were initially used, followed in 1974 by helicopters which were found better suited to the rubber plantation conditions, for spraying against SALB (Bezerra *et al* 1979). Although costlier, less flexible and not yet available for use in Amazonia, aerial spraying gives the desired good effect and speedy coverage of mature rubber areas (Rogers and Peterson 1975; Rocha *et al* 1975). Thus, under the special project for SALB control in south Bahia (PROMASE), some 6,000 ha were aerially sprayed in 1980 interest in aerial spraying increased from 1972 (Alencar *et al* 1975) when some of the large plantations began to use it on a large scale (Rogers & Peterson 1975; Mainstone *et al* 1977).

A project on SALB control, PROMASE ("Special Programme of SALB Control on Rubber Tree"), was established in 1974 to counteract the serious decline in rubber production in south Bahia caused by SALB. Control of SALB having been shown earlier to be a viable technique, large-scale spraying of fungicides was instituted, under the technical supervision of CEPLAC ("Executive Commission of Plan of Cocoa Cultivation") and with financial support of SUDHEVEA, in collaboration with the Ministry of the Agriculture (Bezerra *et al* 1980). By 1983, some 6,000 ha of rubber, involving 70 properties, were covered by this spraying programme. From 1978, the programme was diversified to include implementing the other correct agronomic practices such as weed control and fertilizer applications, integrated with the fungicide treatment. The programme incorporated also the aerial spraying of insecticides in cases of an occurrence of the leaf - eating caterpillar *Erinnyis ello*, and the specific treatment against Phytophthora (Medeiros *et al* 1965) which in recent years had become a serious disease of the new shoots (Rocha 1972).

In the first year of the PROMASE, the two fix-winged aircrafts used were Ipanema 260 and Thrush Commander 600, equipped with Micronair, and one helicopter Hughes 300-C equipped with boom and nozzles. The superiority of the helicopter over the fix-winged aircraft in spraying the often stiff terrains of the rubber areas in south Bahia became clear in the first year of the operation. For this reason, only helicopter, Hughes 300-C, was used in 1975 for spraying 5,000 ha. In 1976, two Hughes 300-C and one Hughes-B were used to treat 5,500 ha. In 1977, three Hughes 500 were used and, in 1978, four helicopters of the same model (Bezerra *et al* 1980).

Although quite satisfactory, aerial spraying of rubber still presents problems which need more detailed studies. Answers are needed in relation to the following questions: fungicide formulations, droplet size and spread over the target (Pereira *et al* 1980). In terms of practicability, it is not possible for the majority of small-and middle-sized plantations to hire helicopter individually for the spraying (Rao *et al* 1980). In the Amazonia, aircraft availability and specialised agricultural aviation services are non-existent at the moment.

Commencing from 1981, however, part of the rubber area in south Bahia was treated with thermal fogging along with aerial spraying. The aim was eventually to replace aerial spraying with fogging or spraying from the ground.

Thermal Fogging and Equipment

In Brazil, the first fogging of fungicidal formulations was made with portable thermal fogging machines such as "SWING-FOG", "KEL-FOG" and "DYNA-FOG". Owing to the small size and power of these machines, a satistactory coverage of the applied chemicals, both in terms of depth and height of the canopy covered, was not obtained (Lim *et al* 1980). A suitable fogging machine should be one that throws the fungicide up to 25-30m in height and envelopes every part of the canopy. Although fogging was first employed in several Brazilian rubber plantations from 1976, it was in Malaysia that this technique for the control of rubber leaf diseases was fully experimented on (Lim & Abdul Aziz 1978). A mounted TIFA-Tart or Leco 120-D fogging machines in tow on or behind a tractor was shown to be capable of distributing the chemical to a horizontal distance of 150-200m, one machine being capable of treating up to 100 to 200 ha/day (Lim *et al* 1980, Abdul Aziz *et al* 1980). A similar calibration study is yet to be done in Brazil.

By 1976, several makes of fogging machines were available in Brazil for SALB control on rubber plantations: TIFA-Tiga, TIFA-Tart, DYNA-Fog and Leco. Although no critical evaluation for efficacy of any of these machines was made, the planters using them to apply mancozeb and thiophanate methyl (Cercobin) for SALB control were apparently satisfied with the results (Chee 1979; Wastie 1978). In fact, fogging was initially tried out once in the PROMASE programme in 1978. It was used along with aerial spraying on the clone IAN 717 which normally has an extended and irregular wintering habit. Fogging was used to treat the trees before the beginning and after the ending of the annually fixed aerial spraying programme (Bezerra *et al* 1980).

Because TIFA machines are highly priced, the thermal fogging machine currently in large scale commercial use is Leco 120-D. Some 50 of this equipment were purchased by SUDHEVEA in 1981 to distribute on free loan to selected planters in south Bahia to treat SALB, *Phytophthora* and *E. ello*. Leco 120-D had earlier been shown to be similar in performance to TIFA-Tart in controlling leaf diseases in

Malaysia (Lim *et al* 1980). Conduru Neto *et al* (1980) subsequently made the only trial to compare the performance of two thermal fogging machines: TIFA-Tart and DYNA-Fog in Para in controlling *M. ulei*. They concluded that the TIFA machine controlled the blight better than DYNA-Fog, especially when mancozeb was applied. The TIFA machine was also better in relation to coverage (150 m against 50 m of the DYNA-Fog), productivity (200 ha/day against 70 ha/day), routine maintenance and cleaning operations.

In an attempt to improve the machine performance and handling, Corrêa *et al* then (1984) effected several modifications to the imported Leco 120-D, such as changing the formulation pump and feeding system of combustion chamber. Also, for the efficient utilization of the Leco, outlets were modified so as not to give a discharge rate above 3 l/min. A formulation made up of mineral spray oil required a lower temperature for "combustion" than a formulation is considered to be favoured by some slight wind movement. The fogger's emission outlet should always be at an angle of 45^{o} from the horizontal ground level during fogging. In relation to position of tractor during forward movement, it should be at 30^{o} from its axis under windy conditions and 60^{o} under a calmer atmosphere. Following the modifications (Corrêa *et al* 1984), Leco 120-D was used satisfactorily in 1982/83 on an experimental scale on Fazenda Cultrosa in Ituberá, south Bahia.

During 1984 SALB season, as part of the large-scale critical evaluation of thermal fogging for SALB control in south Bahia and the Amazonia, a trial against SALB was corroed out in Ouro Preto, Rondonia State. The Leco 120-D was used to apply 1.60 kg mancozeb per hectare, in six aplications at weekly intervals throughout the annual refoliation season. Prior to use, the machine was calibrated in accordance with specifications made by Corrêa *et al* (1984), with mineral spray oil used as a carrier. In the experiment on 8 years old mixed clones of IAN 717 and FX 3899, with the canopy of trees almost closing, fogging mancozeb was effective against SALB, giving a satisfactory 85% canopy retention. In an adjacent block of trees with a more open canopy, fogging 535 g and 1,070 g/ha of thiophanate methyl did not give as good results as mancozeb (Gasparotto *et al* 1984).

When suitably modified and its operations properly controlled, Leco 120D gave a satisfactory control of *Phytophthora* with the new acetamide fungicide

(Curzate-M at 2.5 kg/ha) in Bahia (Pereira *et al* 1984). In Para, triforine (Saprol) when fogged even in rainy weather at a dosage of 1 l/ha, gave promising results against SALB (Stein 1984, personal communication). In south Bahia, a careful observation was also made of a commercial scale fogging on a plantation where a Leco 120D was operated without strict adherence to machine specifications (temperature and output control) and the fogger moving across fields at non-standard, excessive distances between runs. On top of this, practically all the applications suffered severe interferences by rain on the day of fogging or the day after, the frequent rain and low temperature eventually inducing a leaf fall caused predominantly by *Phytophthora*. The effect of fogging triforine and benomyl (Benlate) at increased dosages, or mancozeb at 1.6 kg/ha, of the various mixtures of these fungicedes, as a result, was not demonstrable (Pereira *et al* 1984). Similarly, in Acre, the effect of fogging of triforine was not obtained, due to a very late start in the initiation of treatment rounds (Pereira 1984, personal communication).

In a parallel fogging trial in Amazonas designed to test use of portable fogging machines under smallholding conditions, a PULS-FOG K20/0 was used to apply 190 ml triforine in mineral spray oil per hectare. The 7 years old field of mixed clones (Fx 3899, IAN 717 and IAN 873) averaged 8 m in height. During application, the fog was directed from the ground ro envelope the tree canopy individually (delivering 0.1 l/tree in 0.6 min) to ensure a maximum coverage, in view of the limited throwing capacity of the machine. A total of 4 rounds were made. When evaluated at the end of the treatment, a good retention of the new canopy (85%), with littke or no SALB infection, was obtained.

So far, the 2 fogging machines found satisfactory are both imported from overseas. Besides being costly, users encountered the serious problem of importing spares, due to the corrent tight control in Brazil on foreign exchange. Towards resolving this problem, a proto-type local fogger, similar in capacity to Leco 120D, has been manufactured by Jacto Spraying Machinery Co. in São Paulo. Another portable one, similar to Puls-Fog K-20/0, has also been assembled by Tubolit Machinery and Equipment Ltd. in Rio de Janeiro. As reported by Corrêa *et al* (1984), the Jacto-fogger appeared so far in calibration runs to be equal to Leco 120D in physical characteristics. Its critical field performance test against SALB is being planned for 1985 before recommendation for use the planters.

Spraying and Equipment

The problem of getting a water-based fungicidal spray to reach and effectively cover the huge canopy of tall rubber trees has long been recognised. An early trial in Brazil with a portable low-volume spraying machine from India (Minimicron 77) was unsuccessful (Rocha 1972). On their own, several rubber plantations then attempted utilizing a power sprayer (Platz) mounted on tractor for SALB control. No experimental results were then or subsequently available to support the use of this equipment for treating rubber trees in Brazil. Experiences in Malaysia had, however, shown that a machine of a similar type functioned with efficiency only on flat terrains, with an effective spray swathe restricted to only one or two rows of trees. As such, the machine could cover only a maximum of 30 ha/day, applying 300 to 400 l/ha of the fungicidal formulation, with a considerable wastage during the spraying (Lim *et al* 1980).

In Brazil, several types of spraying equipment are being recommended for use by planters. Following tests under plantation conditions, adaptations to some of these machines had been made, in an attempt to improve their use on rubber. The portable sprayers (eg. mist-blower Jacto PL-45) of relatively low cost may be easily adapted, becoming an indispensable tool for disease control for smallholders. Simple adaptations, such as the elongation of the lance of sprayer or of the duct of air flow, brought about a considerable gain in the height of throw of the sprayed chemical (Gasparotto *et al* 1982). In the 1984 trial comparing fogging and spraying against SALB in Ouro Preto, Rondonia, spraying mancozeb at 1.60 kg/ha and thiophanate methyl at 0.70 kg/ha achieved 80 to 93% of canopy retention with one of these portable sprayers, 500 to 700 l of fungicidal formulation being used per hectare. The mean rate of work was 1/8 to 1/6 ha/h (Gasparotto *et al* 1984). Where terrains permit and in view of the much below-average tree height in relation to age in Brazil, a tractor-mounted pneumatic sprayer or atomizer (eg. Hatsuta TP and Jacto AJ-400) offers good efficiency in disease control in spite of the narrow swathe limited do a maximum of two rows of trees. On terraced plantings, depending on the planting distances, up to 4-5 rows of trees may be effectively covered. Generally the volume of formulation applied averaged 350 - 400 l/ha, working at the rate of 1 ha/h (Gasparotto *et al* 1984). Another piece of equipment is the hydraulic sprayer (eg. Jacto PJ-600) adapted with hoses and lances. Satisfactory results were obtained in the control trial in Rondonia, although it used nearly 1,000 l of the formulation to treat 1 hectare. The resultant treated canopy of the trees was good

(91%) (Gasparotto *et al* 1984).

Fungicides and their Formulations

Over the years, several fungicides were recommended for use against SALB. This list of fungicides, for ground and aerial applications, includes thiophanate methyl (0.3 kg/ha, Cercobin), mancozeb (1.6 kg/ha, Dithane M-45), benomyl (0.2 kg/ha, Benlate), chlorotalonil (1.6 kg/ha, Bravonil), triadimephon (0.3 kg/ha, Bayleton) and triforine (1.0 l/ha, Saprol), (SISTEMA DE PRODUÇÃO... 1983). Particularly in connection with the systemic fungicides, evidence recently suggested that their dosages should be increased to secure the maximum effect and their improved formulation in oils could also give better results.

The fungicide formulations utilized in conventional sprayers being usually water-based, the use of stickers is very important, although it was known that they have little effect under conditions of continuous wetting of the leaves. In south Bahia, up to 0.05% of a suitable sticker, e.g. Aterbane is usually added in a fungicidal mixture in water, for use in aerial or ground spraying.

On the other hand, the formulations used in fogging machines are oil-based. In some cases, the stability of the fungicide/oil mixture presents a problem. Fungicides in wettable powder formulations, in particular, tend to cause a thickening effect, resulting in the clogging of tubings of the machine; flowable fungicides precipitate easily in contact with oil and fungicide emulsiable, concentrates are generally immiscible in oil, causing separation of the different phases during storage . More studies are needed here.

For fogging, the oil carrier used is either a mineral oil or one of vegetable oils. Examples of formulations based on mineral and vegetable oils are: a) mineral spray oil + diesel fuel oil, in the proportion of 5:2 for general fungicidal formulations and 7:3 for copper fungicidal formulations. Using this formulation , the temperature of "combustion" stays near 600^{o} C; b) palm oil + diesel oil, in the same previous proportions. The temperature of "combustion" is higher: 815^{o}C, and c) soybean oil + diesel oil, in the proportion of 2:3 (Corrêa *et al* 1984, Albuquerque 1983). Studies need to be made to compare the efficiency of the different fungicides based on the different oil carriers, or the proportions of the various constituent oils used as a mixture in any one fungicidal formulation.

CONCLUSION

In this brief review highlighting some of the recent developments in fungicidal application technology on rubber in Brazil, several salient points emerged. Among the major constraints, the lack of suitable technology for fungicide application to protect the cultivated rubber against the devastation by SALB, has resulted in the loss of several early plantations in Amazonia and the slow and costly rehabilitation of many subsequent ones in south Bahia and Para.

While effective fungicides were discovered early, efficient equipment that met the special needs of rubber plantations for meting out the protective chemicals rapidly and economically came into use only from 1970s, in the form of aircrafts . Although costly and lacking in the desired maximum flexibility during usage, aerial spraying, particularly with helicopters, was to become the principal means by which susceptible plantations were treated and their recovery from SALB effected under PROMASE in south Bahia.

A wide range of ground-based spraying machinery was available for use since the early days. However, their critical evaluation and appropriate adaptation for use under the demanding and often difficult plantation conditions were not undertaken with vigour or seriously. The main obstacles to their possible general application long recognised were the great height and large canopy of mature trees and the stiff to hilly terrains characterising most of the rubber plantations.

Following recent field evaluation with a few of the portable and tractor-mounted mechanised sprayers (Gasparotto *et al* 1982), some modifications or adaptations had been effected to improve their performance on rubber. Because these machines remained basically unchanged in the main mechanical moving parts and all employed water-borne fungicides with a limited spray swathe and vertical throw , their use can still only be recommended on rubber not exceeding more than 15 m or, under the continuously SALB-infested conditions in Brazil, 6-7 years old. Characteristically, the spray droplets tend to be large and also variable in sizes, hence necessitating use of medium to high volume of spray formulation to ensure an efficient coverage. With a limited coverage range, the rate of working with these tractor-mounted or portable machines is relatively slow, besides a tendency to incur considerable wastage of the chemical during spraying.

Although adapted for use on commercial plantations earliest in Brazil, thermal fogging as an alternative method for applying fungicides, insecticedes and defoliants, had not been critically evaluated until now. Apart form the only experiment in Para camparing the performance of Tifa-Tart and Dyna-Fog in applying mancozeb and thiophanate methyl against SALB (Conduru Nero *et al* 1980), none was subsequently reported. However, against the leaf caterpillar *E. ello* on mature rubber, fogging oil-based trichlorfor (Dipterex) with Leco 120D was apparently effective and is currently being used against the pest in south Bahia, along with aerial sprayong. The heat-stable defoliant thidiazuron (Dropp), when similarly fogged in mature rubber induced a satisfactory defoliation in south Bahia (Romano *et al* 1982), confirming the earlier result in Malaysia (Lim *et al* 1980).

Results of plantation-scale trials with fungicides in 1984, designed to test the effects of fogging under various conditions of climate and plantations in Rondônia, Amazonas, Acre and Para (all in Amazonia) and in south Bahia, suggested that more studies need to be made before the technique can be profitably used in Brazil. Where conditions of weather and trees during treatment are ideal, fogging has a better chance of success. The reverse has been shown to be also ture, underlying the need for extreme caution in quickly adopting, on a large scale, a new technology without the required lengthy period of research, to adapt its use to a different and highly variable local condition as exists in Brazil.

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