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MANAGEMENT OF MICROORGANISMS AND INSECTS FOR COST REDUCTION IN RUBBER PLANTATIONS

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C. Kuruvilla Jacob
Rubber Research Institute of India. Kottayam - 689 009, Kerala, India.

Careful management of microorganisms and insects can improve productivity and reduce cost of production from rubber plantations. Cost reduction, improvement in crop production and healthy farm environment were the goals in crop protection research.

Control of fungal diseases of rubber with reduced inputs cost was attempted. As abnormal leaf fall disease causes significant crop loss, its control can improve productivity even in clones like RRII 105. Reduction in spray volume, mechanization, partial replacement of $CuSO_4$ and use of additives like rubber seed oil to Bordeaux mixture resulted in reduction in cost of fungicide and labour without compromising on the disease control using high volume spraying. In micron spraying, reduction in weight of the sprayer, improvements in atomization of spray fluid, reduction in use of copper oxychloride and partial replacement of spray oil with rubber seed oil were effective in cost reduction. Crown budding and development of resistant clones have long-term benefit.

Control of powdery mildew in disease-prone areas using integrated schedule of systemic and non-systemic fungicides resulted in considerable improvement in crop production. Strategies developed for control of *Corynespora* leaf disease could arrest the spread of the disease beyond South Karnataka. Survey of clones have shown that RRII 105 is highly susceptible and GT 1 tolerant among clones cultivated in the disease affected area. The mechanism of tolerance in GT 1 appears to be due to triggering of PR proteins. Control of *Colletotrichum acutatum* in young plantations could be achieved by integrated use of systemic and non-systemic fungicides.

Prophylactic protection either by painting or spraying on the disease-prone loci with copper fungicide reduced incidence of pink disease. Rain wash of Bordeaux paste could be reduced by using additives like rubber seed oil. Dry rot and patch canker diseases cause problems only in limited areas and could be controlled by fungicide painting on affected portion. Black stripe is a problem during rainy season which demands regular protection. Cheap alternatives for mercurial fungicides could be identified for its control. Root disease incidence is sporadic and its spread can be controlled using systemic fungicides.

Investigations on biotic etiology of TPD have indicated that involvement of phytoplasma, bacteria, fungi and protozoa can be ruled out. Association of low molecular weight RNA with TPD has been observed. Hence a possible viroid etiology is suspected.

Insect pests are confined to limited areas and hence their control strategy is targeted to such areas only. Termites cause problems in relatively dry areas like Orissa but can be controlled by repeated application of insecticide like synthetic pyrethroids. Borer beetles that penetrate dry bark of trees and make galleries into wood causing breakage of trees could be controlled to some extent by painting with insecticides.

Bark feeding caterpillar, though could be controlled using insecticide dust and spray, their use may lead to pollution of environment. Hence biological alternatives are being sought. Crickets damaging rainguards could be avoided by painting repellant oils like cashew kernel oil. Root-knot nematode population in nurseries could be reduced by incorporating leaves of *Pongamia, Azadirachta* and *Mucuna* into the soil.

- Microorganisms which are beneficial in rubber cultivation include N-fixers, P-solubilizers and mycorrhizae. Isolates of *Bradyrhizobium* which promote growth and establishment of cover crops like *Mucuna* and *Pueraria* have been identified, multiplied and used. Among the free N-fixers *Azotobacter* and *Azospirillum* reduce the requirement of N fertilizers in nursery by 25 per cent. Use of phosphobacteria and mycorr hizae reduces the P requirement in nursery culture.

Solid waste from rubber wood processing is found to be a very good substrate for mushroom cultivation. Effluent from sheet processing units is a good substrate for biogas generation. Biogas generation system was developed for households and group processing units. The biogas generated could replace the firewood requirement in smoke houses by about 40 per cent. Its use improved the quality of the sheets produced. The technology has been widely adopted.

- Honey bees are beneficial insects which give additional income to the rubber cultivators. The Indian honey bee, *Apis cerana indica,* has shown signs of revival after the Thai sac brood virus attack and the honey production has improved. Vermicomposting is another beneficial activity on rubber based farms. Rubber wood saw dust is a good substrate for vermicomposting. The vermicompost so developed is useful as organic manure for young rubber.

Microorganisms and insects are either beneficial or harmful in agricultural systems. In both the cases, their careful management is essential for improving farm productivity. Rubber plantations are no exception to this. The management techniques aim at the reduction in their population and activity when they are harmful and increasing their activity and number when beneficial. The cost of production is closely linked to how effectively we achieve this with minimum input. Increase in productivity through maintenance of plant health leads to reduction in cost of production. Cost reduction remained as the major goal of the Rubber Research Institute of India in the field of crop protection. Simultaneously manipulation of beneficial organisms for improvement in crop production and environment management also was attended to.

DISEASE MANAGEMENT

Rubber plants are susceptible to several diseases during various stages of its growth. Most of these diseases are caused by fungal pathogens. The weather conditions which favour the growth and establishment of rubber like high rainfall, moderate temperature and higher humidity are also congenial for the fungal pathogens. The availability of the host plant in large continuous stretches helps faster multiplication of the fungal pathogens and results in epidemics. In rubber plantations, epidemics caused by pathogenic fungi are quite common.

Abnormal leaf fall (*Phytophthora* spp.)

The most important epidemic that causes significant crop loss in rubber plantations in traditional rubber growing areas of India is abnormal leaf fall disease (ALF) caused by *Phytophthora* spp. Estimated crop loss due to this disease in four popular clones from 1996 to 2002 from an experiment is presented in Table 1.

The crop loss in the clone RRIM 600 was severe while in RRII 105 there was loss only during 1996-97 when leaf retention was less than 50%. The leaf retention in RRII 105 remained high even in the unsprayed

Table 1. **Crop loss estimated in popular clones**

Clone	1996-97	1997-98	1998-99	1999-2000	2000-01	2001-02
RRIM 600	16.53	16.69	15.39	43.56	25.67	24.86
RRII 105	21.14	—	—	—	—	—
GT 1	12.23	—	—	4.71	20.36	48.58

Source: RRII (2000 a, b; 2001 a, b; 2002)

plots during the other years at the Central Experimental Station of RRII where the experiment was located.

In contrast to this, the retention of leaf in another experiment at Trichur in clone RRII 105 was very poor in spite of spraying low doses (2 kg/ha) of copper oxychloride registering nearly 16% crop loss during 2001-2002. Further, a survey on leaf fall in RRII 105 covering 1,30,356 hectares under 141 Field Offices of the Rubber Board revealed that 60.35% of the area surveyed had moderate to heavy (more than 25%) leaf fall during 2001-02. This points to the need for prophylactic protection to the clone RRII 105 also in disease-prone areas to increase the productivity of the plantations. Earlier experiments have shown that a minimum dose of 6 kg/ha of copper oxychloride is required to be sprayed in such areas to ensure satisfactory leaf retention and avoid crop loss. It has been estimated that a 5 % increase in crop can compensate for the expenditure on spraying. Good leaf retention is also essential for maintenance of tree health and growth.

Reduction in the cost of spraying without affecting the leaf retention is the best strategy in ALF control. Many small growers resort to high volume spraying of Bordeaux mixture as a prophylactic control measure. The constraints in high volume spraying are high water and labour requirement, high cost of copper sulphate and slow coverage. Experiments conducted to reduce the spray volume and thus the quantity of copper sulphate revealed that mature plantations can be sprayed effectively using around 3000 litres of spray fluid per hectare instead of earlier recommendation of 5000 litres, leading to 40 per cent reduction in cost. In experiments to evaluate spraying equipment, it was observed that using HDP sprayer along with the spray guns the coverage can be increased to 1 ha/day from 0.4 ha/day using rocking sprayer. As the discharge pressure is high, climbing is required only up to the first forking region for covering the entire canopy of all nearby trees.

It was also observed that addition of 0.5% zinc sulphate to 0.5 % Bordeaux mixture could give leaf retention equivalent to that of the recommended 1% Bordeaux mixture. Using this method, the cost of fungicide can be reduced by about Rs.400/ha (Table 2).

Table 2. **Comparative efficacy of different fungicides (Clone RRIM 600)**

Treatment	Spraying system	Leaf retention (%)
Bordeaux mixture 0.5%	High volume	51.0
Bordeaux mixture 1%	High volume	61.0
Bordeaux mixture 0.5% + Zinc sulphate 0.5%	High volume	64.0
Oil-based copper oxychloride	Low volume	78.0

Source: RRII (1995)

Addition of either spray oil or rubber seed oil (at 1% concentration) to 1% Bordeaux mixture improves its efficacy and to 0.5% Bordeaux mixture gives comparable protection to that of 1% Bordeaux mixture

(Table 3) with reduction in cost of copper sulphate.

Table 3. **Effect of addition of rubber seed oil to Bordeaux mixture (clone RRIM 600)**

Treatment	Leaf retention %	
	1998	1999
Bordeaux mixture 1% + RSO 1%	57	62
Bordeaux mixture 0.5% + RSO 1%	49	54
Bordeaux mixture 1%	51	55

Through the collaborative efforts of RRII with the manufacturers of micron sprayers, the weight of micron sprayers could be reduced from 65 kg to 54 kg using materials like anodized aluminium for impeller and moulded plastic for blower case. These sprayers are now in wide use. Two machines were developed in collaboration with a manufacturer, to be carried by two workers one with a throw of 12.5 metres and the other with a throw of 7.5 metres. The second type is useful for spraying in young rubber plantations.

Further improvement in the micron sprayer was attempted by attaching the Micronair AU 8120 atomiser to micron sprayer. This attachment improved the atomization of spray particles and ensured a higher throw of the fungicide resulting in higher leaf retention (Table 4) particularly of the top canopy.

In order to reduce the quantity of copper fungicides used in rubber plantation, alternate oil dispersible formulations were tested. Two formulations mancozeb (70% ODP) and metalaxyl + copper (5 + 50% ODP) were found effective at a lower dose of 5 kg/ha when used for prophylactic aerial and micron spraying. These fungicides can be used in areas planted with moderately susceptible clones like GT 1(Tables 5,6).

Reduction in cost of spray oil by using

Table 4. **Comparison of micron and micronair atomisers**

Treatment	Particle size (μ)	Throw height (m)	Leaf retention %	
			Pudukad	CES
Micronair	130x127	33	66.91	55.75
Micron200x160	25	38.03	36.05	
Control (unsprayed)	—	—	13.06	03.89

Table 5. **Effect of spraying mancozeb on leaf retention**

Treatment	Dose (kg/ha)	Leaf retention (%)		
		RRIM 600	GT 1	PB 235
Mancozeb 70%	5.0	45.39	62.58	57.87
COC 56%	8.0	62.57	75.21	55.59
Unsprayed ..	..	11.26	35.29	20.72

Source: Jacob *et al.* (2001)

Table 6. **Effect of aerial spraying of COC-metalaxyl combination on leaf retention**

Treatment	Dose (kg/ha)	Leaf retention (%)			
		GT 1		RRIM 600	
		Malankara Thodupuzha	SFCK Punalur	RPL Kulathupuzha	Cheruvally Erumeli
COC 50% + metalaxyl 5%	5.0	69.37	87.54	62.54	43.43
COC 56%	8.0	62.22	81.54	72.80	11.18

Source: Jacob *et al.* (2001)

Table 7. **Evaluation of rubber seed oil for partial substitution of mineral oil for spraying copper oxychloride**

Treatment	Leaf retention (%)		
	Pudukkad	CES	
	RRIM 600	RRII 105	GT1
Spray oil +Rubber seed oil (2:1)	51.78	66.88	59.40
Spray oil alone	38.03	71.66	42.75
Unsprayed	13.06	55.88	48.80

Source: RRII (2002)

rubber seed oil as alternative has been attempted. As rubber seed oil has high viscosity it is not possible to use it directly for spraying due to clogging of spray nozzles. Rubber seed oil could be used to replace spray oil by one-third the volume (Table 7). Besides marginal reduction in cost, the rubber seed oil has the advantage that it is an environment friendly product from the rubber estate. If oil is extracted locally, the cost can be reduced further.

Crown budding of susceptible plants with resistant crown is beneficial by avoiding spraying for the entire life of the plantation. The leaf retention in crown-budded plants remains high (Table 8). There is no difference in the latex properties of crown-budded plants when compared to that of trunk clone. However, there is a delay in maturity of trees by over one year. The clones GT 1 and RRIM 600 when crown-budded with F 4542, reduction in girth was observed.

Table 8. **Incidence of abnormal leaf fall in crown-budded plants**

Crown clone	Leaf retention (%)
Fx 516	75.00
RRII 33	70.00
PB 311 (control)	50.00

Source : RRII (2001 a)

Development of clones resistant to *Phytophthora* through breeding and genetic engineering is the best possible method to reduce cost of disease control. The screening of germplasm introduced from Brazil has yielded ten accessions which show consistently low disease incidence. These accessions can be included in future breeding programmes. Attempts were also made to locate markers for resistance to *Phytophthora* in the *Hevea* genome. One RAPD marker which is linked to tolerance could be located. Over-expression of two PR proteins was also observed in a tolerant clone when infected by *Phytophthora.*

Shoot rot (*Phytophthora* spp.)

Shoot rot affects the growth of young plants causing delay in growth and maturity. As all the clones are susceptible to shoot rot, spraying at fortnightly intervals throughout the rainy season is necessary, particularly in first year fields. The systemic fungicide phosphorous acid, besides affording protection favours plant growth (Table 9).

Powdery mildew (*Oidium heveae)*

Powdery mildew disease attacks mature

Table 9. **Control of shoot rot disease**

Location (Clone)	Mundakayam (PB 311)		Palapilly (PB 235)	
Treatment	Phosphorous acid (0.16%)	Bordeaux mixture (1%)	Phosphorous acid (0.16%)	Bordeaux mixture (1%)
Disease index (%)	12.7	8.7	17.0	15.0
Diameter increment (mm)	6.89	6.18	6.26	4.96

Source: Idicula *et al.* (1998)

rubber plants during the refoliation period. Almost all the cultivated clones are susceptible. This disease causes significant crop loss in areas like Kanyakumari, Idukki and Wynad districts and in North East India. Sulphur dusting has been recommended for control of the disease, but since the trees are in various stages of refoliation this contact fungicide sometimes fails due to lack of sufficient leaf area for deposition and due to wash off in rains. Systemic fungicides have the advantage that they are translocated within the plant system. Three systemic fungicides have been identified to give good protection. These are tridemorph (Calixin) 1.5% D, carbendazim (Bavistin) 1.5% D and hexaconazole (Contaf) 2% D. The first two are imported while the last is manufactured in India. Combined application of hexaconazole and sulphur has been observed to give better protection than either of the fungicides used alone (Table 10). As these

Table 10. **Powdery mildew disease control (ClonePB 5/51)**

Treatment	Dose (kg/ha)	Disease incidence (%)
Hexaconazole (2%)	7.0	10.4
Hexaconazole + Sulphur	3.5 + 6.0	8.7
Sulphur	12.0	16.0

Source: RRII (2001 a)

fungicides are formulated samples, cost comparison is not possible now. In nursery plants the protection from powdery mildew disease is required throughout the year. Several systemic fungicides useful for spraying (10-12-day intervals) have been identified (Table 11).

Screening of germplasm collection in order to identify sources of resistance to powdery mildew has yielded several accession which show moderate level of resistance to this disease. Some of these can be incorporated into the breeding pool after further evaluation.

Table 11. **Powdery mildew disease control in nursery plants**

Treatment	Dosage (% ai)	Disease index (%)	
		Beginning	Final
Carbendazim	0.075	38.83	10.75
Myclobutanil	0.04	35.92	9.33
Wettable sulphur	0.20	38.00	11.00
Penconazole	0.025	36.42	7.33
Propiconazole	0.025	43.50	11.00
Hexaconazole	0.01	36.08	8.08
Validacin	0.01	36.25	16.67
Unsprayed	—	37.25	42.08

Source: RRII (2000 a)

Corynespora leaf disease (*Corynespora cassiicola*)

Corynespora leaf disease was earlier confined to the nurseries and was regarded as a minor disease. But this disease caused an epidemic in mature rubber plantations in Karnataka during 1996-1998. The clone RRII 105 is highly susceptible to this disease. A survey conducted in 1998 revealed that 10-62% of the holdings in the different taluks in Dakshina Kannada District was infected. Antecedent weather parameters for incidence of the disease are maximum temperature 34-36°C, minimum temperature 17-21°C RH(morning) 85%, (evening) 40% and sunshine 8 hours per day. Experiments using water-based, oil-based and dust formulation of fungicides were conducted in the disease affected region. Though water-based fungicides mancozeb (0.25%) and carbendazim (0.10%) are effective, the high volume spraying on mature trees is costly. Use of oil-based fungicides like mancozeb and copper oxychloride (Table 12) is effective and economical. Two to four rounds of spraying may be required.

Copper oxychloride was used successfully in the *Corynespora* control campaign in nearly 10,000 hectares in Karnataka and North Kerala during 1989 and the disease progress could be arrested. This

Table 12. **Effect of oil-based fungicides in *Corynespora* leaf disease control**

Treatment	Dose (kg/ha)	Disease incidence (%)					
		1998		1999		2000	
		Initial	Final	Initial	Final	Initial	Final
Mancozeb 75%	7	50.00	22.17	51.50	24.45	43.50	19.20
COC 56%	8	50.00	29.60	56.20	32.30	44.50	28.00
Untreated control	—	52.00	48.40	56.00	53.40	43.00	42.50

Source: Manju *et al.*, (2002)

is a success story in which timely action of scientists, extension workers and farmers with the support of the government through Rubber Board could contain the spread of an epidemic plant disease.

The systemic dust fungicide hexaconazole 2% (9 kg/ha) also is very effective in controlling the disease. As the occurrence of *Corynespora* corresponds with that of powdery mildew, this fungicide may prove useful when both the diseases appear together as both can be controlled simultaneously.

Among the rubber clones cultivated in Karnataka, GT 1 shows a high degree of disease tolerance. The investigations on mechanism of tolerance revealed that the clone produces high level of β 1,3 glucanaces and peroxidases upon infection by the pathogen. Esterases are also involved in the recognition and initiation of infection of the host by the pathogen. Molecular characterisation of isolates of *Corynespora* collected from different locations based on RAPD profiles indicates that there are 10 different groups. The virulent isolates from Kerala and Karnataka have a distinct profile. Virulence is related to the ability for toxin production. The toxins isolated from these fungus could be used for screening rubber clones for susceptibility/resistance.

Colletotrichum leaf disease (*Colletotrichum acutatum*)

This disease was previously known as Gloeosporium leaf disease. Investigations on the casual organism has proved that the pathogen responsible is *Colletotrichum acutatum* . Molecular evidences based on DNA finger printing also have confirmed the identity of this pathogen. A survey on the incidence of the disease indicated that it is widespread in young plantations with Thodupuzha region showing highest (83.12%) and Kanyakumari region the lowest (29.17%) disease incidence. This disease occurs during the rainy season and affects the growth of young rubber plants. The disease could be effectively controlled by spraying common fungicides at fortnightly intervals during the rainy season (Table 13).

Table 13. **Control of Colletotrichum leaf disease**

Treatment	Disease index (%)
Mancozeb (0.2%)	20.80
Carbendazim (0.05%)	22.80
Mancozeb (0.1%) + Carbendazim (0.025%)	17.73
Mancozeb (0.2%) and Carbendazim (0.05%) Alternate spraying	17.07
Bordeaux mixture	22.93
Unsprayed (control)	45.33

Source: RRII (2000 a)

Pink disease (*Corticium salmonicolor*)

With extensive replanting using the high yielding clones, the incidence of pink diseases also is on the increase. Surveys conducted in the traditional rubber growing areas indicate that the disease incidence is more in Mundakayam and Thodupuzha regions while it is insignificant in Kanyakumari. Among the clones, RRII 105, PB 217 and PB 260 are highly susceptible.

As the disease appears during the rainy season, control operations become difficult with consequent increase in cost of disease control. In order to reduce the number of infected plants to manageable levels, prophylactic control measures can be adopted. In disease-prone areas planted with highly susceptible clones, prophylactic painting of the forking region using a long brush can be adopted. Prophylactic spraying of the forking region and brown portions of the stem is a cheaper and effective alternative. Disease incidence could be reduced by 35 % when Bordeaux mixture was sprayed (Table 14). This spraying can be combined with that done for shoot rot and leaf disease control, thus reducing the labour cost.

Rain wash of Bordeaux paste used for painting on pink disease affected region is another concern. Addition of non-edible vegetable oils like linseed oil and rubber seed oil (at 10% concentration) increases the tenacity of Bordeaux paste and ensures prolonged protection. Alternatively other systemic and contact fungicides can be applied using rainfast carriers (Table 15). Different fungicide carries were tested for painting fungicide of these Vinofan, Indtron and Dipicol are observed to be good.

Table 15. **Control of pink disease using fungicides incorporated in rainfast carriers**

Treatment	Dose/k	Recovery (%) Vinofan+ Chinaclay	Rubber kote
Myclobutanil (Systhane)	4 g	70	20
Hexaconazole (Contaf)	4 ml	60	30
Validacin	20 ml	80	60
TMTD (Thiride)	10 g	60	30
Tridemorph (Calixin)	12.5 ml	30	40
Propiconazole (Tilt)	4 ml	73	59
Boradeaux paste			30

Source: RRII (1997)

Dry rot (*Ustulina deusta*)

Dry rot has been observed as a serious disease causing breakage of mature trees and reduction in total stand in the high rainfall areas. The disease incidence can considerably be prevented by proper field sanitation including prompt removal of broken branches and stumps. Chemical control is effective when the disease incidence is detected early. Systemic fungicides are more effective than contact fungicides (Table 16). Bordeaux paste is not recommended for control of this disease.

Patch canker (*Pythium* spp., *Phytophthora* spp.)

Incidence of patch canker is observed

Table 14. **Incidence of pink disease and cost of prophylactic control in a third year plantation of RRII 105**

Treatment	Rounds	Infection %	Decrease over control (%)	Annual expenditure for 100 trees (Rs.) Prophylactic	Curative	Total
Tridemorph (Calixin) 1%spray	2	46.00	7.07	112.00	184.00	296.00
TMTD 0.2% spray (Thiride)	2	49.50	—	88.66	198.00	286.66
Bordeaux mixture 1% spray	2	32.00	35.35	94.00	118.00	212.00
Bordeaux paste 10%	1	40.50	18.18	200.00	128.00	328.00
Control (Detection& Treatment)		49.50	—	—	198.00	198.00

Source: Jacob & Idicula (1997)

Table 16. **Recovery of rubber trees from dry rot disease**

Treatment	Recovery score			Rank
	1995	1996	1997	
Hexaconazole (Contaf 0.02%)	600	600	500	1
Tridemorph (Calixin 1.00%)	—	600	500	2
Penconazole (Topas 0.04%)	—	540	500	3
Validamycin (Validacin 0.06%)	501	525	500	4
Propiconazole (Tilt 0.20%)	220	501	500	5
Myclobutanil (Systhane 0.06%)	180	525	413	6
TMTD (Thiride 0.75%)	166	300	316	7

Source : Joy and Jacob, (2000)

to be more in the clone PB 260. The occurrence is more common near the basal region due to the inoculum carried in rainsplashes. Three fungicides (Table 17) are found to be effective in controlling the disease when incorporated in rubberkote and applied on the affected portion after cleaning the wound.

Table 17. **Control of patch canker disease**

Treatment	Dose (per kg rubberkote)	Recovery (%) 1999	2000
Benomyl (Benlate)	4 g	90.9	100
Mancozeb (Dithane M45)	10 g	100	100
Metalaxyl + Mancozeb (Ridomil MZ)	4 g	100	100
Thiophosphate (Kitazin)	5 ml	100	100
Phosphorous acid (Akomin 40)	5 ml	81.8	91
Bordeaux paste	—	81.8	50

Source: RRII (2001 b, 2002)

Black stripe (*Phytophthora* spp.)

Black stripe disease affects the tapping panel during the rainy season. Regular protection against this disease is essential as the wounds that occur during tapping serve as portal for entry of the pathogen. Experiments have proved that weekly application of protective fungicide can effectively control the disease. Mancozeb and phosphorous acid are effective alternatives for the mercurial fungicides (Table 18) which are now withdrawn from recommendation.

Root diseases

Among root diseases brown root disease caused by *Phellinus noxius* is more common. Although disease affects only very few trees in a plantation, the affected trees are often lost. Field experiments on control of this disease have shown that drenching of bases of trees near to affected trees with fungicides like tridemorph (Calixin 80 EC) 0.5 and 1.0%, propiconazole (Tilt 25 EC) 0.1% and Thiram (Thiride 75 WP) 0.75% are effective in preventing spread of the disease.

Purple root disease caused by

Table 18. **Alternative fungicides for black stripe disease control**

Treatment	Trade name	Dose/L (Formulation)	Disease index I year	II year
Mancozeb	Indofil (Dithane) M45	5 g	33.55	10.67
Phosphorous acid	Akomin 20	4 ml	40.44	14.56
Phosphorous acid	Phosjet 40	2 ml	40.00	15.89
MEMC	Emisan 6 WP	2.5 g	40.33	19.89

Source: Jacob *et al.*, (1995); RRII (1996)

Helicobasidium compactum was observed in some nurseries. Budded stumps infected by this disease when uprooted and dipped in fungicide solutions viz. Calixin 0.25%, Tilt 0.1% or Thiride 0.75% and planted in polythene bags showed recovery. Recovery is more if the treatment is done in early stages of infection.

Tapping panel dryness

Tapping panel dryness is a disorder of rubber trees which has been attributed to physiological changes. Biotic agents were not detected as causal organism of TPD. As the research on this serious disorder has not identified any physiological or biochemical causes, it was thought to be worthwhile to have a relook on the possibility of any biotic cause. It was also believed that the availability of new tools in molecular biology and biotechnology may help in detecting biotic causes if any. A collaborative research project of RRII with the Indian Agricultural Research Institute used molecular tools to study the etiology of TPD. Nucleic acid extracts from leaf and bark tissues of TPD affected plants analysed using R PAGE technique revealed the presence of a low molecular weight RNA of 359 nucleotides similar to the potato spindle tuber viroid. The LMW RNA was purified and cloned in a PUC 19- derived vector using primers specific to potato spindle tuber viroid. When the cloned RNA was random labelled and used as probe in dot-blot hybridisation, extracts from TPD affected trees responded positively while that from healthy trees did not. More studies are required using large number of samples to attribute viroid etiology to TPD.

When larger number of plant samples were tested, majority of TPD affected trees tested positively but a few apparently healthy trees also tested positively (Table 19) indicating possibility of symptomless carriers.

Table 19. **R- PAGE Analysis of *Hevea***

Location	Diseased samples		Healthy samples	
	Total	+ve	Total	+ve
Vaniampara	11	10	4	1
Malankara	14	9	4	1
RRII	6	5	8	6

Source: RRII (2002)

On injection of chemicals like tetracycline, penicillin, carbendazim and flagyl, no remission of symptom was observed indicating that phytoplasma, bacteria, fungi and protozoa may not have causal role in TPD.

INSECT PESTS

Besides the diseases, some insect pests also attack the rubber plants, though confined to limited areas. These include termites, borer beetles, bark feeding caterpillar, crickets damaging rain guards, scale insects, root grubs etc. If control measures are not adopted, their attack may lead to loss of trees.

Termites (*Odontotermes obesus*)

Termites make mud gallery on rubber plants and feed on the corky layer of bark. Consequently the plants are exposed to sunscorch and may dry up. The problem is more severe in dry areas like Orissa. Drenching of insecticides at the base of the plants controls the infestation but reinfesation occurs (Table 20) necessitating repeated treatment.

Table 20. **Chemicl control and post-treatment reinfestation of termites**

Treatment	Dose (%)	Control (%)	Post-treatment-reinfestation(%)	
			after 4 months	after 16 months
Chlorpyriphos	0.2	68.15	41	67
Fervalerate	0.4	27.03	40	54
Endosulphan	0.175	23.14	60	71
Untreated	—	9.83	90	76

Source: RRII (2000 b, 2001 b)

Borer beetles (*Heterobostrychus* sp.)

Borers beetles make entry into the standing rubber trees mostly through the dry regions of bark. They pierce through the bark and reach the wood where they make tunnels and expel the powdered wood through bore holes. Due to their activity, the trees become weak and fall down with the wind. Early detection of borer attack followed by treatment with brush coat application of insecticides (Table 21) is found to protect the trees from severe damage.

Table 21. **Control of borer beetle infestation**

Treatment	Control (%) After one month	Control (%) After two months
Carbaryl 0.5% + chlorpyriphos 0.2%	81.33	88.67
Carbaryl 0.5% + quinalphos 0.25%	87.00	98.00
Carbaryl 0.5% + malathion 0.5%	81.33	84.99
Carbaryl 1.0%	55.67	66.33

Source: RRII (2002)

Bark feeding caterpillar *(Aetherastis circulata)*

Bark feeding caterpillar makes galleries on the surface of the bark and nibbles into the bark. This leads to oozing of latex. The bark often becomes flaky. Severe infestation can weaken the trees and may even lead to drying of branches. As the pest hides under the gallery and may infest regions of the tree which are unreachable, control is often difficult. Dusting of insecticides (Table 22) was earlier found effective but can not be recommended for wide use due to environmental pollution.

Table 22. Effect of insecticide dusting on control of bark feeding caterpillar

Treatment	Dose (kg/ha)	Reduction in caterpillar (%) After 2 days	Reduction in caterpillar (%) After 30 days
Endosulphan 4D	10	18.06	67.64
Fenvalerate0.4D	10	26.87	88.88
Methyl Parathion 2D	10	26.87	88.88
Control		3.12	18.29

Source: RRII (2000 a)

Alternatively spraying of insecticides directly on the stem up to a height of 6 m was tried. Although initial control was good, reinfestation was noticed after 45 days. Among the insecticides Fenvalerate 0.04% spray gave 93.68 % reduction in caterpillars within 7 days and showed maximum persistence after 45 days (20.84 %).

Biological control appears to be the only viable alternative for control of the pest. A fungus causing death of the caterpillar was isolated from the cadaver and has been identified as *Beauveria* sp. Attempts are now being made to develop techniques for its mass multiplication and field application.

Rainguard-damaging crickets *(Gryllacrys* sp.*)*

Crickets damage the rainguards during March – November. They hide under the rainguard and cut holes on them which result in leaking of rainguards. The crickets can be controlled effectively by application of repellents like used - engine oil or cashew kernel oil (Table 23).

Table 23. **Control of crickets which attack rainguards**

Treatment	Attack of crickets on rainguard (%)
Used - engine oil	20.66
Cashew kernel oil	26.82
Neem oil	38.06
Maroti oil	42.21
Caster oil	42.63
Control	65.79

Source: RRII (2001 a)

Root-knot nematodes (*Meloidogyne* spp.)

Soil samples from rubber nurseries and plantations from rubber growing areas have revealed a high population of plant parasitic nematodes. The most frequently occurring parasitic nematode genus is *Meloidogyne* (13.8%) with a relatively high density (35.4%) of occurrence. The population was found to be higher during October to November and an increase in the temperature beyond 30°C caused reduction in population. Both rubber plants and the cover crop *Pueraria phaseoloides* are susceptible to attack by root-knot nematodes.

Aqueous extracts from plants were found to cause mortality of nematode larvae (Table 24). When the leaves of *Pongamia glabra* was incorporated into soils (6g/kg soil) before planting *Pueraria phaseoloides* in pot culture, infestation of root-knot nematode was reduced.

Table 24. **Effect of plant extract (1:1) and leaves on mortality of *Meloidogyne incognita* larvae**

Treatment	In *vitro* mortality (%) after 48 h. exposure to extract	Mortality in soil incorporated with leaves at 6g/kg (%)
Pongamia glabra	96	75
Azardirachta indica	84	58
Mucuna bracteata	76	51

Source: RRII (1997, 2000 a)

BENEFICIAL MICROORGANISMS

By manipulation of the beneficial microorganisms associated with rubber the growth can be improved. Some microorganisms are helpful in reduction of pollution due to wastes.

Nitrogen fixers

These include symbiotic nitrogen fixers like *Bradyrhizobium* and free N-fixers like *Azotobacter* and *Azospirillum*. Inoculation of *Bradyrhizobium* has proved to be beneficial for early growth and establishment of *Pueraria phaseoloides* grown as cover crop in rubber plantations. An isolate of *Bradyrhizobium* was commercialized by developing the culture using lignite as carrier.

Another *Bradyrhizobium* sp. specific for *Mucuna bracteata* has been isolated and multiplied. Inoculation of *Mucuna bracteata* with this isolate helped in the establishment and fast growth of the cover crop.

Five isolates of *Azotobacter* were screened for the survival and the best selected. Among the different carriers tested vermiculite and charcoal were found to be good carriers for *Azotobacter.* When *Azotobacter* was inoculated into soil, the use of N fertilizer could be reduced by 25 per cent (Table 25). This beneficial effect is due to production on IAA, GA and cytokinins, polysaccharides and siderophores and also by stimulating other beneficial micro organisms in the rhizosphere.

Table 25. **Effect of *Azotobacter* inoculation on growth of rubber seedlings**

Treatment	Girth (mm)	Height (cm)
25% N + *Azotobacter*	9.61	99.24
50% N + *Azotobacter*	10.05	101.65
75% N + *Azotobacter*	10.65	105.98
100% N	10.57	105.04

Source: RRII (2000 b)

Two isolates of *Azospirillum* were also collected from roots of rubber and multiplied. These isolates were introduced in pot culture soils and evaluated for their effect on growth of rubber plants (Table 26). These isolates

Table 26 : **Effect of *Azospirillum* on growth of rubber seedlings**

Treatment	Diameter (mm)	Height (cm)
Azospirillum isolate 1+50% N	8.20	130.2
Azospirillum isolate 1+75% N	9.00	135.4
Azospirillum isolate 2+50% N	8.20	140.6
Azospirillum isolate 2+70% N	9.00	142.2
100% N (Control)	7.00	115.0

Source: RRII (2001 a)

helped the plant growth and fertilizer application could be reduced up to 50 per cent.

Phosphate solubilizers

The phosphate availability and uptake by rubber plants can be improved by using mycorrihizae and phosphobacteria. (Table 27, 28) Mycorrhizal fungi infect the plant roots and increase the total absorption surface thus helping the plant to draw more water and nutrients. Their role in phosphorus uptake has been demonstrated. Co-inoculation of two species of mycorrihizae was more beneficial.

Table 27. **Effect of inoculation of VAM on growth of rubber**

Treatment	Height (cm)	Girth (cm)	Infection (%)
Acaulospra + *Glomus* + 75% RP	70.00	5.33	64
Acaulospra + 75% RP	55.00	4.67	50
Glomus + 75% RP	59.33	5.33	64
Unioculated + 100% RP	46.07	4.00	42

Table 28. **Effect of phosphobacteria on growth of rubber seedlings**

Treatment	Girth (cm)	Height (cm)
RP 50%	12.75	134.25
RP 75%	14.75	141.75
RP 100%	16.50	154.25
RP 50% + phosphobacteria	16.75	149.75
RP 75% + Phosphobacteria	16.75	150.50
RP 100% + Phosphobacteria	17.75	149.75

Source: RRII (1995)

Pollution control

Microorganisms can be effectively utilized for management of environmental pollution in rubber-based farms.

Mushroom culture

The solid wastes from rubber wood processing can be utilized for mushroom culture. Mushroom species like *Pleurotus* sp. *Lentinus* sp and *Calocybe* could be grown on rubber wood saw dust. The yield varied from 400-600 g/kg for *Pleurotus* sp.

Effluent from rubber processing

Effluents from rubber processing could be utilized for biogas generation with the help of methanogenic bacteria. Sheet processing effluent is a good substrate for biogas generation for household use in biogas plant (Deen bandu or KVIC model). As the gas contains 1-5% H_2S which is toxic, it needs further purification before use in kitchen. A gadget containing calcium hydroxide and fine soil mixed at 1:1 ratio could be used to absorb the H_2S. When the effluent from RSS processing was fed so as to retain the HRT at 40 days after an initial seeding with effluent from gobar gas plant for establishment of methanogenesis an average of 2.03 m^3 gas could be produced per day from a 3 m^3 plant. The gas production is higher during February to July than the rest of the year.

As the effluent generation in group processing units of RPS is much higher, technology was developed for treatment of the effluent in the two larger anaerobic immobilized digesters along with an aerobic pond. The digester could take 1500 litres of effluent per day. A fixed film assembly was designed to enhance the surface area within the digesters for adherence and action of microorganisms. The HRT could be reduced to 20 days and the gas production enhanced to 14 m^3 per day. The gas generated contains 62% methane, 15-20 % CO_2 and 5-10% H_2S. The gas has been used to replace the use of firewood partially in the smoke houses with the help of a heating device developed for the purpose. This resulted in reduction of cost on firewood by about 40 per cent. Moreover, 60% of the sheets produced in smoke houses which used biogas is of RSS I grade, fetching a higher price. This system is efficient in reducing all the pollution

Table 29. **Characteristics of effluents in immobilized growth digester at different stages**

Source	Parameters					
	pH	TS	DS	BOD	COD	TN
Raw effluent	4.8	20365	18435	15245	26520	940
Plant 1	5.1	6810	4320	8245	12610	620
Plant 2	5.8	2240	1425	240	675	220
Acretor	6.5	2025	675	180	420	185

Source: RRII (2002)

parameters (Table 29) to the desired level. This technology has been adopted by over 60 model RPS.

BENEFICIAL INSECTS

Bee keeping

Rubber is a good source of nectar and bee keeping is a good source of income for the rubber growers. The honey flow from the extra-floral nectaries of the rubber plant is limited to the refoliation period. About 45 per cent of the apiary-honey produced in Kerala is from rubber-based apiaries. The total production of rubber honey in India during 1999-2000 is estimated as 1750 tonnes.

The outbreak of the Thai sac brood virus disease in 1992 devastated the rubber-based apiaries in South India. As the Indian honey bee *Apis cerana indica* was seriously affected, the Italian bee *A. mellifera* was introduced. The expenditure on bee keeping using Italian bees is higher but the income per beehive also is higher (Table 30). The Indian bees showed a revival from 1997 while the Italian bees showed a decline in efficiency. Moreover, the high maintenance cost and the proneness to attack of bee eating birds make the Italian bee keeping more difficult. The economics of bee keeping in rubber-based apiaries have been monitored through surveys.

OTHER BENEFICIAL ORGANISMS

Vermicomposting

Earthworms are beneficial organisms which convert organic wastes into composts which are useful for plant growth. Vermicomposting of rubber wood saw dust has been attempted. The composting is accelerated and the nutrient value of compost improved when the saw dust is

Table 30. **Economics of bee keeping in rubber plantations**

Bee species	1995			1996			1997			1998		
	Cost	Income	BCR	Cost	Income	BCR	Cost	Income	BCR	Cost	Income	BCR
A.c. indica	594	250	0.42	630	705	1.12	706	940	1.33	734	1098	1.50
A.mellifera	2338	2445	1.05	2397	3325	1.31	2483	2560	1.03	2800	4109	1.64

Source: Jose *et al.*, (1999)

Table 31. **Nutrient levels in vermicompost from rubber wood saw dust**

Worm species	Nitrogen (%)		Phosphorus (mg/100g)		Potassium (mg/100g)	
	Before	After	Before	After	Before	After
Perionyx sansibaricus	0.043	0.14	20	28	230	400
Eisenia foetida	0.032	0.11	18	25	340	510
Eudrilus euginiae	0.028	0.13	13	19	315	640
Control (no worms)	0.042	0.062	15	18	280	315

Source: RRII (2000a)

mixed with cow dung slurry. The nutrient levels of rubber wood saw dust improves when it is subjected to vermicomposting. The vermicompost from rubber wood saw dust is useful as manure for young rubber (Table 31).

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CONCLUSION

Manipulation of microorganisms for cost-reduction, improvements in growth and productivity of rubber, additional income generation and alleviation of environmental pollution has been attempted by the Rubber Research Institute of India.

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