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CROP LOSS IN RUBBER DUE TO ABNORMAL LEAF FALL: AN ANALYSIS ON THE ECONOMIC FEASIBILITY OF PLANT PROTECTION MEASURES IN INDIA

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Abstract: The paper attempts to assess the extent of crop loss in rubber plantations in India, measured in terms of loss in latex and timber output and thereby to examine the comparative economics of plant protection measures against *Phytophtora* spp. induced abnormal leaf fall (ALF). The specific objectives were: a) to examine the extent of loss in latex and timber output in unsprayed plots vis-a-vis sprayed plots across prominent rubber clones; b) estimate the value of loss in latex and timber output across clones between sprayed and unsprayed plots; c) examine the comparative economics of plant protection measures in terms of the incremental costs and the incremental returns from sprayed plots across clones; and d) reflect upon the policy imperatives with respect to region-specific Research and Development (R&D) interventions on plant protection measures in India. The study brings out significant clonal differences in loss of latex and timber output in the absence of prophylactic spraying against ALF. The observed clonal differences with respect to feasibility of plant disease control measures indicate the need for region and clone-specific recommendations for plant protection measures in India instead of the currently followed unilateral prescription with due allowance to the costs and potential benefit accrued from the control measures. The study also highlight the need for evolving interventions and agro-management/ plant protection measures for minimising the incidence of tree casualty in rubber plantation, as it amounts to loss of potential income from latex and timber from rubber plantations in India, dominated by the smallholder sector.

Key words: *Phytophthora* spp., abnormal leaf fall, crop loss, latex yield, timber yield, discounted cash flow analysis

INTRODUCTION

Crop production systems are highly susceptible to uncertainties of various kinds, originating from price and non-price factors leading to substantial economic losses and thereby loss of income to the farming communities. About one third of the realisable global crop output has been estimated to be lost annually due to insects, pests, diseases and weeds (Alagh 1988). Factors such as climate, crop diseases, soil type, crop species, irrigation, marketing policies and technology interact to form and alter the uncertainties of alternate farming practices (Pannell et al. 2000). Compared to seasonal/ food crops, the crop loss in perennial crops is more detrimental in effect, in view of the higher initial investment and longer economic life. The incidence of crop loss in perennial crops is also due to a host of plant diseases caused by *Phytophthora* spp. affecting the yield and resulting in significant economic loss. There is growing evidence from India, Southeast Asian countries of Indonesia, Malaysia, Philippines, Thailand and Vietnam on the onslaught of plant diseases and the resultant crop loss in rubber, cocoa, coconut, black pepper and durian (Edathil et al. 2000; Drenth and Guest 2004). For instance, Drenth and Sendall (2004) assessed the economic impact of *Phytopthora* diseases in terms of crop loss incurred from cocoa, rubber, coconut, pepper, durian, citrus and potato and reported an average loss of 2.4 billion USD.

In the case of rubber *(Hevea brasiliensis/* pararubber), several diseases are attributed to a number of species of *Phytophthora,* including *P. botryose, P. heveae, P. meadii, P. palmivora* and *P. nicotianae.* However, *P. palmivora and P. meadii* are isolated most frequently as the causal agents of black stripe, patch canker, green pod rot, green twig blight and abnormal leaf fall (ALF). The symptoms of the disease also include rotting of tender shoots and dieback of twigs (Ramakrishnan and Pillai 1961; Wastie 1975; Erwin and Ribeiro 1996; Drenth and Sendall 2004). The impact of *Phytophthora* diseases on rubber production are a reduction in latex yield, caused by the panel and stem diseases and a reduction in growth due to leaf fall (Sdoodee 2004). The incidence of ALF has been first reported in Sri Lanka (Ceylon) in 1905 (Murray 1930; Jayarathnam et al. 1987; Jayasinghe and Jayaratine 1996) followed by India in 1910 from some private rubber estates in Kerala. Annual occurrence of ALF have also been reported from the Southwest coast of Thailand (Kajornchaiyakol 1977, 1980), the northern and western states of Malaysia (Johnston 1989) and Myanmar (Turner and Myint 1980).

However, the severity of the incidence of crop loss in rubber due to abnormal leaf fall has been found more pronounced in the rubber growing regions in Kerala in India, than elsewhere. While the reported loss due to Phytophthora and the cost of disease control is estimated at 5–10% in Southeast Asia countries (Drenth and Sendall 2004), in India, field trials from Kerala indicated that ALF can cause yield loss of 38 to 56% when left unsprayed for one disease season in some clones (Ramakrishnan 1960, cit. by Edathil et al. 2000). Further trials on yield loss in high yielding susceptible clones of 15 to 25 years of age indicated that leaving the area unsprayed for one season caused 9 to 16% yield reduction due to this disease (Jacob et al. 1989). The intensity of leaf fall in rubber has been reported high as the rubber growing regions in Kerala receive an annual average rainfall of more than 3000 mm, which is three times above the national average. Leaf fall, apart from causing a reduction in crop yield, also adversely affects timber output. As the leaves are the source of photosynthates for growth in rubber, the low leaf retention leads to poor girth and thereby low timber output. The adverse effect of abnormal leaf fall disease on girth increment of rubber clones has already been reported in India (Jacob et al. 1989; Jacob et al. 2004).

The studies on crop loss due to various plant diseases are extensive and there is consensus among scholars that in many circumstances, risk considerations influence adoption of various control measures (James 1974; Carlson and Main 1976; Conway 1977; James and Teng 1979; Teng and Gaunt 1980; Reichelderfer et al. 1984; Reichelderfer and Bottrell 1985; Teng 1985; Onstad and Rabbinge 1985; Pannel 1991; Gotsch and Regev 1996). Specific to rubber, the exploratory studies by Mc Rae (1918), Chee (1969) and Radziah (1985) examined the outbreak of ALF in Malaysia and suggested control measures. In India, it was Ashplant (1928) who first recommended chemical control of ALF through prophylactic spraying. An important consideration in leaf disease control in rubber is the indirect gain obtained through the reduction of weeds with better tree canopy, leading to substantial savings from the reduced level of weeding (Wastie and Mainstone 1969). In India, exploratory studies on the control of ALF were initiated by Mc Rae as early as 1917, followed by Ramakrishnan and Pillai (1961), Pillai et al. (1980), Jayarathnam et al. (1987), Jacob et al. (1989) and Pillai et al. (1989). Jayarathnam et al. (1987) comparing the cost of prophylactic spraying against ALF and price of rubber, observed that a crop loss to the extent of 50 kg per ha in unsprayed area would justify the additional cost for spraying.

While the intensity of ALF and the resultant crop loss were assuming alarming proportions across rubber growing countries, there was hardly any attempt to make comprehensive assessment of the incidence, severity and impact of the disease in region-specific context across countries. More importantly, the economic significance of crop loss in rubber needs to be better understood from a broader perspective so as to reflect crop loss as a cumulative outcome of drop in the latex as well as timber output in the absence of appropriate plant protection measures. Thus, in the present context and from a long-term perspective, the economic feasibility of disease control measures assumes greater importance in view of: (a) steady increase in costs of chemical inputs for plant protection and management; (b) volatility in rubber prices; and (c) growing commercial importance of timber from rubber plantations in the world, especially, since the 1980s with the dwindling timber supply in tropical countries.

Objectives

In this backdrop, a comprehensive assessment on crop loss and the economic feasibility of disease control measures in rubber assumes added significance especially in the Indian context in view of the much contested 'high productivity under high cost syndrome (George and Joseph 2005) that prevail in the traditional rubber growing regions, especially, Kerala state, as against the other natural rubber producing countries. Considering the fact that the traditional rubber growing regions in India are far away from the equator and characterised by a clearly marked pattern of monsoons (south-west and north-east), the need for routine agro-management measures, including plant protection, was highlighted even in the report of the study group sent to India by the Government of Federation of Malaya as early as in 1959 (Newsam et al. 1960).

The present attempt is envisaged as a case study to assess the extent of crop loss measured in terms of loss in latex and timber output and thereby to examine the comparative economics of disease control measures against ALF based on region-specific disaggregate level data. Disaggregate level studies on the comparative economics of crop loss become imperative for two reasons. First, crop losses due to specific diseases can provide the basis for Research and Development (R&D) for evolving control measures commanding scale economies. Second, the comparative economics of preventive measures enables planning for efficient resource allocation specific to regional disease control programmes (King 1977; James and Teng 1979; Brennan and Murray 1989; Long 1989). It is also important to determine whether the extent of crop loss is economically justifiable enough to provide a genuine case for evolving costly and speculative technological solutions for control of the disease. For instance, judging from the history of *Phytophthora* leaf fall in Ceylon, Lloyd (1964) observed that the disease never caused yield decline of significant proportion to justify the economic importance of control measures. Against this backdrop, the present paper attempts to analyse the comparative economics of plant protection measures, particularly spraying against abnormal leaf, and its impact on latex and timber output with respect to four prominent high yielding clones viz., RRIM 600, GT1, RRII 105 and RRII 118, which together occupy more than 50% of the rubber planted area in India (Chandy et al. 2004). Of the four clones, while RRIM 600 is of Malaysian origin, GT1 is a primary clone developed in Indonesia. RRII 105 and RRII 118 are the clones developed by the Rubber Research Institute of India and reportedly, RRII 105 is ranked first in the world in terms of productivity. The commercial yield reported by large and medium rubber plantations in India indicate that RRII 105 is ranked first with an average yield of 1703 kg/ha, followed by RRII 118 (1451 kg), GT 1 (1351 kg) and RRIM 600 (1337 kg) (Joseph et al. 1999).

The specific objectives of the study are:

a) to examine the extent of loss in latex and timber output in unsprayed plots vis-a-vis sprayed plots across clones;
b) to estimate the value of loss in latex and timber output across clones between sprayed and unsprayed plots;
c) to examine the comparative economics of plant protection measures in terms of the incremental costs for and the incremental returns from sprayed plots across clones; and
d) to reflect upon the policy imperatives with respect to region and clone-specific R&D interventions on plant protection measures in India

MATERIALS AND METHODS

Database

The database of the study consisted of time series data pertaining to rubber plots planted during 1976–78 with four clones, viz., RRIM 600, GT1, RRI I105 and RRII

118 by the Rubber Research Institute of India (RRII) at the Central Experimental Station (CES), Chethackal in Central Kerala. The Central Kerala region with a rubber planted area of 0.26 million ha accounts for 45% of the total rubber area and 51% of the total rubber production in India (Rubber Board 2004). The experiment, which forms part of the study on assessment of crop loss due to abnormal leaf fall, included two blocks one ha each of the four clones (8 blocks) with one sprayed plot and the other kept as control. The historic data pertaining to the entire life of the plantations spanning 27 years consisted of: a) cost of spraying (including labour cost) against abnormal leaf fall; b) yield from sprayed and unsprayed plots; c) number of trees tapped; d) tapping days; and e) the price of rubber in nominal terms. Data on timber yield were collated based on measurement of girth and height of rubber trees prior to clear felling with a sample of 35% of the tree population selected at random from both the sprayed and unsprayed plots of each clone.

Analytical framework

While static analysis for a given year/ period is more convenient for seasonal and annual crops, perennial crops like rubber require inter-temporal analysis (Rae 1977). Hence, to account for the value of time and include the concept of time preference, the analysis uses the discounted cash flow approach (DCFA) following (Predo 2003; Brian et al. 2004) to derive the crucial parameters like the benefit cost ratio (BCR), net percent value (NPV) and the internal rate of return (IRR) arising from additional investment for spraying against abnormal leaf fall. Since the initial plantation development costs as well as the routine agro-management costs, like the costs for weeding, inorganic fertilizer application, tapping and others are uniform for both the sprayed and unsprayed plots, only the incremental costs (for material and labour inputs) incurred for spraying were considered for the analysis. Hence, the NPV measures the present value of the streams of net benefits derived from undertaking spraying. In order for spraying to be economically feasible and acceptable, the NPV must be greater than zero (i.e. positive). The NPV derived from undertaking spraying operations over the entire plantation cycle of each plot was computed as:

$$NPV = \sum_{t=0}^{T} \frac{\left(B_t - C_t\right)}{\left(1+r\right)^t} \qquad \text{(Equation 1)}$$

where:B_t = Incremental benefit in monetary terms at time t, C_t = Incremental cost for spraying at time t, r = discount rate, t = time (years) where observation is noted, and T = the entire life of the plantation (27 years), comprising seven years of immaturity period, followed by 20 years of rubber production cycle.

Incremental benefit was considered in terms of the incremental value of output derived from a sprayed plot as against the unsprayed plot in each clone. In standard parlance, output of rubber is expressed as kilogram per ha per annum, which is a cumulative function of the number of trees tapped per ha, price of rubber (Rupies/kg), number of tapping days and the tapping system followed. In general, half spiral alternate daily (1/2S d/2) tapping system is being widely followed in Indian conditions, with an annual average tapping frequency of 150 days. The historic data on price of ungraded rubber was used for estimating the nominal value of crop realised from sprayed and unsprayed plots and thereby arrives at the value of crop loss in the absence of spraying. However, the NPV is expressed in current USD terms, based on the time variant movement of Indian rupee against the USD during the entire life cycle of plantations. The analysis considers two discount rates: 7.5% and 12%, which justify the market rate of interest in the former case and standard commercial rate in the latter case, as also observed in the analysis of agro-forestry projects in India(Nadkarni 2001). IRR is used to evaluate the overall feasibility of undertaking spraying against abnormal leaf fall across the four clones. In the present case, IRR is the discount rate that would be required to make the net present value of the incremental costs on spraying equal to the present value of the incremental benefit due to productivity gains from the sprayed plot. Derivation of IRR is analogous to solving for 'r' in equation 1 (Eq. 1), as:

$$0 = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t} \qquad \text{(Equation 2)}$$

As rubber prices in India have been experiencing cyclical movements in tandem with the international prices during the past one decade or more, it is quite likely that the NPV would be more sensitive to rubber prices. Hence, the paper attempts at a sensitivity analysis with respect to rubber prices so as to arrive at benefit cost ratios (BCR) under different scenarios of rubber prices experienced during the life cycle of the plantations. Accordingly, five different price scenarios considered for calculating BCR are: a) the trend price observed during the entire plantation cycle; b) the maximum rubber price realised; c) the minimum price realised; d) average price realised; e) and the most recent price received prior to the felling of plantations.

For estimating the timber yield, 35 per cent of the trees were randomly selected from both the sprayed and unsprayed plots of each clone. Measurement of girth of the trees was taken at 1.5 m from the bud union and height was recorded using a calibrated metre scale. The data on girth and height of rubber trees were collected prior to clear felling of the plantations in 2004. The total greenwood volume was estimated following the quarter girth volume (QGV) method (Chaturvedi and Khanna 1982). Timber value was estimated based on the farm gate price of timber realised at the tender cum auction. Since timber from rubber plantations is not commercially utilised until the end of the plantation cycle, it becomes unrealistic to estimate the cash flow from timber. Hence, the analysis considers only the timber output at the end of the economic life to compare the differences in timber yield between sprayed and unsprayed plots and account for economic significance of the same in the present context.

Table 1. Profile of sample plots and the extent of casualty

Clone/year of planting and tapping	Trees at felling (No./ha)	Tree casualty (%)	Rubber yield (kg/ha)		Timber yield (m^3/ha)	
			Sprayed	Unsprayed	Sprayed	Unsprayed
RRIM 600 (1977–84)	289	36	2052	1781	122	108
RRII 105 (1977–84)	220	51	2306	2252	96	68
RRII 118 (1977–84)	263	42	1669	1614	154	125
GT 1 (1977–84)	274	39	1545	1815	115	143
Average	262	42	1893	1866	122	111

Note: Parenthetic figures are the respective years of planting and tapping of the plantations

RESULTS AND DISCUSSION

Table 1 provides some baseline information on the plantations under study. As it is evident, the average plantation cycle was 27 years with the plantations established during 1977–78 and opened for tapping in 1984 (Table 1).

While spraying resulted in considerable productivity gains in clone RRIM 600, the effect was only moderate with respect to RRII 118 and RRII 105. However, there were no productivity gains due to undertaking spraying with respect to clone GT1, which indicates tolerance of the clone to abnormal leaf fall. The observations of high positive effect of spraying on yield in clone RRIM 600 and absence of it in GT1 also conforms to the findings by Sdoodee (2004) that RRIM 600 is more susceptible to abnormal leaf fall (ALF) while GT1 being tolerant. Considering the initial planting density of 450 trees per ha, it may be observed that the incidence of tree casualty was very high in RRII 105 (51%), followed by RRII 118 (42%), GT1 (39%) and RRIM 600 (36%). The incidence of tree casualty observed in all the plots was caused by natural damage and cannot be attributed to the absence of spraying. However, unsprayed plots of RRII 105 and RRII 118 had experienced higher extent of tree casualty (62 and 48% respectively) compared to the sprayed plots (51 and 43% respectively), which could be explained as a cumulative effect of dieback of twigs, trunk and branch snaps in these clones in the absence of plant protection measures. Also, in terms of timber yield, sprayed plots had definite adventage over the unsprayed plots, especially in clones RRII 105, RRII 118 and RRIM 600, while timber yield from an unsprayed plot was more than that from a sprayed plot in GT1.

Economic Assessment of crop loss

A comparative assessment of latex and timber output between the sprayed and unsprayed plots is made so as to highlight economic significance of plant protection measures in rubber plantations. The analysis is based on the absolute volume and value (in nominal terms) of output obtained from both the sprayed and unsprayed plots of each clone during the entire crop cycle. The results of comparative assessment are shown in Table 2 pointing the differences in absolute volume of rubber output between the sprayed and unsprayed plots and corresponding value of output across the four clones. The cumulative loss in the value of rubber and timber output was estimated at USD 12930 in the absence of spraying, this was mostly related to the loss observed on unsprayed plot of RRII 118, followed by RRII 105 and RRIM

Table 2. Comparative differences in latex and timber output

Clone	Cumulative rubber output ('000 kg)		Cumulative value of rubber output ('000 USD)		Cumulative value of timber output ('000 USD)		Cumulative crop loss ('000 USD)
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	
RRIM 600	44.62	39.46	40.01	35.41	6.29	5.95	4.94
RRII 105	46.37	43.53	43.09	40.36	5.27	3.24	4.76
RRII 118	34.83	31.37	31.70	28.61	7.97	5.96	5.10
GT 1	33.90	35.44	31.17	32.40	5.45	6.09	–1.87
Total	159.72	149.80	145.97	136.78	24.98	21.24	12.93

600. Conversely, the volume of rubber and timber output realised from unsprayed plot of GT 1 was higher than from sprayed plot, which suggests tolerance of the clone to abnormal leaf fall and thereby unsuitability of control measures as already mentioned. If the cumulative loss in value of rubber and timber output from unsprayed plots is considered on an annual basis, the annual loss of income foregone works out to be USD 497, which implies that the monetary loss incurred in the absence of appropriate plant protection measures, especially, spraying was USD 497 per annum during the economic life of the four plots. Though this suggests the importance of plant protection measures given ensuring the longer economic cycle of rubber plantations, feasibility of undertaking such measures needs to be examined and justified in clone-specific context.

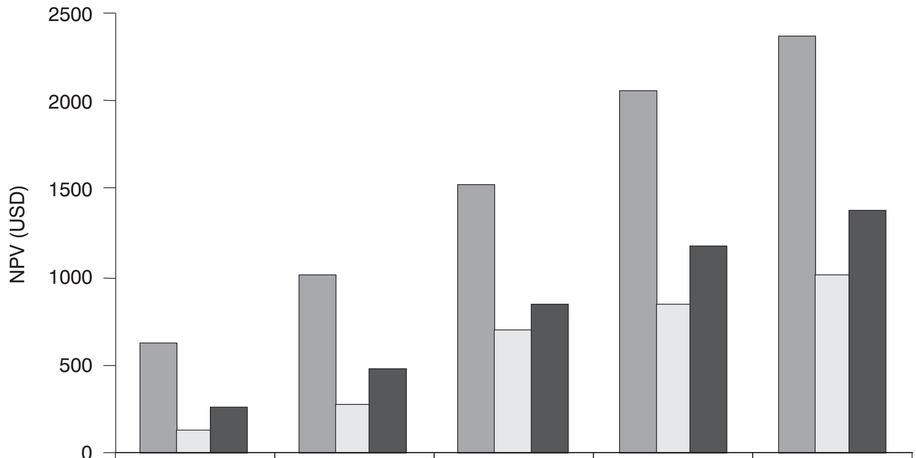
Feasibility of plant protection measures: a sensitivity analysis

Considering the magnitude of loss in value of crop output and timber as observed on the unsprayed plots against the sprayed plots, it is highly contextual to examine the economic rationality of farm level investments for plant protection measures. Such an analysis becomes relevant as plant protection measures (spraying in the present case) have been recommended in India for all clones and regions in similar dosage irrespective of vulnerability of specific clones to ALF. Since the operational costs involved in the agro-management operations other than spraying are the same for both the sprayed and unsprayed plots, only the incremental costs incurred due to spraying were considered for the analysis.

There are three methods of spraying in rubber plantations against ALF disease. While larger estates use aerial spraying, medium-sized estates resort to ground spraying of oil-based copper, using micron type sprayers. Bordeaux mixture using high volume sprayers is used in smallholdings for both young and mature plants (John 1998). The currently available technologies for spraying are mostly oil-based and involve high dose of chemical inputs (copper sulphate and oil). For instance, in the present case, prophylactic spraying was done using a Micron sprayer with oil dispersible copper oxychloride (56%) dispersed in agricultural spray oil at 1:5 ratio at a dosage of 40 litres per ha during the second fortnight of May every year (Jacob et al. 2004). The historic data relevant to the present analysis reveal that the cost of spraying has increased almost three times during the entire life cycle of the plantations from USD 23 per ha in 1977 to USD 55 in 2003. The rise in cost has been mostly accounted for by the substantial rise in the cost of spray oil and copper oxychloride, the combined share of which was as high as 91% according to the latest estimates.

As already described, the feasibility analysis of spraying uses the discounted cash flow approach to arrive at the critical parameters of NPV, IRR and BCR using discount rates at 7.5% and 12%. As the NPV arising from undertaking spraying operations is more sensitive to the volatility in rubber prices, five different price scenarios are considered for calculating BCR. The different price levels expressed in USD are: a) the trend price observed during the entire plantation cycle = USD 0.93 per kg; b) the maximum rubber price realised = USD 1.13 per kg; c) the minimum price realised = USD 0.61 per kg; d) average price realised = USD 0.68; and e) the price received prior to the felling of plantations = USD 1.26 per kg. Since spraying against abnormal leaf fall was not found worthwhile in clone GT1 as evident from the foregoing analysis, the feasibility analysis is confined to only three clones, viz., RRIM 600, RRII 105 and RRII 118. The feasibility analysis also does not consider the cash flow from timber output as commercial utilisation of rubberwood is made possible only at the end of the plantation cycle. The results of the sensitivity analysis of net cash flows from sprayed plots and the BC ratios under different price levels are furnished in Table 3. The clone-wise net benefit at 7.5% and 12% of discount rates as well as the NPV and IRR at the trend prices are given in Table 4. NPV at different levels of rubber prices using discount rate of 7.5% are shown in Figure 1.

The Table 3 reveals that spraying against abnormal leaf fall was most rewarding with respect to clone RRIM 600, followed by RRII 118 and RRII 105 in all cases.



	0.61	0.68	0.93	1.13	1.26
RRIM 600	618	1011	1518	2064	2368
RRII105	127	281	692	851	1015
RRII118	256	477	845	1177	1379

Rubber price (USD/kg)

Fig. 1. Net percent value (NPV) at different clones and different prices

Table 3. Sensitivity analysis of undertaking spraying against abnormal leaf fall in rubber

Clone	Net percent value (USD) at		Internal rate of return at		Benefit cost ratio
	7.5%	12%	7.5%	12%	
1. At trend price level = USD 0.93 per kg					
RRIM 600	1518	1128	23.58	21.75	3.77
RRII 105	692	515	22.52	20.38	2.14
RRII 118	845	626	21.61	19.63	2.50
2. At maximum price level = USD 1.13 per kg					
RRIM 600	2064	1538	26.08	24.21	4.86
RRII 105	851	627	22.38	20.28	2.55
RRII 118	1177	872	23.50	21.52	3.19
3. At minimum price level = USD 0.61 per kg					
RRIM 600	847	618	16.75	15.12	2.62
RRII 105	192	127	7.44	5.98	1.13
RRII 118	368	259	11.34	9.77	1.72
4. At the average price level = USD 0.68 per kg					
RRIM 600	1011	742	18.40	16.74	2.92
RRII 105	281	194	10.15	8.56	1.54
RRII 118	477	341	13.52	11.88	1.92
5. At the most recent price level = USD 1.26 per kg					
RRIM 600	2368	1768	27.75	25.83	5.42
RRII 105	1015	753	24.93	22.75	2.85
RRII 118	1379	1025	25.66	23.61	3.56

Generally, the parameters, NPV, IRR and BCR were found to be the lowest in clone RRII 105 compared to RRIM 600 and RRII118. When rubber price was minimal (USD 0.61 per kg), NPV and IRR at 12% of discount rate, they were the lowest (USD 127 and 5.98 respectively) in clone RRII105, which is suggestive of the cost-ineffectiveness of spraying operations if prices remain close to or fall below the minimum level. This is an important observation especially in the context when clone RRII105 is ranked first in terms of productivity per unit area in the world (Joseph et al. 1999). Besides, over time, the clone RRII105 has assumed prominence in the planting decisions of both the organized plantation sector as well as the smallholder sector with a relative share in planted area of 48% (Chandy et al. 2004) and 86% (Veeraputhran et al. 1998) during the 1990s. Considering this, plant protection measures become cost ineffective especially in the case of clone RRII105 when rubber prices remain close to the minimum level as was experienced during most of the late 1990s following the financial crisis in the South East Asian countries. The impact of the price crisis on the dominant rubber smallholder sector has been much more evident in terms of considerable erosion in adoption of scientific agro-management measures, especially, a perceptible decline in fertilizer application and spraying (Viswanathan and Rajasekharan 2001).

Thus, the feasibility analysis brings out clonal differences with respect to effectiveness of undertaking spraying operations in terms of high financial returns for RRIM 600 and RRII 118 and medium to low returns for clone RRII 105, which is widely adopted by majority of the planting community in the country.

Table 4. Clone-wise annual flow of net benefits, at net percent value and internal rate of return due to spraying in rubber

Year	Net benefits (in USD) at various clones					
	RRIM600		RRII105		RRII118	
	DF= 7.5%	DF= 12%	DF= 7.5%	DF= 12%	DF= 7.5%	DF= 12%
1977	–21.40	–20.54	–21.40	–20.54	–21.40	–20.54
1978	–20.81	–19.30	–20.81	–19.30	–20.81	–19.30
1979	–22.88	–20.61	–22.88	–20.61	–22.88	–20.61
1980	–22.29	–19.58	–22.29	–19.58	–22.29	–19.58
1981	–22.16	–19.04	–22.16	–19.04	–22.16	–19.04
1982	–24.26	–20.45	–24.26	–20.45	–24.26	–20.45
1983	–27.14	–22.50	–27.14	–22.50	–27.14	–22.50
1984	60.33	49.25	78.65	64.20	92.48	75.49
1985	–16.24	–13.08	135.67	109.25	98.67	79.45
1986	66.86	53.18	85.75	68.21	53.44	42.51
1987	22.55	17.74	136.81	107.62	41.17	32.39
1988	32.41	25.24	41.28	32.14	67.18	52.31
1989	110.47	85.22	–0.52	–0.40	46.88	36.17
1990	222.08	169.87	289.24	221.25	8.68	6.64
1991	339.20	257.43	–285.21	–216.46	121.34	92.09
1992	241.22	181.74	47.72	35.96	88.86	66.95
1993	67.34	50.39	–35.12	–26.28	48.13	36.01
1994	144.41	107.39	51.37	38.20	1.18	0.88
1995	177.47	131.21	23.99	17.74	114.03	84.31
1996	117.54	86.43	17.66	12.98	58.02	42.66
1997	–21.88	–16.01	69.57	50.89	40.02	29.28
1998	145.10	105.64	60.69	44.18	46.85	34.11
1999	71.08	51.51	–15.45	–11.20	20.20	14.64
2000	–9.78	–7.06	46.13	33.29	30.38	21.93
2001	–97.42	–70.02	46.05	33.10	–8.24	–5.92
2002	–37.32	–26.72	61.03	43.70	51.03	36.54
2003	43.10	30.75	–2.02	–1.44	–14.31	–10.21
Net percent value	1517.57	1128.09	692.33	514.91	845.05	626.20
Internal rate of return	23.58%	21.75%	22.52%	20.38%	21.61%	19.63%

Note: DF = Discount rates of 7.5% and 12%

CONCLUSIONS AND POLICY SUGGESTIONS

The paper is a modest attempt at examining economic significance of the cumulative loss of crop and timber output in rubber plantations in the absence of plant protection measures, i. e. prophylactic spraying against ALF. Economic significance of crop loss (both latex and timber) assumes importance in view of the relatively higher share of area planted with the four clones under study in the organised plantations, as well as, the dominance of RRII 105 in smallholdings in India. The study highlights the following points for further detailed region-specific investigations. First, there exist significant clonal differences in loss of latex and timber output between sprayed and unsprayed plots. Second, the higher extent of crop loss poses a major R&D challenge deserving interdisciplinary approach for undertaking cost-effective technological interventions for plant protection in India. Third, the observed clonal differences in latex yield between sprayed and unsprayed plots indicate the need for region and clone-specific recommendations for plant protection measures rather than the currently followed unilateral prescription with due allowance to the costs and potential benefit accrued from plant protection measures. Fourth, there is a need for evolving R&D interventions and agro-management/plant protection measures for minimising the incidence of tree casualty in rubber plantations, as it amounts to loss of potential income from latex and timber from rubber plantations.

The results of the study also bring out an important policy dimension that prophylactic spraying against abnormal leaf fall may form part of an official recommendation for agro-climatic regions found ideal for planting RRIM 600 and RRII118. Steps are also needed to evolve an integrated approach to Phytophthora disease management in rubber with special emphasis on developing or modifying clones having genetic resistance to various plant diseases.

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POLISH SUMMARY

STRATY W PLONACH GUMY WSKUTEK OPADZINY LIŚCI; ANALIZA OPŁACALNOŚCI ZABIEGÓW OCHRONNYCH W INDIACH

Produktywność plantacji kauczukowca brazylijskiego [*Hevea brasiliensis* (H.B.K.) Müll.] jest w Indiach obniżana przez kompleks gatunków *Phytophthora*, powodujących nadmierne opadanie liści (AFL), zamieranie pędów oraz zrakowacenia pni. Najczęściej izolowanymi gatunkami grzybów z chorych drzew były *Phytophthora palmivora* oraz *P. meadii*.

W pracy przedstawiono szczegółową analizę opłacalności w USD chemicznych zabiegów ochronnych fungicydami plantacji trzech najczęściej uprawianych klonów kauczukowca RRIM600, RR11105 i RRII118 w odniesieniu do zbiorów lateksu oraz drewna. Porównano opłacalność ochronnego programu profilaktycznego i interwencyjnego.