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Chapter 10

Field upkeep and intercropping

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1. INTRODUCTION

Rubber is a long duration crop and timely adoption of plantation management practices is of prime importance. This will help in the reduction of immaturity period and ensure sustained yield and profitability during the yielding phase of the plantation. Several intercrops are grown in the plantation at various stages for economic sustainability of the planter.

2. FIELD UPKEEP

Rubber is grown in plantations in association with ground cover, and also intercrops, if any. The ground cover can be one or more species of cultivated legume cover crops or a mixture of naturally existing flora, or both. During the initial years of a plantation, the ground cover grows luxuriantly utilizing the abundant sunlight available in the interspaces of rubber. At this stage, it can compete with and affect the growth of young rubber plants. Therefore, in order to provide a better environment for the rubber plants, field upkeep is essential. Various cultural operations like establishment of ground cover, intercropping, weed management, vacancy filling, pruning, mulching, induction of branching and thinning should be judiciously followed to reduce the immaturity period and to obtain optimum stand of healthy trees at minimum cost. This will also help to maintain the productivity of the soil.

Under proper management, the rubber trees dominate in the plant association by the second or third year. As the canopy of the rubber tree expands, sunlight penetrating the canopy gets reduced and consequently growth of the ground cover becomes less luxuriant. From the fifth year of the plantation, the cover plants usually die off due to want of adequate sunlight (Mathew *et al.*, 1989). This process releases considerable amount of nutrients into the soil which later becomes available to the rubber plants (Punnoose *et al.*, 1994).

2.1 Cover crop establishment

Earlier, the practice of clean weeding was adopted to avoid competition of weeds with rubber (for moisture and nutrients) and for easy cultural operations. This practice was slowly replaced by the establishment of suitable leguminous cover crops (Plate 19. a). An ideal cover crop should be : (1) a perennial creeper or twiner of very fast growth; (2) capable of withstanding frequent slashing and cutting; (3) able to smother weeds by growing over them; (4) tolerant to shade and drought; (5) of high nitrogen fixing capacity; (6) tolerant to pests and diseases; (7) unpalatable to cattle and (8) one that competes least with rubber for nutrients and moisture.

Most of these qualities are seen in the leguminous plants which are widely used as cover crops for rubber. These plants have the unique capacity to fix atmospheric nitrogen in the root nodules in association with a group of bacteria belonging to the genus *Bradyrhizobium*. In India, rubber is cultivated mostly on hilly areas which receive high rainfall. Topography and torrential rains cause severe soil erosion when the land is exposed. Leguminous covers prevent the beating action of rain and effectively reduce run off of water, thus minimizing soil erosion. The roots developing from the nodes also help in preventing soil erosion by binding soil particles. They also help to increase soil moisture. Cover crops suppress weed growth, thereby reducing expenditure on weeding. Legume covers return to the soil a large amount of litter. This plant litter is subjected to biological degradation and mineralization by numerous soil microorganisms, as a result of which humus is formed. This humus raises the organic matter content of the soil, serves as a storehouse of nutrients and releases these nutrients into the soil gradually. Humus also improves soil aggregation and water holding capacity.

A leguminous cover crop enhances the growth and yield of rubber. Cost of cultivation is also low if it is properly maintained. In Malaysia, the budded rubber plants under leguminous cover are reported to attain tappable girth in 61 months whereas those with grass cover take 68 months. In the seedling area it was found that trees under legume cover took only 56 months to come into tapping while those under grass and *Mikania* weed reached tapping stage in 59 and 67 months respectively (Chin Siew Lock, 1977).

Leguminous ground covers fix a substantial quantity of atmospheric nitrogen and thus help in reducing the use of costly nitrogenous fertilizers. In an experiment carried out in India, over a period of nine years of tapping, rubber trees with natural cover needed an extra application of 270 kg of nitrogen for the yield to be comparable to that of the trees previously under legume cover. This is the amount of nitrogen fixed by the root nodule bacteria of the legume and its residual effect could be seen up to nine years of tapping (Punnoose *et al.*, 1994).

2.1.1 Leguminous covers

2.1.1.1 *Pueraria phaseoloides*

This is commonly known as 'tropical kudzu' and is raised in grasslands for fodder. It is a member of the subfamily Fabaceae under the family Leguminosae. The plant has a shallow root system. Leaves are trifoliate, broad and pubescent (Plate 19. b). Flowers are pink in colour and occur in long racemes. Pods are cylindrical and measure 6 to 8 cm in length. This is a very vigorous twiner-cum-creeper and when well established, forms a dense thick ground cover. It dominates over the common weeds during the early years when there is no overhead shade. It can easily be established by seeds (Plate 19. c) and cuttings. The seed rate is 3.0 to 4.5 kg per ha. Flowering takes place during January to February. This species produces seeds at the rate of 30 to 40 kg per ha. *P. phaseoloides* is extensively grown in the rubber plantations in India.

2.1.1.2 *Mucuna bracteata*

It is a very fast growing legume with deep roots commonly found in the north-eastern region of India (Panikkar, 1981). It is also a member of subfamily Fabaceae. It grows well under shade and drought conditions. It forms a thick cover which suppresses all weeds. The dried leaves form a mulch, 6 to 10 cm in thickness. The trifoliate leaves are very large and dark green in colour (Plate 19. d). It is less palatable to cattle. It retains comparatively high amount of moisture in the soil and adds 5 to 6 t per ha biomass in four years. It flowers during January to February. Flowers are violet in colour and arranged in racemes. In South India, fruit set is observed only in the high ranges. The seeds (Plate 19. e) are comparatively big (5 x 3 mm) and the seed rate is 200 g for planting in 420 points(1 ha). Stem cuttings can also be used for propagation, but the percentage success is low. Actively growing vines having two nodes are used for establishment by cuttings. A slanting cut is given 1 cm below the lower node and this is planted in polybags filled with 1 kg of field soil mixed with 50 g of dried cow dung. Partial shade is given using either shade net or coconut leaves.

2.1.1.3 *Calopogonium mucunoides*

This twiner-cum-creeper, introduced from Tropical America, is another member of the subfamily Fabaceae. It has profuse shallow roots and has the most rapid initial growth. The leaves are trifoliate and smaller than those of *P. phaseoloides*. The brownish pubescence on leaves and tender shoots is very pronounced. Flowers are very small and pale blue in colour. Pods measure 3 to 5 cm in length and are covered with brown pubescent hairs. It forms a complete cover over the ground within a short period, but is less hardy than the other creeping legumes. Though it is suitable for poor soils, it is neither shade nor drought tolerant. During summer months, this cover crop dries up after profuse seeding and the plants come up again mainly from the seeds during the following monsoon season. The seed rate is 3.0 to 4.5 kg per ha.

2.1.1.4 *Centrosema pubescens*

It is a shade tolerant legume from Tropical America, having both climbing and creeping habit. This is also a member of the subfamily Fabaceae. It is a slow grower in the early stage, but eventually forms an excellent cover. The roots are deeply penetrating. Leaves are dark green and narrow. Flowers are large and pink in colour. Pods are flat and long and attain a length of 10 to 12 cm. Seeds contain a toxic principle which is lethal to nodule bacteria. Seed rate is 5.5 kg per ha.

2.1.1.5 *Mimosa invisa* var. *inermis*

This is a thornless plant belonging to the subfamily Mimosoidae of family Leguminosae (Plate 19. f). It has neither climbing nor creeping habit and is unsuitable as fodder as it is poisonous to cattle. Its thick prostrate growth forms a good cover and keeps weeds in check. It is suitable for areas of marginal rainfall with long dry spells because it dries up during the dry season and regenerates with the onset of monsoon. As this cover crop crosses with thorny species and produces thorny plants in due course, it is not very popular. When the old growth dries up in summer, it is considered to be a fire risk.

2.1.1.6 *Calopogonium caeruleum*

This is a native of Tropical America and is widely cultivated in citrus orchards in Philippines and rubber plantations in Malaysia. The trifoliate leaves are leathery, dark green in colour and without hairs. Flowers are small and blue in colour. Pods are flat, measuring 5 to 7 cm in length. It is reported to withstand shade and drought. Fruit set is not observed in South India and therefore propagation through cutting has to be resorted to. It fixes two to three times more nitrogen than *P. phaseoloides* (Chin Siew Lock, 1977).

2.1.1.7 Mixed cover

None of the cover crops commonly used has all attributes of an ideal cover crop. Hence it is desirable to establish a mixed cover. A mixture of *C. mucunoides*, *P. phaseoloides* and *C. pubescens* seeds in the ratio of 5 : 1 : 4 is used for sowing in Malaysia. In this mixed cover, *C. mucunoides* grows very rapidly and covers the ground quickly during the first year itself. Then *P. phaseoloides* and *C. pubescens* start dominating. The dense and vigorous growth of *P. phaseoloides* suppresses weeds. However, *P. phaseoloides* starts fading out when the canopy closes. Subsequently, *C. pubescens* continues to grow under the shade while the former two cover crops fail to thrive. Thus, all the benefits of an ideal cover crop, starting from the first year of planting, can be obtained if a mixed cover crop is established in rubber plantations. In India, a few estates follow the practice of establishing *Pueraria* and *Mucuna* simultaneously.

2.1.2 Planting

Cover crops are generally established from seeds. However, *P. phaseoloides, M. bracteata* and *C. caeruleum* can also be propagated by stem cuttings.

2.1.2.1 Preparation of beds

Seeds or cuttings of cover crops are planted on raised beds prepared in clean-weeded areas in between rubber rows. About 420 beds of 1.2 x 1.0 m per ha are prepared immediately after the pre-monsoon rains. For better results, it is preferable to raise them immediately after clearing the area for planting, and in the case of replanting, one year ahead of planting, if possible, or soon after felling the old stand of rubber. This helps in reducing the cost of weeding as the area is covered right from the beginning of rubber growth. Another method, called double compressed bed system, is also followed for *P. phaseoloides*. In this system, two strips of 60 cm width in the inter-rows along the contour are prepared and the seeds are sown (Chee Yan Kuan *et al.*, 1983). In the case of *M. bracteata*, 420 pits of 30 x 30 x 30 cm are prepared for sowing the seeds or planting the rooted cuttings.

2.1.2.2 Pre-sowing treatment of seeds

Seeds of cover crops have a very hard seed-coat which delays or inhibits germination. These, therefore, require pre-sowing treatment to ensure uniformity and higher percentage of germination. This also helps in reducing the toxic compounds present in the seed-coat, which inhibit the nodule forming bacteria. As pre-sowing treatments, any one of the following three may be followed :

2.1.2.2.1 Acid treatment

In this method, seeds are treated with concentrated sulphuric acid for a specified period. It is 10 min for *P. phaseoloides* seeds, 30 min for *M. bracteata* and 20 to 30 min for *C. mucunoides* seeds. The seeds are put in a glass or any other acid resistant container and stirred after adding sufficient concentrated sulphuric acid. The seeds thus treated should be placed in a large container having cold water and washed well to remove the acid completely. Acid treatment may adversely affect *C. pubescens* seeds. Acid treated, seeds can be stored under dry conditions for about 10 days.

2.1.2.2.2 Hot water treatment

This is a popular and simple treatment for cover crop seeds of *P. phaseoloides* and *C. mucunoides*. Percentage of germination may not be as high as in acid treatment. Hot water treatment is carried out by pouring water at 60 to 80°C over the seeds in a container till all the seeds are submerged and keeping them as such for 4 to 6 h before sowing.

2.1.2.2.3 Abrasion treatment

It is a very good pre-treatment method for cover crop seeds. The aim is to abrade, scratch or scarify the seed-coats in order to assist moisture absorption from the soil. This is achieved by rotating the seeds in a drum lined with sand paper and operated by an electric motor at 70 rpm for 24 h. If the quantity of the seeds to be treated is less, abrasion treatment is carried out by mixing the seeds with sand (one to two times the quantity of seeds) and then pounding them in a mortar. *M. bracteata* seeds can be held by fingers and scratched over a sand paper or rough cement floor. It is preferable to scratch the seeds on the sides opposite to the seed attachment scar. After the abrasion treatment, seeds may be soaked overnight in water before sowing.

2.1.2.3 Sowing of seeds

The pre-treated and soaked cover crop seeds are mixed with an equal quantity of rock phosphate and sown in beds after the pre-monsoon showers. In places where drought is a limiting factor in the establishment of cover crops, the germinated seeds can be sown during January or February in coconut husk filled with soil and the plants allowed to grow under shade till the pre-monsoon showers are received. These are then planted in patches or strips prepared in the field. The coconut husks containing cover crop seedlings are buried exposing only the seedlings.

2.1.2.4 Planting of cuttings

This method of propagation is practised for *P. phaseoliodes*, *M. bracteata* and *C. caeruleum*. Fresh vines, 60 to 100 cm in length, are collected during June to July when frequent rains are available and planted in beds. The success of establishment is more when rooted cuttings are used for planting.

2.1.3 Aftercare

In the initial stages, weeding may be carried out in the cover crop patches. Cattle grazing and removal of the vines for fodder should also be prevented for ensuring proper growth and ground spread. In the case of severe crop damage by insects, appropriate plant protection measures are to be carried out. Manuring of cover crop is also carried out. Twining of cover crop vines on young rubber should be prevented and the plant bases also be kept free of cover crop growth for three to four years to prevent competition with young rubber.

2.1.4 Biological fixation of atmospheric nitrogen

Nitrogen is a vital element in the nutrition of plants and is continuously depleted from the soil through crop uptake, leaching, volatilization, denitrification and run off. Some bacteria play an important role in making up this loss by the process of biological fixation of atmospheric nitrogen and maintain the nitrogen balance of the soil. Biological nitrogen fixation is brought about non-symbiotically by free-living bacteria or blue green algae. Some bacteria (*e.g. Rhizobium*), actinomycetes and algae also fix nitrogen in symbiotic association with plants. The legume-*Rhizobium* symbiosis is the major source of biological nitrogen fixation in nature. This is effectively utilized for rubber cultivation by growing leguminous cover crops in association with rubber during the early years. Bacteria belonging to the genus *Bradyrhizobium* form nodules in the roots of leguminous cover crops. They infect root hairs of the legumes and stimulate the root tissues to produce characteristic nodules inside which they proliferate. The nodules of the common cover crops grown at present are spherical in shape, varying in size from a pinhead to a pepper berry. The shape of the nodule is determined by the species of the leguminous plant. The nodules of *Calopogonium* sp. have white bands while the nodules of *Centrosema* sp. have raised pinhead-like structures. The nodules of *P. phaseoloides* are often smooth. *M. bracteata* forms branched coralloid nodules. Nodules can be classified into effective, moderately effective and ineffective on the basis of their nitrogen fixing capacity which can be distinguished from their position and colour. The effective nodules are generally pink in colour owing to the presence of leghaemoglobin, and the ineffective ones are pale in colour. Generally effective nodules are present in the collar region.

2.1.4.1 *Rhizobium - Bradyrhizobium*

These are symbiotic, aerobic and gram negative, nitrogen fixing bacteria. They are rod-shaped, measuring 0.5 to 0.9 µ wide, 1.2 to 3.0 µ long, motile when young and commonly changing to bacteroid form. The genus *Rhizobium* is classified into six different groups based on host range and physiological activities. The *Rhizobium* forming nodules in the roots of cover crops is classified under the genus *Bradyrhizobium,* and is not named up to species level owing to its promiscuous nature with respect to nodulation in different groups of leguminous plants. *Bradyrhizobium* spp. are slow growing and non-acid producing bacteria.

2.1.4.1.1 Nodulation and nitrogen fixation

When the leguminous cover crops start establishing, they secrete an organic compound which stimulates the multiplication of *Bradyrhizobium*. The chemical nature of the secretion is still unknown, but the substance may be growth factor or the energy substrate necessary for initiation of infection. Infection occurs through amyloid spots at the tips of the young root hairs. As soon as bacteria enter the root hair, an infection thread is formed which grows towards the base and nodule formation results (Plate 19. g). As the plants mature, nodules become brown, bacteroids disappear and the nitrogen is released to the plant.

Atmospheric nitrogen is fixed in the form of amino acids, proteins and other intermediary products inside the nodule tissues. When the plant starts flowering, all the nitrogen fixed is translocated to the shoot and only a small quantity goes to the soil as exudate. Some species of *Rhizobium* are antagonistic to the pathogenic fungi that infect leguminous plants.

2.1.4.1.2 Bacterization of cover crop seeds

Bacterization is the process of inoculating either seeds or soil with bacteria. In legumes, seed inoculation with *Bradyrhizobium* spp. is widely practised for effective nodulation and maximum nitrogen fixation. Successful legume seed inoculation can be beneficial in soils in which the specific *Bradyrhizobium* is absent or sparse or where local *Bradyrhizobium* is ineffective or submaximal in their nitrogen fixing capacity. Inoculation of specific strains of *Bradyrhizobium* makes the host quickly independent of soil nitrogen and results in increased yield and better quality of herbage. Even if the introduced *Bradyrhizobium* is displaced by an emerging naturalized population, the use of inoculum is likely to favour early nodulation and nitrogen fixation. The *Bradyrhizobium* population in acid soils is comparatively low and ineffective. As the rubber growing soils are acidic in nature, seed inoculation results in better nodulation and faster growth of cover crops (Kothandaraman *et al.*, 1993). Inoculation of cover crop seeds can effectively be carried out by pelletization with calcium carbonate or rock phosphate using gum-arabic as adhesive. Calcium carbonate (chalk powder) is preferred because it enhances the pH of the soil around the seed temporarily and favours early nodulation by the inoculated bacteria. For bacterization of 3 to 4 kg of *P. phaseoloides* seeds with *Bradyrhizobium*, the pre-treated seeds are mixed with a paste made out of 125 g of wheat flour (maida) followed by 200 g of *Bradyrhizobium* biofertilizer. Then 1.5 to 2.0 kg of either rock phosphate or chalk powder is added. The mixture is stirred and finally pelletized (Kothandaraman *et al.*, 1993).

2.1.4.1.3 Non-symbiotic nitrogen fixation

Microbes which can fix atmospheric nitrogen independently in soil are known as non-symbionts and the process as non-symbiotic nitrogen fixation. Both aerobic and anaerobic microorganisms fix nitrogen depending upon the soil condition and crop cultivation practices. In rubber fields, only the aerobic bacteria can carry out their functions and influence the growth of rubber. *Azotobacter* and *Beijerinckia* are the two major genera of aerobic nitrogen fixing bacteria. Of these, *Beijerinckia* spp. are acid tolerant and can survive in acid soils of rubber plantations. However, there are a few species of *Azotobacter* which are reported to be tolerant to acidic conditions. *Azospirillum* is another genus capable of fixing nitrogen under varying soil conditions. They are present in some of the rubber soils of India. When inoculated, they survive for a long time and congregate in the rhizosphere of rubber. Besides fixing atmospheric nitrogen, these groups of bacteria produce auxins, vitamins and enzymes which influence the growth of higher plants. Their antagonism to major plant pathogens reduces the population of pathogenic microorganisms.

2.1.4.2 Mycorrhizae

Mycorrhizae are symbiotic associations between fungi and plant roots, a common feature in most plants. The two main groups of mycorrhizae are ectomycorrhizae and endomycorrhizae. Vesicular arbuscular mycorrhizae now known as arbuscular mycorrhizae (AM), are the common endomycorrhizae associated with cultivated plants. Different genera of AM such as *Glomus, Gigaspora, Acaulospora* and *Sclerocystis* are found in rubber growing soils (Joseph, 1997). AM association is unique in leguminous plants and the occurrence of AM in different cover crops is well established (Joseph *et al.*, 1988).

The most apparent and important benefit of AM association with leguminous plants is the absorption of phosphate from soil. Phosphorus is an important macronutrient for leguminous plants due to its role in energy transfer during the process of nitrogen fixation. It is also essential for effective nodulation. AM also augments zinc and copper uptake by plants. Increased photosynthesis and amino acid levels in plants were also reported due to AM infection (Gianinazzi-Pearson and Gianinazzi 1983). Even the biochemical constituents of plants colonized by AM fungi are reported to have changed and such a phenomenon favours root nodulation by *Bradyrhizobium* spp. (Linderman, 1992). AM fungi vary vastly in their symbiotic effectiveness and show host preference (Joseph, 1997).

2.2 Weed management

Rubber plantations in both immature and mature phases are infested by various weed species. On commencement of the pre-planting operations, whether it be new planting or replanting, natural weed species start growing and soon dominate. In the traditional rubber growing regions in India, the dominant weed species encountered are *Borreria* sp., *Chromolaena odorata, Mikania micrantha, Mimosa* sp., *Pennisetum* sp., *Ageratum conyzoides, Cyanadon dactylon, Panicum repense, Axonopus* sp. and *Digitaria* sp. to name a few. In North East India, *Imperata cylindrica* and *Mikania micrantha* grow luxuriantly and can strangle newly established plantations. Weeds compete with rubber at all stages of growth for nutrients and soil moisture. In the early immature plantations, they compete for sunlight also. Excessive weed growth may create difficulties in proper supervision. They may also serve as alternate hosts for insects and pathogens and during summer months the dry weeds can become serious fire hazards. Management of these weeds, therefore, assumes importance in the proper upkeep of plantations.

Maintenance of a luxuriant ground cover species in the early phase of a plantation can minimize the weed infestation to a great extent. However, during the first year till the time the cover crops are fully established, weeds which sprout around the cover crop patches need to be controlled to help in early establishment of the cover. Once the ground cover has been established, weed management efforts need be concentrated only on the planting strips during the immature phase of the plantation. A circle of about 2 m diameter around individual plants in the case of square and rectangular planting, and planting lines to a width of about 2 m in the case of contour planting (Plate 20. a), may be maintained free of weeds and cover crops.

2.2.1 Methods of weed control

Weed control can be achieved by adopting either manual methods alone or by the use of chemicals known as herbicides. However, an integrated approach which is a combination of these two methods in an appropriate manner is more economical and environmentally more sustainable.

2.2.1.1 Manual

Manual method of weed management has been the traditional option since time immemorial. Slash weeding in the planting strips and mulching the plant base with the dry weeds help in the early establishment of young rubber. Scraping the plant basin using a spade is also resorted to. As clean weeding leads to soil erosion, the plant base has to necessarily be mulched. Bushy plants growing in the inter-rows are controlled by four to six rounds of hand weeding for the first two years. During this period, the leguminous cover crop will establish and keep the weeds in check. In the third and fourth years, at least four rounds of slash weeding in the planting strips are required for maintaining good growth of rubber. From the fifth year, in a well-maintained plantation, rubber trees dominate in the plant association and their canopy closes, resulting in less weeds. A schedule of weed management operations required where rubber is grown in association with leguminous ground cover is given in Table 1.

Table 1. Schedule of manual weed management operations

Year of planting	Operations recommended	Rounds per year
1	Overall manual weeding in inter-rows and planting strips	4
2	Manual weeding in planting strips	5
	Overall weeding including uprooting of noxious weeds from inter-rows - optional	4
3	Manual weeding in planting strips	4
	Overall weeding in the inter-rows - optional	2
4	Manual weeding in planting strips	4
	Overall weeding in the inter-rows - optional	2
5	Overall weeding including weeding in planting strips	2

2.2.1.2 Chemical

Weed management at all stages in a plantation cycle can be undertaken using chemicals commonly known as herbicides (Plate 20. b). There are two main types of herbicides namely, pre-emergent (applied on the soil) and post-emergent (applied on the weeds). Herbicides are sometimes applied in combination mostly to save application cost. Recommended doses of each herbicide and their combinations are given in Table 2. Pre- and post-emergent herbicides controlling growth of narrow- and broad-leaved species are available in the market and the use of each of these is determined by the weed flora present and the mode of action of these herbicides. Herbicides, when applied on the target weed, disrupt its physiological functions either through contact or systemic action. Pre-emergent herbicides like diuron (Karmex, Klass) are soil-applied and prevent weed growth by damaging the germinating weed seeds. Post-emergent herbicides 2, 4-D (Fernoxone), paraquat (Gramoxone) and glyphosate (Roundup, Glycel) on the other hand are applied on target weeds. They are either systemic or contact in action. Due to the relatively high cost of certain translocated herbicides like glyphosate, additives like kaolin and urea were evaluated to enhance their effectiveness. It was found that addition of kaolin at 2.5 kg per ha could reduce the effective dosage of glyphosate (Mani *et al.*, 1991). Use of additives reduces unit cost and also lowers the herbicide load in the environment.

Table 2. Recommended combinations and dose of herbicides

Name	Dose/ effective ha	Frequency/year	Target weed species	Volume/ effective ha
Paraquat (Gramoxone) and 2,4-D (Fernoxone) tank mix	2.25 L 1.25 kg	4 rounds at an interval of 6 - 8 weeks	Broad-leaved weeds like *Chromolaena* sp. *Borreria* sp.	500 - 600 L
Glyphosate (Glycel, Roundup or Weedoff)	2.0 L	2 - 3 rounds at 3 month intervals and spot application of 0.5 - 2.5 L paraquat/ha	Grass weeds and overall weed control	400 L

In most rubber growing areas, a limitation to herbicide effectiveness can be rain. Glyphosate, a translocated herbicide, requires several hours for full absorption and its effectiveness can be impaired by intermittent rain, but paraquat is absorbed by the foliage at spraying and is little affected by rain received after 1 to 2 h (Watson, 1989). The stage of growth of the target weed is important while deciding the time of herbicide application. For effective control, herbicide application may be undertaken when the weeds are in the active growth stage. To avoid drift of the spray liquid, herbicide spraying should be undertaken only on wind-free days. Apprehension about the possible environmental hazard can be laid to rest if necessary precautions are observed. Herbicide spraying should be done using knapsack sprayers or controlled droplet applicators (CDA) only and not by micron sprayers or mist blowers under any circumstances, whatsoever. Herbicides on sale are subject to pesticide regulations. Precautions on their use are labelled on the packings. Weed management using herbicides is gaining popularity in India particularly in view of its lower application cost and labour requirement.

2.2.1.3 Integrated

A combination of manual and chemical weed control methods and cover crop establishment can be integrated for optimizing weed management. Preliminary indications from a trial in the immature phase on the different methods of weed control have shown that herbicide application in the plant basin and slash weeding the remaining inter-plant area along the contour terrace was effective in controlling the weeds most economically (Philip *et al.*, 1998). An integrated approach can be adopted either by manual weeding followed by herbicide application or application of herbicides in plant basin and manually weeding the remaining area. As the effectiveness of an applied herbicide is maximum when the plants are in their active growth stage, herbicides can be sprayed after the regeneration following slash weeding.

2.2.2 Weed mangement in different stages of rubber

2.2.2.1 Seedling nursery

A seedling nursery is vulnerable to weed infestation right from the time of bed preparation. Weeds sprout and grow along with the rubber seedlings soon after planting. If left unchecked, weeds will eventually dominate and adversely affect seedling growth. The first round of weed control operations is carried out manually six to eight weeks after planting, coinciding with the first fertilizer application. The weeds are then kept aside for application as mulch after the side dressing with urea is complete. Manual control of weeds involves hand hoeing and picking. This operation is labour intensive. Application of pre-emergent herbicide, diuron, at 2 kg per ha was observed to keep the weeds in check for six to seven weeks after planting. This helps in avoiding the first round of weeding prior to fertilizer application (Lakshmanan *et al.*, 1995a). Subsequent weeding rounds can be undertaken manually. Mulching the beds after fertilizer application reduces the weed population substantially. Use of recycled polythene material for mulching plant base has also been shown to curtail weed growth (Lakshmanan, *et al.*, 1995b).

2.2.2.2 Immature rubber

In the newly prepared planting strips, the growth of weeds is fast as the soil and climatic conditions are ideal for growth. Management of weeds in the immature phase may be decided by the grower, based on the different methods mentioned earlier. In trials conducted by the RRII, application of diuron at the rate of 2 kg per ha and simazine (Tafazine) at the rate of 3 kg per ha was found to keep weeds in check in the planting strips for three months thereby avoiding one round of manual weeding (Mathew and George, 1975). Though spade-scraping of planting strips was found to significantly reduce weed population over the year, the cost incurred was high compared to herbicide application (Philip *et al.*, 1998). In the north-eastern region *Imperata cylindrica* ('lalang' or thatch grass), is a major weed infesting young plantings. Manual weeding to control this weed is not very effective and requires many rounds for keeping it under check. In studies conducted in the traditional region, Mathew *et al.* (1977) suggested repeated spraying with dalapon (Tafapon) at the rate of 10 kg per ha for the control of this grass.

2.2.2.3 Mature rubber

As the trees grow old, the foliage is at great height from the ground. This permits more sunlight into the inter-row spaces. As a result, weeds gradually reappear. The weed growth is much more if vacant patches are present. It can be controlled by slash weeding or with the application of herbicides.

2.3 Vacancy filling

Failure of establishment in the newly-planted areas leads to vacant points in the field. Vacancies should be filled up as early as possible to achieve uniformity in growth. If budded stumps are used for field planting, casualty is likely to be more as compared to polybag planting. During the year of planting, casualties noticed should be filled up as early as possible using polybag plants of comparable size. More plants may die during the ensuing summer. These points may be filled up during the subsequent rainy season using polybag plants of advanced growth. The extent of casualties depends on the quality of upkeep, the planting material used and the weather conditions following planting. Supplying during the third year need be attempted only if numerous vacancies occur in contiguous patches. Stumped buddings can also be used for vacancy filling at advanced stages if adequate care is taken.

2.4 Pruning

When budded stumps are used for planting, the offshoots (also called false shoots) arising from the stock should be removed by weekly inspection. A single vigorous sprout arising from the bud patch alone should be allowed to develop. The shoots arising from bud patch are usually bright green in colour while those from the stock are dark coloured. It is not desirable to allow branching up to a height of 2.5 m from the ground. Pruning of the side shoots which arise periodically should be done in a systematic manner using a sharp knife (Plate 20. c). Once branching has taken place at the desired height, further pruning of branches should only be for achieving a balanced crown (Leong and Yoon, 1985).

2.5 Propping

During the initial years of growth, some plants particularly those of clones like RRIM 600 show a tendency for severe bending. In such cases the plants have to be pulled erect by providing adequate support. Propping can be done using wooden or bamboo poles. This can also be achieved by tying coir ropes at a convenient height on the stem, pulling the plant erect and tying the other end of the ropes to pegs fixed on the ground. It is desirable to tie the rope from three sides in a triangular manner. The stem of the plant must be protected at the point of contact with a pad of sack or other suitable soft materials to avoid damage to the bark.

2.6 Irrigation

Though the traditional rubber growing belt in India receives an average annual rainfall of 3000 mm, only a few rains are received during the summer season (December to April). A moderate water stress is experienced during this period. Rubber plantations in these areas are usually raised under rainfed conditions with the plants growing on the residual soil moisture during the summer season. Under rainfed conditions, rubber plants have an immaturity period up to seven years. Irrigation during summer season can enhance the growth and reduce the unproductive period (Pushparajah and Haridas, 1977; Omont, 1982; Jessy *et al.*, 1994).

In the non-traditional areas of North East India, Orissa, West Bengal and Maharashtra, climatic conditions are less congenial for growth of rubber and hence irrigation is essential in the initial years of planting.

2.6.1 Water requirement

Water requirement of a crop is the quantity of water required for its evapotranspiration and metabolic activities. Since the quantity of water required for the metabolic activities is negligible, evapotranspiration can be taken as the water requirement. This varies with the nature and stage of the crop, weather conditions and soil moisture availability. In Malaysia, the mean daily evapotranspiration of young rubber grown in a glasshouse varied from 2.1 to 6.9 mm per day and under field conditions, this was found to be 4.4 mm per day when averaged over 21 months (Haridas, 1980).

Evapotranspiration of immature rubber was measured using lysimeters in Central Kerala. The mean evapotranspiration was 2.60, 4.24 and 4.98 mm per day during the first, second and third year respectively, during the summer season when the plants were sufficiently irrigated to avoid any moisture stress. In another experiment, the mean evapotranspiration of two year old rubber plants was measured as 4.97 mm per day during the summer season (Jessy *et al.*, 1992). The quantity of water required by a plant can be estimated as 6, 19, 44, 82 and 99 L per day during the first, second, third, fourth and fifth year respectively (assuming that the canopy coverage increases from 10 per cent in the first year to 90 per cent in the fifth year). From the fifth year, the water requirement is fairly constant. The irrigation requirement, during dry months, of a mature rubber tree was estimated as 10000 L (Vijayakumar *et al.*, 1988).

In the non-traditional areas, prolonged drought coupled with high temperature, low relative humidity and dry winds restrict the growth of rubber. In these areas, the water requirement is high compared to the traditional areas. In the Konkan region (Maharashtra), the irrigation requirement of rubber trees was estimated to be around 33500 L per tree at a planting density of 400 trees per ha (Vijayakumar *et al.*, 1998).

2.6.2 Irrigation in nurseries

Irrigation is beneficial in rubber nurseries during the summer season even in the traditional areas. Sprinkler or pot irrigation can be practised in the nurseries. In large nurseries, sprinkler irrigation is advantageous due to its high efficiency and low labour requirement. Besides, it provides an ideal microclimate for the growth of rubber seedlings. Irrigation should preferably be given once in two to three days and care should be taken to wet the soil to a depth of at least 10 cm. In small nurseries, pot irrigation can be practised. Irrigation may be given in the morning and evening, though evening irrigation is preferred to minimize evaporation losses.

2.6.3 Effect on immature rubber

Under rainfed conditions, rate of growth in terms of girth increment is very low during the summer season. Irrigation during this period enhances the growth and helps to reduce the immaturity period. In the traditional belt, summer irrigation can reduce the immaturity period by six months to one year (Jessy *et al.*, 1994). Irrigation at 50 per cent of the crop evapotranspiration was sufficient to enhance the growth (Jessy et al., 1996a). In North East India, temperatures falling below 10°C during the winter season restrict the growth of rubber. Irrigating the plants during this period will help the plant to mitigate the effect of this low temperature (Philip, 1997).

In some of the non-traditional areas like North Konkan, plants require more than 10 years to attain tappable girth. A significant increase in growth was observed with summer irrigation in this region (Mohankrishna *et al.*, 1991). Irrigation at 50 per cent of the estimated crop water requirement could reduce the immature period from 10 years to six years (Vijayakumar *et al.*, 1998).

2.6.4 Choice of irrigation method

Choice of the method of irrigation depends on the water and labour availability and terrain. Both basin irrigation and microirrigation (drip irrigation) can be adopted for rubber. If properly scheduled and managed, these methods are comparable with respect to their effect on growth of rubber (Jessy *et al.*, 1994). However, when water availability is limited, drip irrigation is advantageous due to its high efficiency. It has the added advantage of lower labour requirement also. But initial investment is higher in the case of drip irrigation than basin irrigation.

In the traditional rubber growing areas, care should be given to conserve water during the rainy season through proper soil and water conservation measures so as to reduce the intensity of moisture stress during the summer season. However, in the non-traditional rubber growing areas, irrigation is essential at least in the initial years for the establishment and growth of rubber.

2.7 Mulching, shading and whitewashing

In young rubber plantations clean weeding is a usual practice along the planting rows and basins around the plants. However, this exposes the soil in the immediate vicinity of the plants to the direct impact of heavy rains and sunlight which results in undesirable soil condition around the young plants. Mulching or covering the clean area around the young plants protects the soil in the plant basin (Plate 20. d,e).

Mulching around the plant prevents the formation of hard crust of soil in the plant basin (George, 1962). The addition of organic residues as mulch supplements plant nutrients and humus to soil (Samarappuli, 1992). Addition of materials like legume cover crop cuttings and legume tree loppings having a narrow carbon to nitrogen ratio has greater effect in improving soil fertility, while addition of grass cuttings and paddy straw with wide carbon to nitrogen ratio contributes more to improvement of physical condition of soil (George, 1962).

Mulching at the end of the rainy season helps to slow down the rapid upward movement of soil moisture as the summer advances and reduces evaporation losses from soil surface. If mulching is done after the two fertilizer applications, soil erosion and leaching loss of fertilizers are reduced during the rainy season (George, 1962; Samarappuli and Yogaratnam, 1984).

Another important beneficial effect of mulching is that it prevents weed growth in the plant basin to a great extent (George, 1962; Lakshmanan *et al.*, 1995b). The presence of mulch also helps to minimize the soil temperature during summer months and improves the formation of surface feeder roots (Lakshmanan *et al.*, 1995b).

Organic waste materials such as crop residues are ideal as mulch material and legume crop residues are the best due to their narrow carbon to nitrogen ratio. Cover crop cuttings, tree loppings, dry leaves, weed cuttings which do not contain mature seeds and all kinds of crop residues are good mulch materials.

The net benefit of proper mulching is improved growth of plants and reduced immaturity period (Samarappuli *et al.*, 1992; Samarappuli and Yogaratnam, 1995).

During the year of planting the young plants may be protected by shading before the beginning of summer. Plaited coconut leaves or used gunny bags can be used for this purpose (Plate 20. f,g). The brown bark of the young plants can be protected from the scorching action of the sun by whitewashsing the main stem of the plant from the second year of planting (Plate 20. h). This may be continued till the canopy of the plants develops and partially shades the plantation. However, plants on the road sides may need whitewashing for a longer period as they are more exposed to sunlight. Whitewashing can be done using lime or china clay.

2.8 Induction of branches

It has been observed that to achieve a high rate of girth increase the rubber plant should produce branches at a height of about 2.5 to 3.0 m from the ground. In high branching trees girth increment has been found to be poor compared to low branching trees. Some plants show a tendency for high branching, particularly clones like RRIM 600 and GT 1. In such cases branching has to be induced by encouraging a few lateral buds to develop. The branches thus induced should develop in different directions in an equally spaced manner to ensure a well-balanced canopy. Techniques like the double blade ring cut device and the leaf cap method can be utilized for this (RRIM, 1974; 1976).

The double-blade ring-cut device has two V-shaped blades fixed 20 cm apart on a rod. By pressing the V-shaped blades and rotating them around the trunk complete ringing of the bark is done down to the surface of the wood. The cuts are made above a cluster of leaf scars so that a number of trunk shoots is produced around this region. This method can be applied only on greenish brown or brown tissues and is not suitable for young green tissues. In young green tissues, the leaf folding or leaf cap method can be used. In the leaf folding method, the leaves of the top whorl are folded down at the point of contact of the petiole with the lamina using only the upper few leaves to enclose the apical bud (Plate 21. a). The leaves are then tied with a rubber band. After three to four weeks they are released. In plants where the terminal whorl of leaves are in the leaflet or bud break stage, the leaf cap method is recommended (Plate 21. b). Here, three mature leaflets are taken to form a cap to enclose the terminal bud and tied with a rubber band. The cap is then removed three to four weeks later.

2.9 Thinning out

When budded stumps or polyclonal seeds are used for planting, large variation in the growth of plants is noticed even in well-maintained plantations. In such cases it is judicious to have a high initial density which gives opportunity for gradual removal of weaker plants during immaturity and the initial few years of tapping. This results in greater uniformity, lower maintenance cost, higher yield per tree and lower tapping cost. With polybag plants, it is easier to establish a uniform stand without severe thinning out as there is an opportunity to choose plants of uniform growth for planting which are likely to grow to a more uniform stand.

The thinning operation should be gradual and realistic. By the third year, really worthless plants are to be identified and removed. In the case of budded stump planting, seedling trees which develop from false shoots should also be removed. Subsequent rounds of thinning can be done on a half-yearly basis. It is important not to remove trees which are near an already existing vacant patch. In contour planting where the contours are wide apart, a slightly lower proportion of trees should be removed. On the contrary, where the contours are closer and the stand is dense in a pocket, a slightly higher proportion can be removed. This results in a more even stand.

2.10 Roads and firebreaks

Roads may be kept in good condition by periodic maintenance (Plate 21. c). This can be done during lean periods of work, preferably soon after the rains. Firebreaks (firebelts) have to be made just before the commencement of summer to a width of 3 to 5 m (Plate 21. d). This has to be done along all the boundaries of the plantation. All the weeds and dry leaves should be removed from the firebreak strip and from the roads at frequent intervals during the summer.

2.11 Contour retaining walls and silt pits

Stone-pitched contour retaining walls ('edakayyalas') once constructed have to be periodically repaired and maintained in good shape (Plate 21. e) to restrict surface run off. In the silt pits, along with water, soil also will get deposited in due course and reduce their volume. Therefore, the pits have to be renovated by removing the soil deposited in them (Plate 21. f). The ideal time for doing this is before the beginning of the regular southwest monsoon. The soil thus removed from the pits should be deposited on the lower periphery of the pit and pressed down well.

3. INTERCROPPING

During the initial years of establishment of a rubber plantation, the interspaces of rubber receive plenty of sunlight. The lack of vegetative ground cover and absence of shading in the inter-rows in the initial years expose the soil to extreme weather conditions and potential hazards of soil erosion. Inter-row management is therefore important and growing of a legume ground cover or short-term intercrops or a combination of both is a judicious practice (Yusoff *et al.*, 1989). Small farmers in particular, practise intercropping for deriving short-term income. Intercropping when properly done has been found to enhance the growth of rubber (Jessy *et al.*, 1996b). Legume cover can be integrated in the intercropping system by setting apart alternate inter-rows for them or by growing them in available interspaces.

When intercrops are grown in rubber plantations, they should not be allowed to dominate the association and affect the growth of rubber. Competition can be eliminated by the right choice of intercrops, duration and density of planting and spacing. It is very important to plant the intercrops sufficiently away from rubber to minimize competition. Varieties of tapioca with spreading habit and of banana with tall growth and profuse suckering habit are found to retard the growth of rubber plants (Mathew *et al.*, 1978).

Growing of intercrops necessitates tilling the soil to different degrees depending on the requirement of the crop. Since any tillage operation is likely to predispose the soil to erosion, it is safer to restrict intercropping activities to level lands and gentle slopes. In steep slopes, it is advisable to keep the entire interspaces of rubber under legume ground cover.

The following guidelines are to be considered when intercropping is practised. (1) Priority may be given to those crops which need only less soil disturbance. (2) Intercrops should be sufficiently away from the young rubber plants such that their roots do not overlap much and the canopy of intercrop does not overshadow rubber plant. (3) When annual crops are grown repeatedly, their stand per unit area should be reduced progressively for every subsequent crop. (4) Intercrops should be separately and adequately manured. (5) Bulky organic manures like cattle manure or compost should be liberally used. (6) Tillage operations for intercrops should be restricted to the minimum and on no account should the interspaces be completely dug.

3.1 Commonly-cultivated intercrops

3.1.1 Banana

Banana is very suitable for growing in level lands and gentle slopes. Non-ratoon types like 'nendran' banana are ideal for the initial two years (Plate 22. a). During the first year 1200 plants can be grown in a double row system at 2 x 2 m spacing along the inter-row spaces of rubber. The stand may be reduced to about 600 during the second year in a single row system. It has been found that growing of 'nendran' banana for the first two years improves the growth of rubber and gives good profit (Mathew *et al.*, 1978; Krishnankutty, 1979; Rodrigo, 1989). Banana has been found to serve as a nurse crop for rubber during this period. If ratoon banana types like 'palayankodan', 'poovan', *etc.*, are grown, only a single row should be planted. After harvesting the first crop, only one sucker should be allowed to grow during the second year (Rodrigo, 1989). The pseudostem, leaves and mother rhizome left after the harvest should be used for mulching the rubber plants.

3.1.2 Ginger and turmeric

Since thorough digging of the soil is needed for the cultivation of these crops, they may be grown only in level and nearly-level lands. Heavy application of cattle manure or compost and liberal use of organic mulches are important in the cultivation of ginger and turmeric during the initial two years of rubber plantation (Plate 22. b). A high rate of income can be obtained from their cultivation (Mathew *et al.*, 1978; Krishanankutty, 1979).

3.1.3 Vegetables

Many seasonal vegetables like cowpea, cucumber, lady's finger, amaranthus, *etc.* can be grown as intercrops with proper addition of organic manures (Plate 22. c).

3.1.4 Pineapple

Pineapple is a highly profitable intercrop grown in several parts of the country (Rajasekharan, 1989) and can be planted along with rubber (Plate 22. d). Two or three rows of pineapple suckers are planted along the inter-rows of rubber in trenches. If the land is having slope the trenches should be taken across the slope parallel to the contour terraces. This helps to conserve the soil from erosion. Proper manuring using organic and chemical fertilizers is necessary to ensure high yield and to prevent depletion of soil fertility. Yield can be obtained up to four years after which the remaining suckers should be uprooted and removed from the field.

3.1.5 Coffee

Being tolerant to shade to a certain extent, coffee has been found to grow in rubber plantations (Plate 22. e). In rubber plantations above the age of four years, coffee plants are seen to establish easily under rainfed conditions in South India. *Coffea canephora* var. *robusta* and *Coffea arabica* var. *cauveri* were established in experiment plantings (RRII, 1995). *C. arabica* can be planted in a single row at 3.4 m spacing in the inter-rows of rubber. This will permit about 450 coffee plants per ha. The variety *cauveri* is grown 1.8 m apart in a single row or in double row system accommodating 850 and 1700 coffee plants per ha respectively. The intercroppped coffee plants take longer time to commence yielding compared to a pure plantation of coffee. The yields are also less in comparison to pure stands. A maximum yield of 250 kg per ha of dry cherry coffee was obtained in experimental plantings. However, the cost of cultivation of coffee is less and the prices are attractive. The main advantage is that the growth and yield of rubber are not affected (RRII, 1995). Establishing coffee in young rubber under rainfed conditions is more difficult. It needs temporary shade plants like banana during the initial years of the rubber plantation.

3.1.6 Medicinal plants

Some shade tolerant medicinal plants can also be grown in rubber plantation (Plate 22. f, g). *Strobilanthus haenianus* ('Karimkurinji'), *Adhatoda vasica* ('Valiya Adalodakam') and *Plumbago rosea* ('Chuvanna Koduveli') are found suitable for cultivation in mature rubber plantations. Experimental plantings indicated that they did not adversely affect the yield of rubber (Joseph *et al.*, 1995). The marketability of medicinal plants should be ascertained before starting large-scale cultivation.

3.1.7 Fodder grass

Fodder grasses can also be grown during the initial years of a rubber plantation. Shade tolerant varieties may be chosen for this.

3.1.8 Other crops

Annual crops like *Sesamum* are also cultivated along with other intercrops in some areas (Plate 22. h). Other perennial intercrops like cocao and black pepper are also grown as intercrops with limited success (RRII, 1995). Timber yielding trees like teak (*Tectona grandis*), mahogany (*Swietenia mahoganii*), *etc.*, can also be grown along the boundaries of rubber plantations.

Growing of cardamom in mature rubber plantations has been reported from certain high elevation localities in Idukki, Wynad and Palghat districts in Kerala (Sivadasan and Nair, 1988). However, low yield from both rubber and cardamom was noticed since the rubber trees in these areas were old and cardamom varieties were not high yielding while disease incidence and drought were severe. This situation can be improved by cultivating cardamom varieties suitable for low elevations and by using rubber clones suitable for slightly higher elevations and with scientific cultivation practices.

Yogaratnam *et al.* (1995) have reported that intercropping tea in rubber has been successful in Sri Lanka. The rubber trees provide sufficient shade for tea. Similar attempts have been initiated in north-eastern India with rubber planted in wide avenue system.

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