CHALLENGES TO OVERCOME IN MEETING INCREASING GLOBAL DEMAND FOR NATURAL RUBBER

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INTRODUCTION

The global scenario for natural rubber is very encouraging with projections of increasing demand till year 2020 and possibly beyond. There are indications that Natural Rubber (NR) share of the total elastomers consumed globally will increase from it's present level of forty percent. It has also been projected that the prices for natural rubber will remain promising with prices likely to only fluctuate within a narrow band from prevailing prices. There is consequently a need to increase the production of natural rubber to meet the projected increase in demand over the next two decades. There are however several challenges to overcome if natural rubber is to satisfy the increasing global demand. The existence of these challenges has prompted the search for alternatives which definitely is not a welcome prospect for natural rubber over the long term. This paper will discuss the challenges facing the global NR industry and highlight approaches that could possibly be adopted to overcome some of these challenges and thus enable adequate production to meet the increasing global demand for NR.

PROJECTIONS ON NR PRODUCTION AND CONSUMPTION

NR Consumption

Data published by IRSG (2009) on projections of total natural rubber consumption (' 000 tons) up to year 2018 based on projected consumption in the tyre sector and the general rubber goods sector are as follows :

REGION	2010	2015	2018
NORTH AMERICA	1146	1163	10
EUROPE	1389	1672	1663
ASIA	6673	8812	9648
MIDDLE EAST	83	101	116
AFRICA	123	146	145
LATIN AMERICA	543	774	795
OCEANIA	31	27	25
WORLD TOTAL	**9936**	**12642**	**13386**

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The projections on NR consumption shows that it will increase from 9.9 million tons in year 2010 to 13.4 million tons in year 2018 with an increase of 3.5 million tons. It is noteworthy that bulk of the increase will be in Asia amounting to 3 million tons or 86 % of the total projected increase. It is assumed that a significant portion of this increase will be in China and India. It is projected that NR consumption in North America will register a decline while the increase in Europe will not be that significant.

NR Production

The IRSG has also published data on projected normal NR production ('000 tons) up to year 2019 based on a continuation of past planting policies. These projections for the respective NR producing countries in Asia, Africa and Latin America are as follows :

REGION	2010	2015	2019
ASIA	8556	10633	12171
AFRICA	473	572	685
LATIN AMERICA	265	325	373
WORLD	9293	11529	13228

As expected the bulk of the increase is projected in Asia with the production projected to increase from 8.6 million tons to 12.2 million tons or an increase of 3.6 million tons. The increases projected for both Africa and Latin America is less significant. The bulk of this projected increase will be in four countries namely Thailand (0.723 million tons), Indonesia (0.379 million tons) , China (0.582 million tons) and Vietnam (0.687 million tons).

The total area under NR cultivation as per statistics published by IRSG is expected to increase from 10.5 million hectares in year 2010 to 11.4 million hectares in year 2019 in 11 Asian countries. The bulk of increase in hectarage will be in Indonesia (0.196 million hectares), Vietnam (0.130 million hectares) China (0.143 million hectares) and Myanmar (0.223 million hectares).It has also been reported by IRSG that there has been a dramatic increase in total new planting by 11 Asian countries during the period from year 2005 to 2008 with more than 1 million hectares added during this period. This is expected to have an impact on total production from year 2011 to 2014 when these trees come into production.

In addition to the new planting it is also estimated by IRSG that in year 2010, there will be 147,000 hectares replanted , in year 2015 there will be 172,000 hectares replanted and in year 2019 there will be 184,000 hectares replanted. The bulk of the replanting during the period from 2010 to 2019 is expected to be in Thailand, Indonesia and Malaysia. The IRSG Secretariat in a paper presented at the World Rubber Summit held in Qingdao, China in March 2010 has predicted that NR share of the global elastomer consumption will increase from approximately forty two percent in year 2010 to slightly above forty six percent in year 2020.

DEVELOPMENTS OF SIGNIFICANCE TO FUTURE OF NATURAL RUBBER

There is a current EU- Pearls Project with the objective of developing alternative natural rubber sources for Europe(**Polymers & Tyre Asia, June/July 2010**). In particular the focus is on two latex bearing plants namely Russian Dandelion (Taraxacum koksalayz) which contains high molecular weight rubber and Guayule (Parthenium argentatum). The compelling factors driving the move for alternatives is heightened concerns about droughts in China & Indonesia, heavy and persistent rains in Sumatera and the continuing replacement of rubber plantations with Oil Palm. There is also an inherent fear that the dreaded South American Leaf Blight Disease (SALBD) if it should spread from its base in Brazil to South East Asia could potentially devastate rubber plantations and critically threaten NR production. In addition there is a growing perception in Europe that the increased production of natural rubber may all be consumed in Asia particularly in China and India with limited quantities of NR available for Europe. Rubber and Latex from Guayule and Russian Dandelion are presently too expensive because the plants require further breeding and the processing is more complicated but it is estimated that in ten years it may be possible to go in to large scale production.

The discovery of a method to switch off the activity of an enzyme namely Polyphenol Oxidase which causes polymerization when the dandelion plant is cut will allow for copious flow of latex (**Polymers & Tyre Asia, February / March 2010**). The natural rubber produced from this plant is claimed to have the same properties as latex from Hevea brasiliensis with the added benefit that latex produced from the dandelion plant does not cause allergies. The discovery of the above technique is a big boost in the drive to find alternative sources of natural rubber. Research efforts are in progress to cultivate genetically modified dandelion using conventional breeding techniques.

An industrial biotech company in California, Genencor in collaboration with Goodyear has found a method to make greener tyres using genetically modified bugs to produce isoprene biologically (**The Economist, April 24th to 30th 2010**). In the laboratory Genencor has produced enough of what it calls BioIsoprene for Goodyear to build and successfully test prototype tyres made with the new material. Genencor used a genetically modified form of E-coli , a favourite species of bacterium in microbial genetics to produce BioIsoprene. The company was able to engineer synthetic metabolic pathways that enable the bacteria to produce isoprene from the sugars found in plant materials such as sugar cane , corn cobs and switchgrass a tall growing variety native to North America. Research is continuing into using other micro-organisms such as yeast.

STRUCTURE OF NATURAL RUBBER INDUSTRY

The last several decades has seen the transformation of the natural rubber industry into one that is largely smallholder based industry. The smallholders have become the driving force of the NR industry in four of the top six NR producing countries save for China and Vietnam with plantations in these countries moving out into cultivation of more lucrative and less labor intensive crops. This structural change is particularly significant because the bulk of the smallholdings are of uneconomic size with holdings being mostly less than three hectares with limited stand of trees.

Smallholders due to ingrained perceptions, familiarity with age old systems and inherent fears generally shy away from adopting state of the art technologies that are extensively adopted by large plantations (**Buncha Somboonsuke, 2009**). It is widely accepted that smallholdings will have to transform into entities that are technology driven if the increasing demand for NR is to be met over the next decade. This is a daunting task for extension specialists who are involved in transfer of technologies to smallholders but nevertheless one that needs to be expeditiously implemented despite the odds. In particular areas that should be of concern to extension workers involved with rubber smallholdings are the need for planting of good quality planting materials of proven high yielding clones, reduced immaturity period with adoption of appropriate agronomic practices, maintaining a high stand of trees at time of opening for tapping and adoption of effective exploitation systems that will allow for sustained high yield over the long term without reduction of the economic life span of the trees. The technology based transformation of smallholdings is the key to the future strength of the Global NR industry and one that will ensure that NR is the preferred elastomer for years to come.

CHALLENGES TO OVERCOME IN MEETING INCREASING GLOBAL DEMAND FOR NR

There are several inherent challenges that the NR industry will have to overcome if it is to meet the increasing demand projected till year 2020 and if NR is to maintain its pole position as the preferred polymer. These challenges among others are :

Narrow Range of Clones planted in major NR Producing Countries

The clones extensively planted over large areas in four of the top six NR producing countries are as follows :

NO	COUNTRY	% OF PLANTED AREA	CLONES PLANTED
1	THAILAND	80	RRIM 600
2	INDIA	90	RRII 105
3	INDONESIA	60 TO 70	GT 1 BUDDINGS OR CLONAL SEEDLINGS
4	CHINA	50 TO 60	RRIM 600 & GT 1

The planting of a single clone over large areas is potentially very risky particularly if there should be a major disease outbreak that could wipe out large areas thus adversely affecting production of rubber. The preference for planting of a single clone despite the availability of several new clones which have come on stream in the last couple of years is a challenge that needs to be addressed and overcome.

There is a need to diversify and broaden the range of clones planted from the perspective of long term survival of the NR industry. The respective Rubber Research Institutes in NR producing countries have through relentless and concerted efforts produced several new clones which are vigorous growing and precocious high yielding clones. Data provided in **Figure 1** shows that there are several new clones available in a number of major NR producing countries for commercial planting with yield potentials ranging from 2000 to 3000 kg per hectare per year. These recommended clones should progressively replace the existing narrow range of clones planted over large areas.

It is also in the long term interest of all NR producing countries to remove the embargo on movement of their best clones across borders so that there is a free flow of these clones among the NR producing countries. With increasing global demand for NR and the share of this demand well worked out between the respective NR producing countries it makes no sense to protectively hold on to these clones. The mechanics of how these clones should be transferred between NR producing countries needs to be worked out among members of both ANRPC and IRRDB .This will be a great advantage for countries such as Kampuchea and Myanmar with abundant land suitable for rubber cultivation and which have no access to some of the latest recommended clones. They are therefore obliged to continue planting of a primary clone such as GT 1 and RRIM 600 which was introduced for commercial planting in the early sixties with minimal potential for high yield productivity.

Translating Genetic Potential to Commercial Yields

The rubber breeders have through successive breeding programs raised the genetic potential yield of rubber trees from 500 kg per hectare per year in the nineteen thirties to 3000 kg per hectare at the present time. However the commercial yields achieved in most NR countries is less than the genetic potential yield due to several factors. These include poor stand of tappable trees, presence of several runts or laggards in a given stand and reduced number of tappings. Hence a comparison of experimental and commercial yields of two popularly planted clones namely GT 1 & RRIM 600 (**Figure 2**) shows that over a fifteen year cycle of tapping the commercial yields of both clones was only 80 to 93 % of the experimental yields. The national average yields in most of the NR countries has not changed very much over the last couple of years with levels hovering around 1300 to 1900 kg per hectare per year (**REP Main Report, LMC, 2004**).Thus examination of the annual average yields for the last ten years (2000 to 2009) for Surattani Province in South Thailand shows that the yields have ranged from 1605 to 1943 kg /ha/yr (**Table 1**) with a variation of only 338 kg/ha/yr. The data in fact shows that there has been a progressive decline in annual average yields from year 2005.

Thus planting of precocious high yielding clones will not result in the desired yield productivity unless efforts are made to bridge the gap between experimental and commercial yields. Breeding of new clones has resulted in high tree productivity (grams per tree per tapping) but this can only be translated into high land productivity (kg/ha/yr) if there is a reasonable tappable stand per hectare and the required number of tappings are achieved per month or per year.

Protracted Immaturity Period & Poor Stand at Maturity

A major disincentive for investment in NR cultivation is the prolonged immaturity period with zero returns during this period for the grower. Data summarized in **Table 2** for several countries shows that for popularly planted clones RRIM 600 and GT 1 the immaturity period can range from 6 to 8 years. It is a challenge to reduce this immaturity period to five years or less if rubber cultivation is to be attractive and if recent plantings can expeditiously contribute to the growing demand for NR. It has already been proven in research trials that a reduced immaturity period can be achieved but this needs to be reflected in large scale commercial plantings be it in smallholdings or large plantations.

It is the practice to plant between 480 to 550 trees per hectare at time of planting but invariably at time of opening for tapping , 6 t0 7 years from planting the stand would have been reduced to 450 trees or less. The loss in trees from planting to maturity could be due to white root disease which is a serious problem in some countries, pink disease which affects the fork of branches leading to premature branch break and storm damage. This is further compounded by lack of uniformity in a given stand due to use of poor quality planting materials at time of planting and the practice of protracted supplies for failed initial plantings thus resulting in a high percentage of runt trees or laggards which seldom catch up in growth or in yield productivity with plantings carried out initially.

The challenge is to ensure a high and uniform stand at time of opening for tapping if high yield productivity is to be achieved. This would be possible from planting of very vigorous and uniform planting materials through rigorous culling and selection of good quality planting materials in the nursery, using rootstocks resistant to white root disease , high yielding clones that are not susceptible to pink disease and adopting the recommended agronomic practices. White root disease is increasingly becoming a serious problem in several locations and there is a need to screen a broader range of potential rootstocks for resistance to this disease so that the industry has a wider choice to choose from.

Prevention of Major Leaf Diseases

There are two leaf diseases of major concern to NR namely South American Leaf Blight (Microcyclus Ulei) and Corynespora leaf disease (Corynespora cassiicola). These two diseases have a devastating effect on rubber trees with complete defoliation of the canopy in affected trees. This in turn will adversely affect the yield productivity of the trees. It is fortunate that most of the widely planted clones are resistant to these two diseases. However with the unrestricted movement of goods and people between Brazil and major NR producing countries there is an inherent risk that SALB could spread to other countries. It is apparent recently that there is a breakdown of resistance to Corynespora leaf disease with reports of several clones in Vietnam and Clone RRIM 600 in East Thailand being afflicted by this disease.

There is a need for heightened vigilance against these two diseases with adequate emergency measures in place to effectively tackle these two diseases in the event of a major outbreak. Additionally it will be necessary to screen all new clones for resistance to SALB in Brazil , possibly in Michelin Plantation in Brazil in collaboration with CIRAD, France (**Polymer & Tyre Asia, June/July 2010**). In a review of the Corynespora leaf disease in major NR producing countries carried out in year 2003 for the Common Fund for Commodities (**Sivakumaran & K.H Chee**) it was proposed that an international budwood nursery be set up in Sri Lanka under the auspices of the Rubber Research Institute of Sri Lanka where clones produced by various NR countries can be screened for resistance to Corynespora. It is not certain if this recommendation was implemented but it may be one option worth considering in view of the disease re-surfacing in some countries.

Increasing Problem of Tapper Shortage

This is a serious problem which is now affecting several NR producing countries even in countries such as India, Thailand and Cameroon where there is abundant labor. It is abundantly clear that rubber plantations be it smallholdings or large plantations are unable to attract workers to work as tappers even with prevailing unemployment. This problem is likely to become more serious in the years ahead with dire consequences for rubber plantations in trying to meet the increasing demand for NR. The failure of rubber plantations to attract workers could be attributed to several factors which among others are the low wages paid relative to employment in other sectors of the economy, strenuous work in mostly difficult environments particularly now that rubber cultivation has been relegated to marginal lands with planting on hilly terrain and steep slopes and the low social status accorded to rubber tappers in a given community.

In the short to medium term the only option is to opt for new exploitation technologies such as the RRIMFLOW short cut system which can help overcome some of the problems discouraging labor from working in rubber plantations. However for the long term the only option is to mechanize or automate tapping and collection operations though past attempts in this field were not very successful due to several practical problems encountered. It is generally accepted that tapping & collection operations in rubber are not easily amenable to mechanization or automation but nevertheless there is a pressing need for renewed and intensive R & D activities in this area for the long term survival of the NR industry.

Shortened Economic Life Span of Rubber trees

With proper management of the bark reserves on the rubber tree through use of appropriate exploitation systems the economic life span of rubber trees can be maintained up to thirty years or more. However most smallholders tend to exploit their trees with intensive tapping systems (long cuts on daily frequency of tapping) with consequently valuable bark sacrificed without compensatory increase in yield productivity. Further smallholders avoid tapping high yielding upward panels till two or three years before replanting with most of this bark consumed within a limited period. In view of these exploitation practices the economic life span of rubber trees in smallholdings is drastically reduced to twenty years or less with the need for accelerated replanting.

Since the smallholders will be the driving force in meeting the increased demand for NR it is necessary for effective transfer of appropriate exploitation systems such as the RRIMFLOW short cut system to smallholders to enable them to better manage the bark reserves on their trees with higher yield productivity and simultaneously achieving the desired economic life span of thirty or more years.

Impact of Climate Change on Yield Productivity

Although climate change involves several parameters nevertheless the discussion in this paper will be confined to rainfall incidence and number of days rain because it has a direct bearing on yield productivity of rubber trees through its effect on number of tapping days achieved per month or per year.

The total annual incidence of rainfall in various provinces of NR producing countries is summarized for six years from year 2004 to 2009 in **Table 3.** It is apparent from the data that though there is no consistent pattern of progressive increase in rainfall incidence from year 2004 to 2009 nevertheless there is a general trend towards an increase with exception of some years in the respective provinces in the five NR producing countries. Similarly the data for number of days rain per year summarized in **Table 4** shows that there is generally an increase towards the later years relative to the earlier years for most of the provinces in the five countries.

The increased number of rain days per year will mean reduced number of tapping days and consequently lower yield productivity. This is borne out by data extracted for rubber plantations in Kerala, India. Thus data summarized in **Table 5** for three years shows that the total yield of the plantation during high rainfall months was half or less than half of the total yield produced during the low rainfall months. The relationship between rainfall incidence and average yield productivity per hectare over a five year period illustrated in **Figure 3** shows that the yield per hectare was higher during years when the rainfall incidence was relatively low and vice versa during years with very high rainfall.

If with climate change the trend is towards higher rainfall incidence and rain days in years to come then this will affect the yield productivity of rubber plantations from reduced number of tapping days and curtail the ability to meet the increasing demand for NR. The potential losses in crop production due to tappings lost to rain are summarized in **Table 6.** The data worked out on the basis of several assumptions shows that the total yield lost due to rain can be substantial if large hectarages are involved. In monetary terms at current selling prices of rubber the losses in income can range from USD 76.5 million to 408 million for half a million hectares of mature rubber. The potential loss in crop due to rain can negate to a large extent the contribution of crop from 1 million hectares of rubber planted between years 2005 to 2008. It is evident that climate change will be a major challenge in meeting the increasing demand for NR.

TECHNOLOGY TO OVERCOME SOME OF THE CHALLENGES

An established technology that can provide a solution for some of the challenges highlighted above is the RRIMFLOW short cut system of exploitation (**Sivakumaran et al, 1996**). This system involves tapping of short cuts of standard 10 cm or 20 cm length cuts on reduced frequency of once in three or four days tapping in combination with gaseous hormone stimulation once in 10 days. The gaseous hormone is applied from a gas cylinder into a PVC applicator fixed at the desired position on the bark of the tree through a one way valve connected by a plastic tubing to the outlet tube attached to the body of the applicator.

The RRIMFLOW system of exploitation can markedly increase both tapper and land productivity with consequently higher incomes for tappers and higher profitability per hectare for plantation owners or smallholders. This technology will enable realization of the full genetic yield potentials of a given clone, markedly increase the tree productivity thus increasing the total productivity of low stand of trees , prolong the economic life span of rubber trees through use of short cuts and reduced bark consumption, - overcome to some extent the problem of tapper shortage through reduced frequencies of tapping and increased task sizes due to short cuts , attract workers to rubber plantations with prospect of higher incomes with minimal stress due to reduced length of tapping cuts , render uneconomic size smallholdings as profitable entities and increase by two or three fold the yields per tapping whenever trees can be tapped thus obviating to a large extent the loss of yield from reduced number of tappings. In addition adoption of this technology on a large scale will contribute significantly towards meeting the increasing demand for natural rubber.

Data provided on yield performance of the RRIMFLOW system in uneconomic sized smallholdings in both Malaysia and Thailand in **Figures 4 & 5** shows that the tree productivity was markedly increased by more than 3 to six times than that obtained from corresponding trees exploited on conventional tapping systems. In terms of land productivity the yields for smallholdings in Malaysia despite their uneconomic size were in the range of 2072 to 3249 kg per Ha Per Year.

The economic impact of the RRIMFLOW system on uneconomic sized holdings summarized in **Tables 7 & 8** shows that the smallholders earned high incomes per year despite having holdings of 0.6 to 1.6 hectares with 172 to 457 trees in Malaysia and holdings ranging in size from 0.53 hectares to 6.8 hectares with 187 to 2380 trees in Thailand. Data provided shows that the RRIMFLOW system is a viable option over the short to medium term to overcome some of the challenges highlighted in this paper.

CONCLUSION

1.Data published by IRSG shows an increasing demand for natural rubber from year 2010 to 2019 with NR share of the total elastomers consumed globally expected to increase from present levels of 42 % to 46 %. IRSG has also projected that there will be an increased production of NR to meet the increasing demand. These projections are based on past planting policies primarily in eleven Asian countries and the new planting of nearly one million hectares between the years 2005 to 2008.

2. The IRSG projections on production not withstanding it is apparent that there are several challenges to overcome if NR producers are to meet the increasing demand for NR. These concerns in part could account for moves in Europe and North America to look for alternatives to NR from other latex producing plants and genetically modified bacteria. These developments on the horizon are potential threats to the future of the NR industry.

3. Smallholders have become the largest producers in four of the six major NR producing countries. Hence the technology based transformation of smallholdings is the key to the future strength of the Global NR industry and one that will ensure that NR is the preferred elastomer for years to come.

4. The challenges that the NR industry has to overcome in meeting the increasing demand for NR are the narrow range of clones planted in major NR producing countries, translating genetic potential to commercial yields, protracted immaturity period and poor stand at maturity, prevention of major leaf diseases , increasing problem of tapper shortage, shortened economic life span of trees and impact of climate change on yield productivity.

5. An established technology that can provide a solution to some of the challenges highlighted over the short to medium term is the RRIMFLOW System of Exploitation.

ACKNOWLEDGEMENT

The Authors wish to express their thanks and appreciation to the conference organizers , Rubber PLAS 2010 for kindly accepting our paper for presentation at the Conference in Bangkok from 9th to 12th September 2010.

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FIGURE 1: SEVERAL NEW HIGH YIELDING CLONES WITH YIELD POTENTIALS OF 2000 TO 3000 KG/ HA / YR

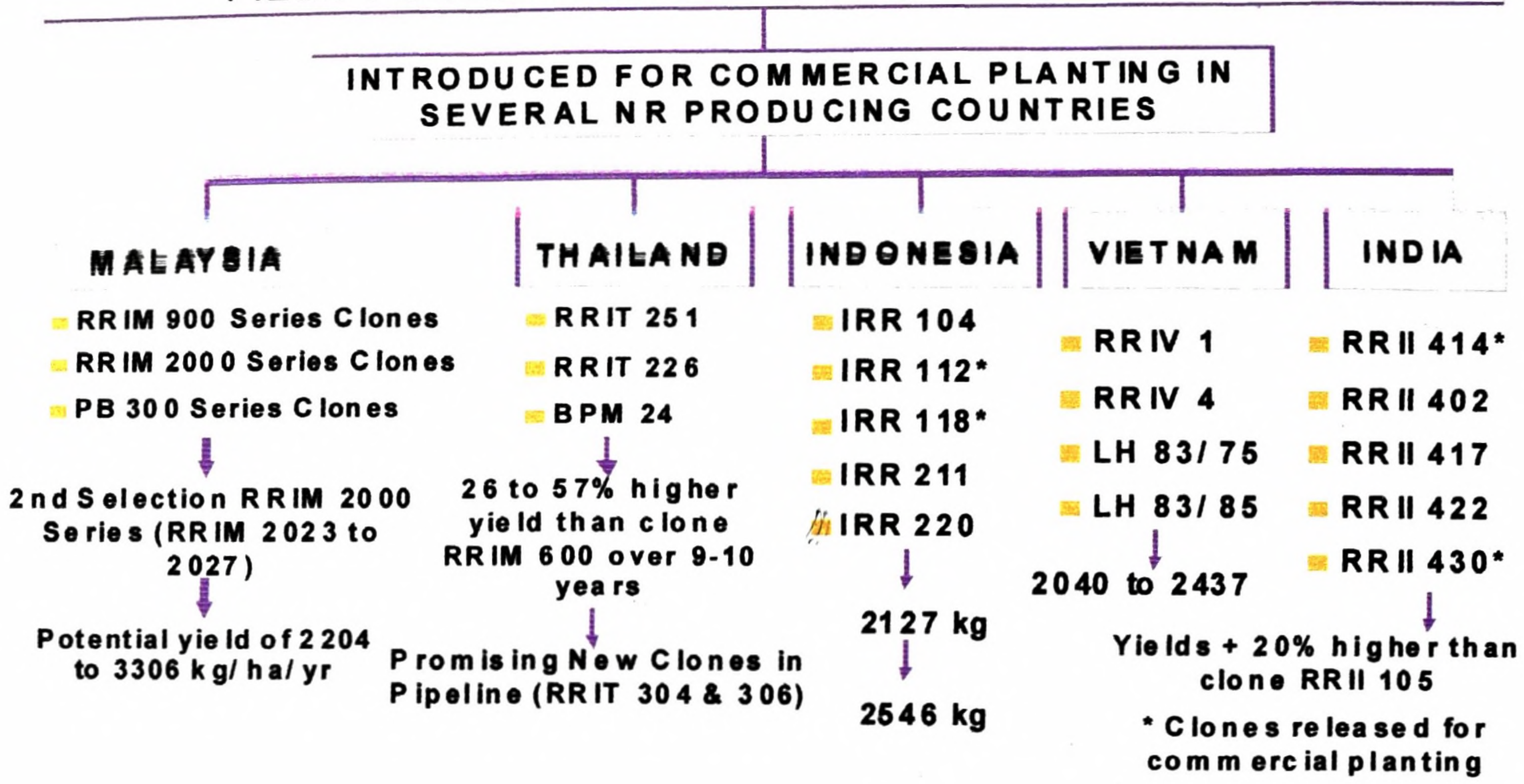
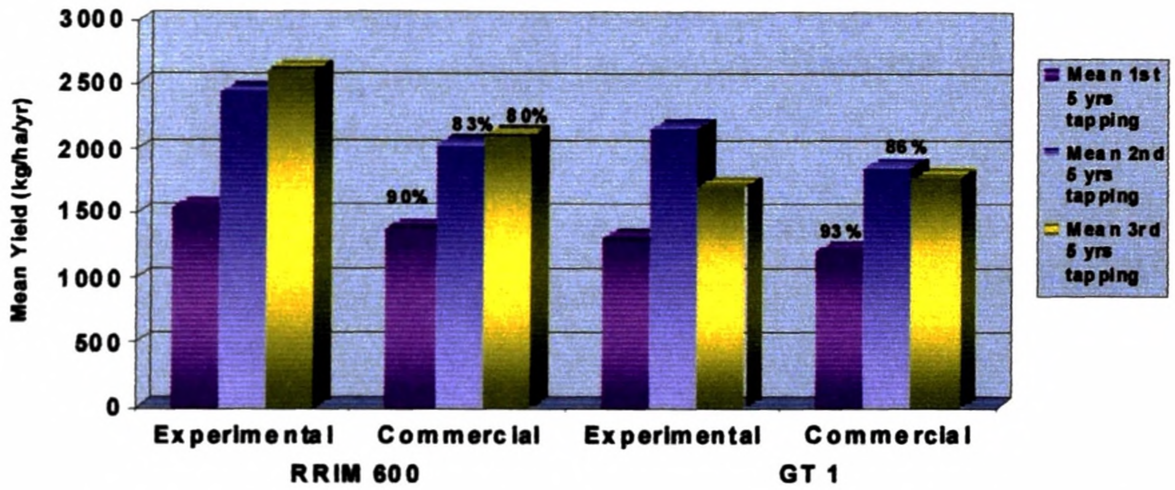
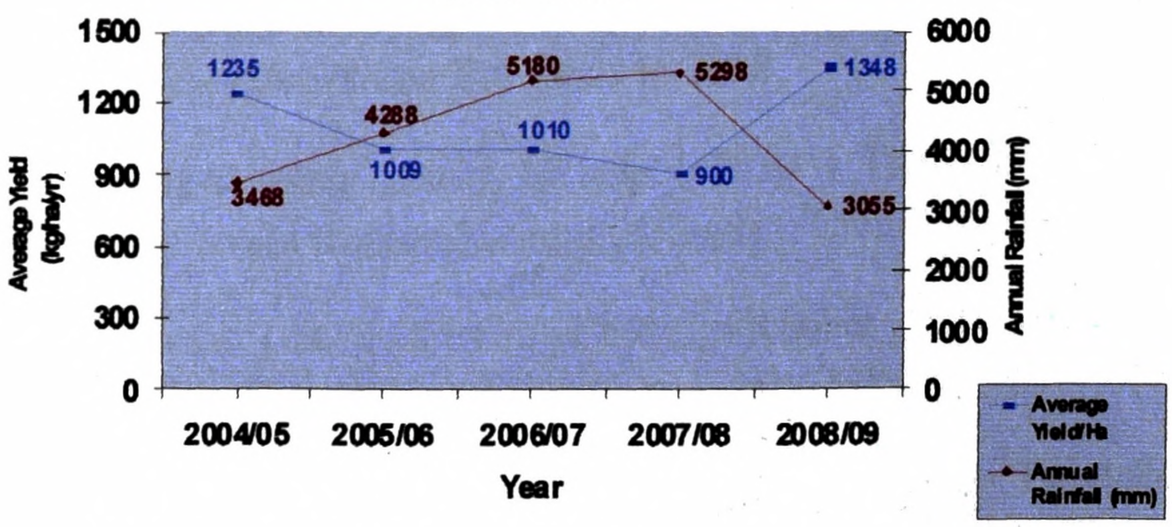


FIGURE 2: EXPERIMENTAL AND COMMERCIAL YIELDS COMPARED FOR TWO POPULARLY PLANTED CLONES (RRIM 600 & GT 1)



* Data extracted from MRB Publications; Data given for commercial data refers to several sites

FIGURE 3: RELATIONSHIP BETWEEN AVERAGE YIELD PER HECTARE AND ANNUAL RAINFALL INCIDENCE OVER FIVE YEAR PERIOD



* Data extracted from records of Rubber Plantation in Kerala, India

FIGURE 4: YIELD PERFORMANCE OF RF SYSTEM IN SMALLHOLDINGS IN MALAYSIA (OWNER-OPERATOR)

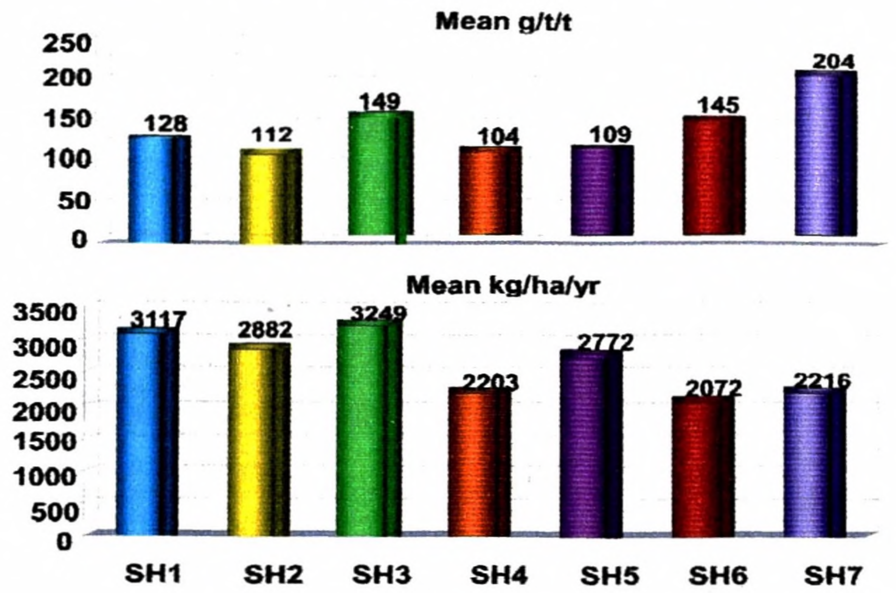


Figure 5: Yield Performance of RF System in Smallholdings in Thailand (Agent Based Management System)

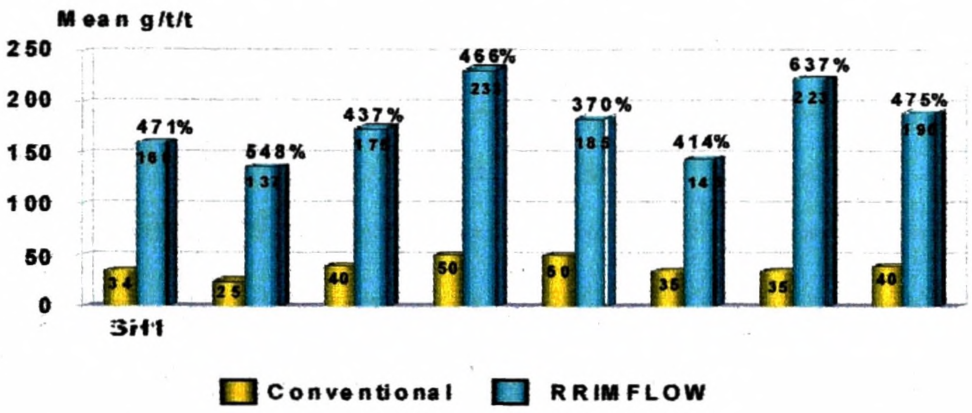


TABLE 1: CHANGES IN AVERAGE YIELDS PER RAI IN SURATTANI PROVINCE, THAILAND OVER A 10 YEAR PERIOD (2000 TO 2009)

No	Year	Average Yield (kg/Rai/yr)	Average Yield (kg/ha/yr)
1	2000	272	1768
2	2001	293	1904
3	2002	289	1878
4	2003	296	1924
5	2004	299	1943
6	2005	290	1885
7	2006	284	1846
8	2007	247	1605
9	2008	256	1664
10	2009	249	1618

*** Surattani Province has a mature area in tapping of 258,000 hectares and has the largest rubber hectarage among the 14 Southern Provinces.**

TABLE 2: IMMATURITY PERIOD OF RUBBER PLANTINGS IN SEVERAL NR COUNTRIES

No	Country	Location	Clone	Yr of Planting	Yr of Opening	Immaturity Period (years)
1	Malaysia	Land Scheme (Organised Holding)	Mixed (GT 1, RRIM 600, RRIM 712, PB 235, PB 217)	11/86	6/94	7+
2	Kampuchea	Plantation	GT 1	1999	2006	7
3	Papua New Guinea	Plantation	GT 1/GT 1 Mixed RRIM 600	1986	1994	7 to 8
4	Cameroon	Plantation	GT 1/ RRIM 600	1984	1990/91	6 to 7
5	Ivory Coast	Plantation	GT 1	1990	1996	6
6	Bangladesh	Plantation	RRIM 600	2003	2009	6

TABLE 3: CHANGES IN TOTAL ANNUAL INCIDENCE OF RAINFALL (mm) IN VARIOUS PROVINCES OF NR PRODUCING COUNTRIES

No	Country	Location	Year					
			2004	2005	2006	2007	2008	2009
1	Malaysia	Pendang, Kedah	-	2083	2368	2609	2127	2411
		Bahau, Negeri Sembilan	1726	1811	2096	2152	1993	1449
2	Sri Lanka	Estate 1	-	3418	3704	2437	3831	2654
		Estate 2	-	3805	3898	3784	4656	4062
		Estate 3	-	3194	3296	3129	3377	2951
3	Indonesia	Jambi	-	2159	1624	2424	2328	2356
		Jambi	2586	2630	2419	2676	-	
		Pekan Baru	3659	3037	2715	3615	-	-
		Sumatera Utara	2144	3213	3421	3167	-	-
		Palembang Sumatera Selatan	2389	3295	3406	4029	-	-
		West Kalimantan	2974	2906	2609	2608	2848	-
		Palembang	2355	2977	1753	2843	2590	2425
4	Cameroon	Niete	-	2098	2401	2312	2446	2514
5	Thailand	Songkla	1740	2608	1726	2001	2465	2345
		Surattani	-	1750	1703	2167	2485	1477

TABLE 4 : CHANGES IN TOTAL NUMBER OF DAYS RAIN IN A YEAR FOR VARIOUS PROVINCES IN NR PRODUCING COUNTRIES

No	Country	Location	Year					
			2004	2005	2006	2007	2008	2009
1	Malaysia	Pendang, Kedah	-	139	152	160	144	157
		Bahau, Negeri Sembilan	76	75	133	130	126	93
2	Sri Lanka	Estate 1	-	130	126	100	136	144
		Estate 2	-	185	192	178	208	213
		Estate 3	-	184	144	182	174	179
3	Indonesia	Jambi	118	115	104	140	126	135
		Jambi	112	142	110	111	-	
		Pekan Baru	128	102	123	169	-	-
		Sumatera Utara	144	158	166	149	-	-
		Palembang Sumatera Selatan	111	142	127	130	-	-
		Sekayu, Palembang	80	113	109	132	124	139
		West Kalimantan	119	146	120	143	139*	-
4	Cameroon	Niete	-	112	108	93	109	114
5	Thailand	Songkla	169	188	202	190	199	170
		Surattani	-	116	131	144	126	121

TABLE 5: TOTAL CROP PRODUCTION OF A PLANTATION COMPARED BETWEEN HIGH RAINFALL AND LOW RAINFALL MONTHS OVER A THREE YEAR PERIOD

No.	Year	Month	Rainfall Incidence (mm)	Total Crop (in tons)
1	2003-04	June	687	27.5
		July	672	44.3
		Aug	489	41.2
		Sept	7	85.3
		Dec	14.2	105.4
		Jan	0	80.8
2	2006-07	June	1031	1.2
		July	816	24.5
		Nov	976	92.5
		Oct	491	77.9
		Dec	0	120.6
		Jan	0	98.5
3	2007-08	July	1717	26.1
		Aug	822	32.6
		Sept	860	36.2
		Nov	132	76.7
		Dec	0	95.4
		Jan	0	71.1

*** Data extracted from records of rubber plantation in Kerala, India.**

TABLE 6: POTENTIAL LOSSES IN CROP PRODUCTION DUE TO TAPPINGS LOST TO RAIN*

No	Country	Hectarage	Increase in Tappings Bet Periods 2001 to 2004 & 2005 to 2009	AV Yield/Ha/ Per Tapping (kg)	Lost Yield per Ha/Yr (kg)	Total Yield Lost Due to Rain (Tons)	Lost Revenue (USD in (Million)
1	Jambi Indonesia	500,000	6	15	90	45,000	76.5
2	Sekayu Palembang Indonesia	500,000	32	15	480	240,000	408
3	Sri Lanka	110,000	106++	10	1060	116,600	198
4	Malaysia	500,000	18+++	15	270	135,000	229.5

*** Projections based on several assumptions**

1. Assumed Total Hectarage
2. Assumed Selling Price of TSR 20 is USD 3/kg & assumed cost of production of USD 1.30 per kg; Margin/kg = USD 1.70
3. ++ Lost Tappings due to rain over last 5 years (2005 to 2009)
4. +++ Increase in Lost tappings between year 2005 & 2009.

TABLE 7: ECONOMIC IMPACT OF RF SYSTEM IN SMALLHOLDINGS IN MALAYSIA (OWNER-OPERATOR)

Small-holding	Hectares	No. of Trees	Net Income/ Holding/Yr. (USD)
1	0.674	192	2,814
2	0.714	354	4,508
3	0.600	172	2,398
4	1.600	457	4,065
5	0.810	244	1,905

TABLE 8: ECONOMIC IMPACT OF RF SYSTEM IN SMALLHOLDINGS IN THAILAND (AGENT BASED MANAGEMENT SYSTEM)

Small-holding	Hectares	No. of trees	Additional Income/ tree/yr. (USD)	Additional Net Income for owner/tree/yr. (USD)
1	1.080	378	6.60	3.60
2	0.53	187	7.40	4.40
3	2.42	848	7.10	4.10
4	6.80	2380	14.50	11.50
5	15.3	5349	10.30	7.30
6	3.0	1056	7.24	4.24
7	1.35	537	13.11	10.11
8	1.19	417	9.87	6.87

*** Costs paid to Agent for RF System/tree/yr. – USD 3.00**