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Chapter 19

Plant protection equipment and chemicals

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1. INTRODUCTION

Several diseases and pests occur in rubber plantations. As compared to diseases, pests are less economically important and their occurrence is mostly sporadic. To protect the rubber plants and the associated ground cover crops from diseases and pests, appropriate equipment and chemicals are required in a plantation. For keeping off some large vertebrate pests like wild animals, electric fencing is used.

2. PLANT PROTECTION EQUIPMENT

The plant protection equipment like sprayers, dusters, fogging equipment, pressure injectors, *etc.* are used in rubber plantations for dispensing the chemicals to the targets.

2.1 Sprayers

Depending on their nature, sprayers are mainly grouped into (1) manually-operated and (2) power-operated. In the former, human labour is employed mainly for pressurizing the unit and discharging the spray, whereas in the latter, the main operations are mechanized. Power sprayers have greater operational efficiency than manual sprayers.

2.1.1 Manually-operated sprayers

Manually-operated sprayers are grouped into two *viz.* (1) compressed air sprayers and (2) hydraulic sprayers.

2.1.1.1. Compressed air sprayers

These sprayers have an air pump to pressurize the spray tank and are also referred to as pneumatic sprayers. The tank of the sprayer is never completely filled with liquid so as to provide space for air pressure development, which maintains the flow of liquid to the nozzle. Domestic sprayers (atomizers) and compression sprayers (air compressed or shoulder slung) are the two types under this category.

Domestic sprayers or atomizers are small, compact, handy units having a plastic or metal body and are useful for spraying small plants in limited areas. A plunger-type pump fitted to the unit builds adequate pressure (up to 1 kg per cm^2).

Compressed air sprayers (Plate 58. a) are also known as shoulder slung, hand compression, knapsack or backpack sprayers. These sprayers are useful for spraying one year old rubber plants in the nursery and in the field. The sprayer is carried on the back or shoulder of the operator. The essential parts of a sprayer are a spray tank (made of brass, copper, stainless steel or galvanized steel) fitted with shoulder or back strap, a filler hole with airtight cap, an air pump and a discharge line. A pressure gauge and air release valve are also provided in some sprayers. The build up of pressure in the sprayers ranges from 9.0 to 12.8 kg per cm^2.

2.1.1.2 Hydraulic sprayers

Manually-operated hydraulic sprayers depend on hydraulic pressure developed by the direct action of a pump on the spray fluid. This pressure forces the spray fluid through the nozzle which splits the fluid into droplets of various sizes and disperses them to produce a spray pattern characteristic of the nozzle used. The droplets thus formed are 300 to 400 μm in diameter (Bindra and Singh, 1971).

Syringes, hand sprayers, foot sprayers (pedal pumps) knapsack sprayers, stirrup pumps, rocker sprayers, *etc.* are included in this group. Among them, the rocker and knapsack sprayers are commonly used in rubber plantations.

2.1.1.2.1 Knapsack sprayer

The lever-operated knapsack sprayer (Plate 58. b) is one of the most widely-used small sprayers, the design of which has changed very little since its first manufacture in

the late nineteenth century (Galloway, 1891; Lodeman, 1896; Matthews, 1979). It consists of a tank which stands erect on the ground and, while in use, fits comfortably on the operator's back; hence its name, backpack. The tank is made of brass, galvanized iron, stainless steel or plastic moulded from high density polythene or polypropylene. The capacity of the tank usually varies from 10 to 15 L, but in some cases it may be as much as 30 L (WHO, 1974).

The pump assembly, which is enclosed within the tank or fixed outside, is worked continuously by operating the lever while spraying. There is thus no advance pressurizing as in hand compression knapsack sprayers. The lever-operated knapsack sprayers are grouped into those with an overarm lever or underarm lever and again those with a piston or a diaphragm pump. The lever may be fixed on either side, permitting right or left hand pumping. The spray lance is connected to a trigger or cut off valve at one end and single or multiple nozzles at the other end. Knapsack sprayer fitted with a 2 m long lance, goose-neck and nozzle is reported to be effective for spraying fungicides on the trunk and branches of two to three-year-old rubber trees (Jacob and Idicula, 1997). Knapsack sprayers used for weedicide spraying have a pressure regulator attached to the spray lance and are fitted with a flood-jet nozzle.

2.1.1.2.2Rocker sprayers

Rocker or rocking sprayers (Plate 58. c) are portable, handy and are ideal for plantations, orchards and farms. In rubber plantations, the rocker sprayers are used mainly for spraying Bordeaux mixture against abnormal leaf fall disease. Spraying on mature trees using rocker sprayer is a slow process with an effective coverage of only 0.4 ha per day as the worker has to climb each or at least every alternate tree.

The sprayer consists of a pump assembly, an operating lever, a pressure chamber, a suction hose with a strainer and a delivery hose, all fitted into a frame mounted on a wooden platform. The rocking movement of the handle works the pump and this results in building up of pressure up to 36 kg per cm^2 in the pressure chamber. As the sprayer is not fitted with a tank, the liquid is taken separately in a container and the suction hose of the unit is used for sucking the liquid into the pump assembly. The piston of the plunger is usually made of plastic. The delivery hose is of convenient length, 30 m or more for spraying in rubber and is connected by a trigger valve to a suitable lance. A bamboo lance with a length of 2 m or more is commonly used in rubber plantations. One or more nozzles may be attached to a lance. If more than one, the nozzles are set in different directions to ensure wider coverage. Rocker sprayers with two discharge lines and two plungers working in opposite direction are also used.

The double suction pumps (DSP) used earlier for spraying Bordeaux mixture in rubber plantations work on the same principle as that of rocker sprayers.

2.1.2 Power-operated sprayers

Spraying with power-operated sprayers is more rapid and economic. In some cases, the power-operated equipment may prove to be superior in performance. Hydraulic, gaseous or centrifugal energy is utilized for pressurizing the liquid for atomization.

Hydraulic energy sprayers include portable power sprayers, power take off (PTO) sprayers (tractor mounted), traction sprayers, wheel barrow sprayers, *etc.* Of these, portable high volume power sprayers have been tested for spraying Bordeaux mixture on mature rubber trees.

2.1.2.1 Portable high volume power sprayers

The essential parts of this sprayer (Plate 58. d) are a pump (usually with an air chamber), pressure regulator, pressure gauge, strainers, filters, control valves, distribution system and power source. The power source is usually a four-stroke, 2.6 kW (3.5 hp) or more petrol/kerosene engine and the pump may have either single, double or triple cylinders with a discharge of 12, 24 and 36 L per min respectively. Of the three types, the sprayer with double piston pump has been found ideal for spraying Bordeaux mixture in mature rubber plantations. The delivery lines may be single or more, each consisting of a long heavy duty hose with a spray gun attached. As the spray fluid is discharged from the spray gun to a distance of nearly 5 m, young trees can be sprayed from the ground itself. On mature trees also, almost the entire canopy can be sprayed from one or two points.

2.1.2.2 Portable low volume power sprayers

The gaseous energy (air-carrier) sprayers are high concentration, low volume and low pressure sprayers. The sprayer consists of a power source, a fan or a blower, a pesticide container and a nozzle. The atomization is effected by the injection of the spray liquid into air of high velocity, instead of depending upon the energy from the hydraulic pressure. Various names used for these sprayers are blow applicators, air-blast sprayers, mist blowers, micron sprayers, *etc.*

2.1.2.2.1 Mist blower

The knapsack mist blowers (Plate 58. e) are fitted with 35 to 70 cc two-stroke petrol engines. A direct drive connects the engine to a centrifugal fan which is usually mounted vertically on a frame and is also provided with a shock proof cushion which not only fits comfortably on the back of the operator but also eliminates the vibrations of the engine. The machine can deliver 2.7 to 9.1 m^3 of air per min at a velocity of 175 to 320 km per h at the nozzle (Clayphon, 1971). The high velocity air stream produced by the fan is diverted through a flexible discharge hose having a nozzle (shear nozzle) at its end. The spray tank has a capacity of 7 to 12 L and is mostly made of high density polyethylene. These sprayers weigh 7 to 15 kg when empty. The spray fluid is loaded in the tank leaving a little space for air cushion. A part of the air generated by the blower is diverted into the spray tank to form an air cushion over the spray liquid which ensures uniform delivery of the liquid. The liquid from the tank passes through a tube to the nozzle on the spray lance by gravity. For spraying on trees, a rotary pump and tree spray lance may be fitted additionally.

For centrifugal energy sprayers, a fan or blower, either of the axial flow or the centrifugal type, is usually used to create an air current for carrying the droplets to the targets. The low volume sprayers such as minimicron and micron sprayers used in rubber

plantations come under this category. Using these sprayers, copper oxychloride-spray oil mixture (in 1:5 proportion) is sprayed in mature rubber plantations against abnormal leaf fall disease.

2.1.2.2.2 Minimicron sprayers

These sprayers were commonly used in rubber plantations earlier, but are now being replaced by more powerful sprayers. Minimicron sprayers are fitted with JLO 73 cc, two-stroke petrol engine and a blower. The blower case is made in such a way that the discharge unit is projected up like a tube to lead the air current up. A rotary atomizer with an aerofoil is fitted in the centre of the tubular body at its top. The fungicide is taken in a separate container to which a hose for agitation and another for delivery are fitted. The other end of the delivery hose is connected to the base of the atomizer. When the engine is operated, the air current produced by the impeller makes the atomizer turn at a high speed. The pressure build up in the container forces the fungicide through the delivery hose. This fungicide is atomized into fine particles which are carried to the target by the air blast from the blower.

The Minimicron-77, a sprayer developed by M/s. Shaw Wallace & Co., Chennai, was suitable for spraying trees of 15 to 17 m height. This sprayer is not manufactured now. A modified sprayer named Microspray Junior-300 is manufactured by M/s. Skoda (India) Engineering (P) Ltd., Chennai. M/s. Power Mobiles (P) Ltd., Chennai manufacture a small micron sprayer named Microflex which can be used for spraying trees of 7 - 10 m height (Plate 59. a).

2.1.2.2.3 Micron sprayers

This power sprayer (Plate 59. b) is fitted with a four-stroke petrol/kerosene engine which develops a power up to 3.25 kW (4.5 hp) at 3000 rpm. Other essential parts include a tank for spray fluid, pump, delivery hoses, nozzle, atomizer and blower assembly. These sprayers are suitable for spraying COC-oil mixture on trees having 20 - 23 m height. Both minimicron and micron sprayers work on the same principle. The volume mean diameter (VMD) of the deposited particles ranges from 150 to 180 μm.

This sprayer can be converted into a duster for dusting sulphur against powdery mildew. In India, M/s. Skoda (India) Engineering (P) Ltd., Chennai, market a micron sprayer of the name Microspray Power-400, and M/s. American Spring and Pressing Works Pvt. Ltd. (ASPEE), Mumbai, manufacture another machine named Aspee Turblow Mist Blower. The machine is carried by four workers through each planting row at a walking speed of 2 to 3 km per h. The desired height may not be achieved if spraying is continued in a windy atmosphere. One micron sprayer can cover 4 to 5 ha of mature area in a day. The engine oil level should be checked every day before and after spraying. The machine should be run with spray oil alone taken in the tank for cleaning any copper particles adhering in the nozzles after the spraying operation (Jacob and Jayarathanam, 1993).

Tractor-mounted micron sprayers (Plate 59. c) are being developed now, in which a modified spraying unit is attached to a tractor and is carried on it. The power for operating the sprayer is provided by the power take off (PTO) of the tractor. The fungicide tank

is of higher capacity and the discharge is also more. There are some practical difficulties in using tractor-mounted sprayers. The mobility of the tractor in contour-planted rubber plantations is difficult and therefore, adequate space for the movement of tractor may be provided right at the time of planting. Since the vehicle is plied after leaving several rows, the effective coverage is also found to be a problem. Matthews (1992) observed that vehicle-mounted mistblowers in Brazil were ineffective in mature rubber due to poor coverage of spray on trees away from the applicator.

2.1.2.3 Portable ultra low volume sprayers

Attempts to reduce spray volume using nozzles with fine orifice have largely been unsuccessful due to blockages. Ultra low volume sprayers with a rotating disc spray head was developed to overcome this. In such sprayers, the droplet size is controlled by regulating the disc speed and flow rate. Although controlled droplet applicators (CDA) which depend on electrical energy or on air pressure were developed, the former is more popular.

Initially, CDA sprayers were used for drift application of oil-based formulations of insecticides. Later, it has been widely used for herbicide application. The essential parts of electrically operated CDA sprayer are a plastic rotary disc-type spray head, spray tank, a DC motor to drive the rotating disc, a long handle and a power supply which is a battery of wet or preferably dry cells.

In CDA sprayers (Plate 59. d), herbicides are used at high concentrations (about 10%) and as the total spray fluid requirement is low, it reduces the water requirement. Due to the ease in spraying, the coverage per day is much more than knapsack sprayer thus reducing labour requirement (Mani *et al.*, 1989).

2.1.2.4 Aircraft

Aircraft were first used in the 1920s in USA when lead arsenate was used to control *Catalpa sphinx* (Houser, 1922). Two basic types of aircraft have been employed for applying pesticides to agricultural crops : fixed-wing and rotary-wing (helicopter). Long runways are required for fixed-wing aircraft for their operation. Paucity of such facilities in rubber plantations in India has restricted the use of fixed-wing aircraft for spraying. Besides, these are not easily manoeuvrable on hilly terrains. Helicopters do not require large landing strips and all the operations for spraying can be managed within the estate itself. Moreover, helicopters are easily manoeuvrable in difficult terrains. These factors have resulted in the widespread use of helicopters in the rubber estate in South India for spraying oil-based COC dispersed in diluent oil for *Phytophthora* leaf fall control. Depending on the weather and type of helicopter, it is possible now to spray up to 300 ha of mature rubber in a day.

Helicopters (Plate 60. a) commonly used for spraying in rubber are Bell 47 G2 and Bell 47 G5. Other types of helicopters with more loading capacity like Hiller and Cheetah are also being employed in rubber plantations. The Bell G5 has a carrying capacity of 200 L, Hiller 400 L and Cheetah 600 L of spray fluid. The helicopters are fitted with two tanks each on either side. The COC and spray oil are usually mixed near the helipad itself (Plate 60. b) and filled in the spray tanks of helicopter either manually or using a

pump. The flow of spray fluid into the delivery system is generally by gravity or sometimes under pressure. Simplex spray systems are now incorporated into helicopters. The spray assembly utilizes the air blast of the cooling fan of helicopter engine to atomize the mixture delivered at a pressure usually of 2.8 kg per cm^2 from a centrifugal pump through various types of nozzles. Matthews (1992) suggested that rotary atomizers (micron air equipment) could provide an appropriate droplet spectrum when oil-based formulations are used. Normally, the boom length is 15 m and swath is 30 m wide. Sometimes, longer booms with more nozzles are also attached. On helicopters, the booms can be longer than the rotors whereas in fixed-wing aircraft the boom extends only for most of the wing span. Matthews (1992) suggests the need of a cross wind for effective dispersal across the swath and impaction of small droplets on leaves. Improved penetration of droplets through the crop canopy in the strong downwash of air current by the rotor of helicopter is not achieved unless the helicopter is operated at a speed less than 25 km per h. The atomization and the distribution of the spray fluid are influenced by the nozzles, the placement of the nozzles on the spray boom, physical properties of the spray fluid, spraying pressure, flying speed, flying height and the atmospheric conditions.

2.2 Dusters

Dusters are used for the application of insecticides or fungicides in dust form and may be manual or power operated. Dusters consist essentially of a hopper (usually with an agitator), a metering device to feed particles at a constant rate to the delivery unit and a blower or bellows which produces the air stream that carries the dust to the target.

2.2.1 Manually-operated dusters

The manually-operated dusters are of different kinds, *viz.* package dusters, plunger dusters, bellows dusters, rotary dusters, *etc.* Only the rotary duster is of some use in dusting sulphur in rubber nurseries against powdery mildew disease.

2.2.1.1 Rotary dusters

This is also known as crank-type duster and is extensively used in India for the application of pesticide dusts in fields and nurseries. The equipment is either shoulder mounted or belly carried, and both have equal operational efficiency. The essential parts are a hopper for holding the dust, a blower assembly and lance. An agitator is provided in the hopper. The hopper and the blower assembly are balanced to ensure maximum ease in carrying and handling. The average weight of the machine is 6.5 kg with a hopper capacity of 5 kg. The hopper is usually filled to three-fourth of its capacity. By rotating the crank handle, the gears are operated to drive the fan at a high speed. The fan draws the dust from hopper and discharges the dust through the discharging pipe (lance). The movement of the agitator prevents caking up of the dust in the hopper and ensures its free flow.

2.2.2 Power-operated dusters

Power-operated dusters (Plate 60. c) are very commonly used in rubber plantations for dusting sulphur for the control of powdery mildew disease. The micron sprayer used for spraying against leaf fall disease can be converted into a duster by attaching a duster

unit (Plate 60. d). The fungicide tank and pump are removed and a hopper is attached. The rotary agitator provided inside the hopper is driven by a reduction gear from engine shaft which ensures free flow of the dust to the feeding mechanism. The metering device may be a plate with holes or a plain orifice with provision for adjusting the discharge. The dust from the hopper is directly fed to the blower and discharged through a vertical pipe or flexible hose and is blown up to a height of about 25 m.

Power dusters like Mistral II AB, Shaw duster cum sprayer, Shaw Microspray Junior 300 duster-cum-sprayer, Skoda Microspray Power 400, Aspee tree duster and Aspee Turblow mist blower-cum-duster are being used in rubber plantations in India. One power duster can cover 10 to 12 ha in a day.

2.3 Fogging equipment

Fog generating equipment is a newer introduction in rubber plantations for plant protection work and several diseases have been reported to be controlled by the use of such machines (Chee, 1978; Radziah and Lim, 1979; Lim 1982; Edathil *et al.*, 1984a; Edathil *et al.*, 1984b). Fog is produced when aerosol droplets, having a diameter less than 15 μm, fill a volume of air to such an extent that visibility is reduced. The obscuring power of fog is greatest when droplets are 1 μm in diameter (Matthews, 1979).

In thermal fogging machines, the pesticide, usually dissolved in an oil of a suitable flash point, is injected into a hot gas and vapourized. A dense fog is formed by condensation of the oil when discharged into the atmosphere. Most fogging machines produce droplets larger than 15 μm diameter also.

Fogging equipment include large tractor-mounted types such as TART, LECO, JACTO, *etc.* and smaller shoulder-slung types like TIGGA, Pulsfog (Plate 60. e), Swing fog, Dynafog, Enfog, *etc.* In Brazil, it was observed that about 200 ha mature rubber area could effectively be covered in a day using an improved model of fog generator (Silva, 1979; Chee and Wastie, 1980). In India, fogging equipment like TIGGA and Puslfog were field tested for fogging copper fungicide and some systemic fungicides. Although disease control was satisfactory, it was not recommended due to frequent clogging of nozzle and fire hazard.

While fogging, the foliage should be dry with temperature between 18 and 29°C. Fogging in high humidity and direct sunlight should be avoided to minimize the risk of phytotoxicity. Application is often more effective if fogging is done in the evening (Matthews, 1979). Great care must be taken to avoid inhalation of fog, as it is not trapped in the nasal area and may be carried to the lungs.

2.4 Pressure injectors

Pressure injectors are used for injecting chemicals into the conducting vessels of tree crops. Some diseases in trees have been suppressed by the injection of fungicides into the trunk. The severity of Dutch elm disease caused by the fungus, *Ceratocystis ulmi* could be reduced by injecting benomyl or carbendazim into the trunk (Gibbs and Dickinson, 1975). The equipment using air pressure is useful in injecting large volumes of relatively dilute solutions into the plant system. The portable machine consists of a compressed

air tank of 12 L capacity, made usually of brass, to hold the chemical solution, connecting hoses, shut off valves, screws and couplings. For injection, the solution is taken in the tank, shut off valves closed after expelling the air, and the tank pressurized up to 5 to 6 kg per cm^2. Three holes, 5 to 8 cm deep, are bored into the trunk of the tree at about 1.5 m height at three equidistant points using an auger or drill. The lag screws are screwed in slowly to the minimum depth into the wood at which the screws can get a firm hold and then the supply hoses are coupled to the screws. The tank is held at a higher level above the injection holes and tied to the trunk. The valves are turned on and the fluid is injected into the conducting system of the tree and is taken up. A pressure injection equipment was tested in rubber for the control of various diseases (Thankamma *et al.*, 1979). The technique is slow and labour intensive. Simpler techniques involving injection with a simple syringe into a bored hole or cut surface have been successful against diseases in other crops (Jones *et al.*, 1974).

2.5 Electric fencing

Electric fencing (Plate 60. f) keeps off animals, including wild animals, with a short, sharp but safe shock. The energizer (also referred to as the unit/controller) is the heart of the system. The energizer has to be set up with an earthed terminal. The energizer's live terminals are connected to the galvanized wire (2.5 mm) and these wires pass through the insulators fixed on wooden posts or stone pillars. For protection against elephants, fence line has to be set up at a height of 1.8 m, while for wild boar, 15 cm height is enough. Thus the fence lines are to be fixed according to the size of the animals. Any animal touching the live wire gets a shock.

A.C., D.C. and solar-powered energizers (Plate 60. g) are available now. Each pulse (7 kV) of the energizer will be 'ON' for about 0.3 ms and the pulses are spaced about 1 s apart.

The cost of a five-line electric fencing system works out to be approximately Rs. 20000 per km excluding the cost of posts. RRII has successfully erected electric fences for protection of rubber plantation from wild animals using 12 V batteries/solar panels in the Regional Research Station, Nagrakatta, West Bengal and the *Hevea* Breeding Sub-station, Nettana, Karnataka (Baby, 1993).

3. CHEMICALS

Among the different methods adopted for disease control in plants, chemical control is the most important one. In rubber, most diseases are caused by fungi, while pests include insects, non-insect invertebrates, vertebrates, *etc.* The chemicals used for plant protection in rubber plantations are briefly discussed below.

3.1 Fungicides

The word fungicide has originated from two Latin words *viz.* 'fungus' and 'caedo'. The word 'caedo' means 'to kill'.

3.1.1 Classification

Fungicides are classified based on their chemical nature, mode of action or general use (Nene, 1971).

3.1.1.1 Based on chemical nature

Based on the presence of metals or the chemical composition, fungicides are grouped as sulphur, copper, mercury, quinone, heterocyclic nitrogenous, *etc.*

3.1.1.2 Based on mode of action

Fungicides which are effective only if applied prior to fungal attack are termed as protectants, whereas those which can eradicate the fungus even after infection has taken place are known as therapeutants. Systemic fungicides are those which on application are absorbed into the plant system and translocated to distant parts.

3.1.1.3 Based on general uses

Fungicides can be termed as seed protectants, soil fungicides, foliage and blossom protectants, *etc.* based on their use.

3.1.2 Formulations

Fungicides and other plant protection chemicals available commercially are formulated in various ways.

3.1.2.1 Wettable powders

Wettable powder formulations are available in powder form and are sprayed after dispersing in water. These are also known as water soluble (WS) and water-dispersible powders (WP). Thiride 75 WS, Bavistin WP, Blitox 50 WP, *etc* are examples.

3.1.2.2 Oil-dispersible formulations

Oil-dispersible powder and paste formulations of the fungicide are dispersed in agricultural spray oil for spraying. Copper oxychloride is available in these formulations for spraying against abnormal leaf fall. Oil-based formulation is expected to give better penetration, retention and subsequent persistence following rain (Matthews, 1992). Due to the lower specific gravity of the spray fluid, oil-based formulations can raise higher up to reach top canopy of tall trees when sprayed with micron sprayers.

3.1.2.3 Emulsifiable concentrates

In emulsifiable concentrates, the active chemical is dissolved in a solvent. The fungicide is diluted with water to form an emulsion for spraying. Calixin EC is such a product used in rubber.

3.1.2.4 Dusts

Dusts are applied in dry form and should be light enough to be carried by a slight breeze for considerable but controlled distances. Sulphur dust used in rubber against powdery mildew is an example.

3.1.2.5 Granules

The toxic chemical with inert materials is formed into granular particles. The active ingredient is generally low. This formulation is easy to handle and is usually applied as soil treatment. Some systemic fungicides are available in granular form.

3.1.2.6 Suspensions

A dry form of the toxic chemical when mixed with a liquid forms a suspension or slurry. Slurries usually have high content of active ingredient as in wettable powders.

Suspensions are mixed with diluents before use and thorough stirring is required for proper mixing.

3.1.3 Adjuvants

Adjuvants are inert materials added to the fungicide for improving the physical properties of spray fluid. The wetting agents, spreaders, stickers, deflocculents, *etc.* are included under this category. The surface tension makes the spray fluid to form tiny globules which may roll down the surface of leaf lamina and get lost. Most of the wetting/ spreading agents act against the surface tension thus reducing the contact angle of the spray particle on the target surface, helping its spread. The stickers help in faster adhesion. Deflocculents prevent the settling of the suspended particle in the spray fluid. Sandovit, Tenac, Teepol, *etc.* are some of the adjuvants used (at the rate of 0.5 ml per L of fungicide solution) in rubber plantations.

3.1.4 Commonly-used fungicides

The fungicides commonly used in rubber plantations belong mainly to sulphur, copper and systemic groups.

3.1.4.1 Sulphur fungicides

3.1.4.1.1 Sulphur dust

The sulphur dust formulation used against powdery mildew disease contains a minimum of 70 per cent active chemical, the rest being talc and adjuvants. The particles should be dry, fine and free flowing and 80 per cent of the particle should pass through a 325-sized mesh (40 microns). Sulphur dust is also useful in checking mite attack.

3.1.4.1.2 Wettable sulphur

The wettable sulphur fungicides are recommended at the rate of 2.5 g per L of water for spraying in immature rubber against powdery mildew disease. These are commercially available in the names Microsul, Sulfex, Thiovit, Wetsulf, *etc.*

3.1.4.1.3 Other organic sulphur fungicides

3.1.4.1.3.1 Thiram (TMTD - Tetramethylthiuram disulphide)

Thiram (0.75%) is used in rubber against pink and dry rot diseases (Edathil and Pillay, 1976; Idicula *et al.*, 1990). This is mixed in a petroleum wound dressing compound or pidivyl-china clay compound and applied on the affected portion. The chemical is marketed under the name Thiride 75 WS.

3.1.4.1.3.2 Mancozeb

Mancozeb is marketed as Indofil M45 and Dithane M45. It is found to be a substitute for organomercurial fungicides for controlling bark rot disease (Edathil *et al.*, 1988a). Mancozeb is recommended at the rate of 0.375 per cent against bark rot disease (Jacob *et al.*, 1995) and 0.2 per cent against leaf spot diseases (Joseph *et al.*, 1987; 1994).

3.1.4.2 Copper fungicides

Among the various copper preparations, copper sulphate and copper oxychloride (COC) preparations are mainly used in rubber.

3.1.4.2.1Copper sulphate preparations

Bordeaux mixture and Bordeaux paste are the two fungicides coming under this group.

3.1.4.2.1.1 Bordeaux mixture, its prepration and use

Ever since the accidental discovery of Bordeaux mixture in 1882 by Millardet, this fungicide remains as the best non-systemic fungicide with regard to its efficacy and wide range of disease control. This mixture of copper sulphate and lime was earlier known as 'Bouillie bordelaise'. Various combinations of copper sulphate and lime were tested for the control of a variety of plant diseases. For disease control in many crops, one per cent Bordeaux mixture is found to be effective (Nene, 1971).

The reaction of copper sulphate and lime is rather complex and even now the exact composition of the basic mixture is not well understood (Nene, 1971).

One per cent Bordeaux mixture is recommended for spraying against many leaf diseases in rubber. Copper sulphate, lime and water in the proportion of 1:1:100 are used for preparing one per cent Bordeaux mixture. In order to prepare 100 L of the mixture, 1 kg of copper sulphate is dissolved in 50 L water. Copper sulphate crystals can be made easily soluble by powdering. Alternatively, pre-soaking the crystals tied up in a piece jute hessian or cloth and hung in such a way that the lower portion of the bundle just touches the surface of water taken in a suitable container for 10 to 12 h also help in easy dissolution. In another vessel, 1 kg of fresh quick lime is slaked by sprinkling water (warm water ensures quicker slaking) and the volume of lime solution is made up to 50 L. The lime solution may be filtered to remove any undissolved foreign matter, hard lumps, *etc.* The copper sulphate solution is then poured into the lime solution, vigorously stirring the mixture during mixing. Both solutions can also be poured simultaneously into a third vessel with constant stirring. The containers used for preparing the mixture should not react with copper sulphate and therefore, plastic, wooden, earthen, brass or copper vessels are preferred.

Ready to use Bordeaux mixture is also available commercially which eliminates the difficulties in preparing the mixture. These preparations are sold in dry or paste forms.

Presence of free copper in the mixture renders it phytotoxic and to test for excess copper, a polished iron blade can be used. The blade is dipped for a few minutes in the mixture. Copper coloured deposits are formed on the blade if copper is in excess, which can be corrected by adding more lime. Excess lime in the mixture also reduces its fungitoxicity.

Bordeaux mixture should be sprayed while fresh. On standing, it loses its fungicidal property. Bordeaux mixture has both merits and demerits. The merits are (1) natural adhesiveness or tenacity, (2) relative cheapness, (3) efficacy in controlling wide variety of diseases and (4) safety in handling. The demerits are (1) phytotoxicity on certain crops, (2) the difficulty in preparation and (3) corrosive reaction with metallic containers.

Experiments conducted at RRII revealed that a mixture containing 0.5 per cent zinc sulphate and 0.5 per cent Bordeaux mixture is as effective as one per cent Bordeaux mixture in controlling shoot rot in young plants (Idicula *et al.*, 1992).

3.1.4.2.1.2 Bordeaux paste

Bordeaux paste is similar to Bordeaux mixture, but for the proportion of the ingredients. It is in a paste form as copper sulphate, lime and water are taken in 1:1:10 proportion. Bordeaux paste is used in rubber for controlling pink disease, patch canker, *etc.* and also as a wound dressing fungicide (Ramakrishnan and Pillay, 1962; Ramakrishnan, 1963). It is also used for repelling slugs and snails when applied around the stem of young rubber plants (Jose *et al.*, 1989).

3.1.4.2.2 Copper oxychloride preparations

Oil-dispersible copper oxychloride formulations and wettable powder formulations are effective for controlling *Phytophthora* leaf fall and shoot rot respectively (Pillay and George, 1973; Idicula *et al.*, 1992).

Oil-dispersible copper oxychloride is available in two formulations, *viz.* 56 per cent powder and 40 per cent paste. The powder or paste formulation is mixed with agricultural spray oil in 1:5 proportion for micron spraying. COC powder formulation is marketed under the trade names Chlorocop, Fycop, Parikh, Solar, *etc.*, whereas the paste formulations are Oleocop, Fycol-8, *etc.* In case of paste formulation, the required quantity of fungicide is taken in a vessel preferably a drum and oil is added while stirring. When powder formulation is used, the required quantity of oil is taken in a drum and the fungicide is added to it in small quantities while stirring the mixture vigorously. The paste formulation has become less popular due to the difficulty in packing and transport. Moreover, settling and caking up of the solid component, on storage, also make mixing difficult. The mixture should be sieved through a 60 mesh before spraying.

For micron spraying, depending on the canopy, 30 to 37 L of fungicide-oil mixture (1:5 proportion) is required to cover 1 ha of mature rubber, whereas for aerial spraying 6.2 L of paste or 8 kg of powder formulation in 37 to 40 L of spray oil is used (Pillay, 1977).

Spraying of wettable or water-dispersible powder formulation of COC is not recommended against abnormal leaf fall disease due to their lower persistence. It is effective at 0.5 per cent in checking shoot rot disease when sprayed at fortnightly intervals (Idicula *et al.*, 1992). Blitox, Blue copper,Fytolan, *etc.* are some of the available wettable formulations of COC.

3.1.4.3 Mercury fungicides

A few organic mercury fungicides such as methoxyethyl mercury chloride (MEMC) under the trade name Emisan were used in rubber against black stripe, dry rot, root disease, *etc.* However, owing to its high mammalian toxicity, its use in rubber plantations is now banned and the recommendations were withdrawn.

3.1.4.4 Systemic fungicides

A few systemic fungicides are used in rubber for disease control. Continuous use of any systemic fungicide is not advisable as the fungus may become resistant to the chemical.

3.1.4.4.1Carbendazim

This fungicide is marketed as Bavistin WP, *etc.* and is used at 0.05 per cent against powdery mildew and *Gloeosporium* leaf disease and 0.02 per cent against other leaf spot diseases.

The dust formulation of the fungicide with a low active ingredient (1.5%) is also found effective when dusted on mature trees against powdery mildew disease (Jacob *et al.*, 1996).

3.1.4.4.2Tridemorph

Tridemorph (Calixin EC) is recommended against pink and root diseases. For pink disease, the application is by incorporating in a carrier like pidivyl-china clay compound or one per cent ammoniated field latex. Soil drenching is practised for root disease control. Tridemorph in dust form (Calixin 1.5% D) is found to check powdery mildew disease when dusted on mature trees (Edathil *et al.*, 1988b).

3.1.4.4.3Propiconazole

This chemical (Tilt 25 EC) is recommended against pink (0.1%) and dry rot (0.2%) diseases. A petroleum wound dressing or pidivyl-china clay compound is used as a carrier.

3.1.4.4.4Hexaconazole

Hexaconazole (Contaf 5 EC) at 0.02 per cent has been found effective for the control of dry rot disease (Joy and Jacob, 1998).

3.1.4.4.5 Phosphorous acid

PO_3- ion is the active part of phosphorous acid preparations and is effective against *Phytophthora*. Akomin and Phosjet are the commercial preparations and are recommended against bark rot (Jacob *et al.*, 1995) and shoot rot (Idicula *et al.*, 1998).

3.1.5 Carriers for fungicides

Different carriers are used for fungicides which reduce the run off of the chemical through rain water and enable better spread. The carriers used in rubber plantations are listed below.

3.1.5.1 Agricultural spray oil

Agricultural spray oil is a petroleum product and is used for dispersing COC for spraying against abnormal leaf fall disease, using a micron sprayer or helicopter. The use of an oil will provide a better control of droplet size, by reducing evaporation between nozzle and target (Matthews, 1992). The spray oil should have the following specifications:

Unsulphonated residue (USR) value	:	above 75%
Flash point (minimum)	:	85°C
Viscosity at 100°F (37.8°C)	:	2.5 - 4.0
Specific gravity at 25°C	:	0.8 - 0.85
Pour point (°C)	:	0 - 15
Phytotoxicity to rubber plant	:	negative
Suspensibility with COC at 1:5 ratio	:	85%

3.1.5.2 Pidivyl-china clay compound

This compound is prepared by mixing pidivyl (polyvinyl acetate), china clay and water in the proportion of 1:2:4 by volume. The required quantity of fungicide is mixed thoroughly and applied to affected surfaces (Jacob and Edathil, 1986).

3.1.5.3 Ammoniated latex

One per cent ammoniated latex is used as a carrier for tridemorph for treating pink disease. Addition of 0.15 per cent carboxy methyl cellulose to latex can enhance the sticking property.

3.1.5.4 Petroleum wound dressing compounds

These compounds protect wounds by keeping off moisture on cut surfaces. The disease affected part is cleaned by removing the dead bark and wood. Fungicide solution is applied there, which is followed by the application of wound dressing compound. Incorporation of fungicides directly into the compound by thorough stirring is also practised. Waxy compounds should be molten and cooled before applying fungicides into it. Atlasol, Rubberkote, Sopkot, Treseal, Wellcoat, *etc.* are some of the available wound dressing compounds.

3.2 Pesticides

Pesticides like insecticides, molluscicides and rodenticides are used in rubber plantations to combat the attack of insect pests, slugs and snails, rodents, *etc.* They are also formulated as dust, wettable powder, emulsion concentrate and granule.

3.2.1 Commonly-used insecticides

Insecticides are chemicals used for specifically killing insects. The mode of action of insecticides varies such as stomach poison, contact poison (nerve poison) and respiratory poison. Classification based on the chemical nature and some of the relevant names are given below.

3.2.1.1 Chlorinated hydrocarbons

These are derivatives of organochlorine. This group of insecticides has residual toxicity. These are nerve poisons and hence have contact toxicity. Many of the insecticides *viz.* aldrin, benzene hexachloride (BHC), chlordane, dichlorodiphenyltrichloroethane (DDT) and heptachlor were found to have long residual toxicity and were hence banned in many countries including India. Endosulfan is the only available one at present under this category.

3.2.1.1.1 Endosulfan

This is marketed as Thiodan 35 EC and Endo 4 D. The former is used as 0.1 per cent spray for control of caterpillar and grubs infesting leguminous cover crops. The dust formulation also can be used against pests of leguminous cover crops and bark-feeding caterpillar of rubber at the dose of 10 kg per ha. The insecticide is reported to be safer than others to bees.

3.2.1.2 Organophosphates

These are contact insecticides and inhibit the cholinestrase enzyme. There are systemic and non-systemic insecticides available in this group. Generally these insecticides are highly toxic to insects but have short residual toxicity. Insecticides like parathion and phorate are highly toxic to insects as well as man.

3.2.1.2.1Methyl parathion

This insecticide is marketed as Folidol 2 D, Metacid 50 EC, Paramer 50 EC, Paratox 50 EC, *etc.* Folidol two per cent dust is applied at the rate of 10 kg per ha for control of bark-feeding caterpillar (Jayarathnam *et al.*, 1991).

3.2.1.2.2Malathion

This insecticide has contact action and it is less toxic to human beings. Malathion 0.05 per cent spray is recommended for control of scale insects and mealy bugs. It is marketed as Cythion 50 EC, Malathion 50 EC, *etc.*

3.2.1.2.3Chlorpyriphos

It is a broad spectrum contact insecticide. The trade names are Classic, Cyfos, Dursban, Hilban, Radar, Tafaban, *etc.* The product is formulated as 20 per cent EC and has to be diluted to 0.1 per cent with water. It is substituted for termiticides like aldrin against termites and has short residual toxicity.

3.2.1.2.4Dimethoate

It is a systemic insecticide marketed as Rogor 30 EC and 0.05 per cent spray is effective against sucking insects.

3.2.1.2.5Phorate

It is marketed as Thimet 10 G. This is a very toxic insecticide available in granular form. The insecticide is used for control of white grubs (cockchafer grubs) affecting the rubber seedlings nursery (Nehru and Jayarathnam, 1988). Phorate is also used as a nematicide (Singh and Prasad, 1973).

3.2.1.3 Carbamates

These are derivatives of carbamic acid. Several potent insecticides come under this group.

3.2.1.3.1Carbaryl

It is marketed as Sevin 50 WP and Sevin 5 D. Sevin five per cent dust is used for the control of bark-feeding caterpillar at the rate of 10 kg per ha (Jayarathnam *et al.*, 1991).

Carbaryl 0.05 per cent spray is applied for the control of caterpillars attacking leguminous cover crops of rubber.

3.2.1.3.2Carbofuran

It is marketed as Furadan 3 G. It is a powerful insecticide used for control of soil inhabiting caterpillars and grubs. It is having systemic action and is a known nematicide (Singh and Prasad, 1973). In rubber nurseries, carbofuran at the rate of 15 kg per ha was found effective in checking the root-knot nematode population (Thankamony *et al.*, 1997) whereas 25 kg per ha was effective against white grub (Nehru and Jayarathnam, 1988).

3.2.1.3.3Aldicarb

It is marketed as Temik 10 G. It is an extremely toxic chemical and has broad spectrum effects in the control of various pests. In rubber, it is mainly used as

molluscicide and rodenticide. Against slugs and snails, 0.01 per cent slurry with 'maida' (fine wheat flour) and water applied on the stem as a band of 5 cm is effective (Jose *et al.*, 1996). Due to its high toxicity, it is hazardous to human beings. Temik 10 G is also used as nematicide (Singh and Prasad, 1973).

3.2.1.4 Synthetic pyrethroids

These are the synthetic derivatives of pyrethrum which is the toxic content of the plant chrysanthemum. These insecticides have quick knock down effect on insects and are also less toxic to man.

3.2.1.4.1Fenvalarate

It is a synthetic pyrethroid insecticide having contact action, and is formulated in dust form as Fenval 0.4 D. It is dusted at the rate of 7 kg per ha for the control of bark-feeding caterpillar (Jayarathnam *et al.*, 1991). Spraying 0.005 per cent fenvalarate (Sumicidine 50 EC) is effective against caterpillars and mooply beetles.

3.2.1.5 Bioinsecticides

Toxicants derived from plants are used for insect control. Nicotine, pyrethrum, rotenone and neem are few examples.

3.2.1.5.1Nicotinoids

Nicotine is found in the leaves of tobacco and contributes about 97 per cent of the alkaloid. Nicotine sulphate is very stable and less volatile. It is a highly toxic nerve poison and is absorbed through the cuticle or tracheae. Alkaloids containing 40 per cent nicotine sulphate are safer and more convenient to use and the free alkaloid is liberated by the addition of soap, lime or ammonium hydroxide to the spray solution. Tobacco decoction is prepared by boiling 1 kg tobacco waste in 10 L of water for 30 min. After cooling, add 50 L of water and 120 g of soap with stirring. This spray mixture is effective for control of scale insects, mealy bugs and certain sucking pests.

3.2.1.5.2Pyrethroids

Chrysanthemum cinerariaefolium (Compositae) plants are the source of pyrethrum. The insecticidal properties of pyrethroids are attributed to five esters, *viz.* Pyrethrin I and II, Cinerins I and II and Jasmoline II. Pyrethrum powder is prepared by grinding the flowers. The powder mixed with diluent such as talc or clay is known as pyrethrum dust. It is prepared just before use as otherwise, it deteriorates rapidly. It is also used as emulsion, solutions and aerosols. Pyrethrum is unstable in light, air, moisture and in contact with alkali. The residues deteriorate very rapidly after application. Pyrethroids are powerful contact insecticides. The characteristic action of pyrethroid is the rapid paralysis or knock-down effect. These pyrethroids are effective for control of scale insects and certain caterpillar pests.

3.2.1.5.3Rotenoids

Rotenone is the insecticidal compound extracted from the roots of leguminous plants *Derris* sp. and *Lonchocarpus* sp. The insect poisoned with rotenone shows a steady decline in oxygen consumption followed by paralysis and death. It is generally harmless to mammals.

3.2.1.5.4Neem

Neem (*Azadiracta indica*) kernels possess extraordinary repellent properties which are attributed to the active principles nimbidin, meliantriol and azadiractin. Neem seed kernel powder, neem seed extract or neem cake extract are effective for control of insect pests in general (David and Kumaraswami, 1982).

3.2.2 Molluscicides

The chemicals which are specifically toxic to slugs and snails are called molluscicides. Most of the insecticides are not effective in killing the slug and snail pests of rubber. Among the insecticides, only aldicarb (Temik 10 G) is molluscicidal. However, there are several molluscicides coming under the carbamate group, *viz.* methiocarb, Tranid, Zectran *etc.* (Crowel, 1967; Judge, 1969). The most common molluscicide effective against slugs and snails is metaldehyde.

3.2.2.1 Metaldehyde

Metaldehyde is mixed with rice or wheat bran, lime and cement in the ratio 1:2:6:6 by weight. Then sufficient water is added and the bait is made into small pellets. These baits are recommended at the rate of 10 kg per ha for effective control of slugs and snails infesting young rubber plants and have to be applied broadcast. Spraying of 0.5 per cent metaldehyde suspension in water on the infested shoots is also effective (Pillay, 1968).

3.2.2.2 Bordeaux paste

Painting of Bordeaux paste around the stem to a height of 30 cm above the bud union is recommended for prevention of slugs and snails attacking young rubber plants. This gives repellence for a period of 45 days (Jose *et al.*, 1989).

3.2.2.3 Aldicarb

Aldicarb (Temik 10 G) at the rate of 0.01 per cent in 'maida' made as a slurry with water is a good bait for control of slugs and snails. The slurry, when smeared as a narrow ring on the stem of young rubber plants gives control of slugs and snails (Jose *et al.*, 1996). The chemical is also effective when applied broadcast around the plant base (Jayarathnam and Rajendran, 1979).

3.2.3 Rodenticides

These are specific chemicals used for killing rodents which include zinc phosphide, calcium arsenate, aluminium phosphide, anticoagulants such as bromodiolone, *etc.* Toxic granular insecticides such as aldicarb 10 G and carbofuran 3 G are also used in baits (Nehru and Jayarathnam, 1985).

3.2.3.1 Zinc phosphide

Zinc phosphide is a well-known rodenticide . It is a potent rat poison and contains phosphorus which gets volatilized in the presence of moisture. Generally, two to four per cent of active ingredient is used for preparation of baits. When baits are prepared, a small quantity of coconut oil is also added to prevent the volatilization of phosphine gas. The feeding materials used for the preparation of the bait are tapioca, sweet potato,

rice flour, wheat flour, fish, copra, *etc.* Two recipes for preparation of baits are given below :

Bait I

Zinc phosphide	:	2 per cent
Rice/wheat flour	:	95 per cent
Coconut oil	:	3 per cent

This is thoroughly mixed and used as such.

Bait II

Zinc phosphide	:	50 per cent
Rice/wheat flour	:	10 per cent
Vaseline/coconut oil	:	30 per cent
Sugar	:	10 per cent

This is made as paste and incorporated in a suitable food carrier (Chitty and Southern, 1954).

3.2.3.2 Bromodiolone

It is a single dose anticoagulant of blood marketed as Roban. The ready-made bait cakes can be directly placed in the burrow or the rat infested areas (RRII, 1992).

3.3 Dilution calculations

3.3.1 From concentrated chemicals

For calculating the quantity required for preparing a diluted spray solution from the available concentrated chemical, the following formula can be used.

$$V_1S_1 = V_2S_2$$

where V_1 is the volume (or weight) of concentrated chemical,
S_1 is the strength of concentrated chemical (%),
V_2 is the volume of diluted spray (ml) and
S_2 is the strength of diluted spray (%).

$$\text{So, } V_1 = \frac{V_2S_2}{S_1}$$

Example

Find out the quantity of Indofil M45 required for preparing 1 L of spray fluid of 0.2 per cent?

Indofil M45 contains 75 per cent active ingredient of mancozeb as given on the packing

Here, V_2 = 1000, S_1 = 75 and S_2 = 0.2. By substituting in the formula,

$$V_1 = \frac{1000 \times 0.2}{75} = 2.66 \text{ g}$$

So, 2.66 g of Indofil M45 is to be mixed in 1 L (1000 ml) of water.

3.3.2 From concentrated dusts

Example

Prepare a 70 per cent dust from the given 90 per cent and 40 per cent dusts.

Given : Two dusts of 90 per cent and 40 per cent concentrations.

Wanted : Dust of 70 per cent concentration.

In order to find out how much of each given dust is to be used, write the required concentration at middle and substract the smaller figure from the larger figure diagonally as given below and then read horizontally.

$$\begin{array}{lcl} 90 & & 30 \\ & 70 & \\ 40 & & 20 \end{array} \qquad \textit{i.e.} \quad \begin{array}{l} 90 - 70 = 20 \\ 70 - 40 = 30 \end{array}$$

So, mixing 30 parts of the 90 per cent dust and 20 parts of 40 per cent dust would give a 70 per cent dust.

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