THESIS

EFFECTS OF FERTILIZER AND IRRIGATION ON YIELD AND QUALITY OF RUBBER (*Hevea brasiliensis*) GROWN AT CHANTHABURI PROVINCE, THAILAND

SOPHEAVEASNA MAK

GRADUATE SCHOOL, KASETSART UNIVERSITY

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NAME: Mr. Sopheaveasna Mak

THIS THESIS HAS BEEN ACCEPTED BY

.... **THESIS ADVISOR**
(Professor Aphiphan Pookpakdi, Ph.D.)

.... **COMMITTEE MEMBER**
(Assistant Professor Poonpipope Kasemsap, Ph.D.)

.... **COMMITTEE MEMBER**
(Miss Sali Chinsathit, Ph.D.)

.... **PROGRAM CHAIRMAN**
(Associate Professor Somnuk Wongtong, Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON ....

.... **DEAN**
(Associate Professor Vinai Artkongharn, M.A.)

THESIS

EFFECTS OF FERTILIZER AND IRRIGATION ON YIELD AND QUALITY OF RUBBER (*Hevea brasiliensis*) GROWN AT CHANTHABURI PROVINCE, THAILAND

SOPHEAVEASNA MAK

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The experiment on the effect of fertilizer and irrigation on yield and quality of rubber (*Hevea brasiliensis*) grown at Chanthaburi province was an on-farm research conducted at the rubber plantation of Sindane Thai Rubber Co, Ltd. The objective of the experiment was to investigate the effect of irrigation and fertilizer on yield and quality of rubber and whether this practice might be used to increase the economic return of the farmers. Experimental design used was a split plot with three replications, having irrigation and non irrigation as main plots and three formula of NPK fertilizer of 15-7-18, 30-5-18 and 23-5-18 as subplots factorially arranged within each main plot. The trial was conducted on the clay loam soil of Klongluk series having the pH of 5.0 with 1.6% organic matter, 103.3 and 134 ppm of P and K respectively. The result of the experiment revealed that irrigation treatment increased the yield per tree per tapping, monthly production and also total rubber production per year. Latex yield also increased as the result of irrigation treatment. Under non-irrigation, the percentage of dry rubber content (DRC) was higher than those of irrigation treatment. Percentage of DRC was negatively correlated with both rubber yield and latex yield. Result of latex diagnosis analysis showed that sucrose and total solid content (TSC) of samples were not affected by irrigation and fertilizer treatments. Inorganic phosphate (Pi) increased in the irrigated plot than those of non-irrigation but was not significantly differed ($P>0.05$) among others. Thiol content in latex samples taken from the irrigated plot were significantly ($P<0.05$) higher than non-irrigated plots. Girth of rubber increased as the result of irrigation application while the percentage of tapping panel dryness (%TPD) was higher in non-irrigation treatment. The result of this study did not showed the effect of fertilizer treatments in any of the parameters measured. It may be possible that it would take a longer time than the experimental period before the effect of fertilizer will be pronounced.

______________________ ______________________ 21 / July / 2006

Student's Signature Thesis Advisor's Signature

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Sopheaveasna Mak

June, 2006

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INTRODUCTION

Natural rubber is an important agricultural commodity essential for the manufacturing of a wide range of products, the largest single market (70% of world consumption) being the tire industry.

Natural rubber co-exists with a range of synthetic rubbers, each of which a defined position in the properties/price spectrum. Natural rubber is the strongest of all rubbers and has excellent dynamic properties such as resistance to fatigue but it is less resistant to environmental damage (e.g. by ozone in the atmosphere and by oils) than are some synthetic rubbers. In some products the choice of rubber is determined solely by properties (e.g. aircraft tires which require 100% natural rubber) but in many products there is a competition between natural and synthetic rubbers on the basis of price and properties.

World production of natural rubber in 1996 was 6.34 million tons while the world consumption during the same year was 6.13 million tons which correspond to 39% of world consumption of all elastomers (i.e. natural plus synthetic rubber).

Natural rubber is sold through a complex chain of local, national and international dealers on world markets at a price which is, in theory, determined by supply and demand, but there is a growing trend towards direct producer/consumer deals bypasses the markets.

Production of rubber from the tree *Hevea brasiliensis* plays a major role in the socio-economic fabric of many developing countries. Over 80 percent of production comes from small farms, each typically two hectares or less.

Asia is the centre of production, accounting for 95% of world production. The three largest producers are Thailand, Indonesia and Malaysia. Production in Africa accounts for 4% while production in tropical America, the original home of *Hevea,* is only 1%.

Traditionally, natural rubber is an exported crop and until recently consumption was mainly in the industrialized countries. A significant new trend has emerged in recent years whereby most of the producing countries are moving “downstream”, converting a significant proportion of their production into manufactured products for domestic use and export with the result that the three largest exporting countries have now joined the ranks of the 12 largest countries imported (e.g. United States, Japan, Germany, France, Italy, Britain, China, Korea Rep, Spain, Brazil, Canada and Greece) (INRO, 1997).

Driven largely by increasing demand from China and other Asian countries, rubber prices in world major rubber exchange markets continued upward in 2003 and early 2004. The average price of RSS3 rubber in 2003 in Thailand was 44.5 Baht/kg (around US $ 1.07/kg), which was 36% higher than that in 2002 and 77% higher than 2001. After reaching 55.9 Baht/kg in June in 2004, the price of RSS3 rubber in Thailand started falling because of expected higher production in 2004 and lower growth in demand from China. The average price in August was still around 52 Baht/kg, about 16% higher than in 2003 (FAO, 2004). The Thai natural rubber industry consisted of about 200 rubber factories and 100 exporting companies. There are more than 3 million farmers (nearly 5% of the population in Thailand) working in over 2 million hectares of rubber plantation. 97% of the plantations are smallholdings with areas of two-four hectares located mostly in the southern and Eastern provinces of Thailand. The average yield of natural rubber is 1560 kg/ha/year in Thailand.

Smallholders sell their rubber in the form of unsmoked sheets, cup lumps or latex to a few hundred outlets comprising local dealers or the bigger district dealers who then resell them to processors/exporters. Thai exports are to 67 countries including Japan (36%), USA (15%), China (15%) and South Korea (7%) (RRIT, 2004). The price of oil, which is the basic material for producing synthetic rubbers, has risen significantly over the past few years to exceed US$ 50/barrel, thus giving natural rubber some price competitiveness over synthetic material.

Global production recorded 8 million tons in 2003, which was about 9 per cent higher than the record production of 7.35 million tons set in 2002, while, production in Thailand, the world's largest producer, reached another new record of 2.87 million tons after reaching 2.62 million tons in 2002, reflecting about 10 per cent rising in output. Higher prices have been the major factor to induce intensive tapping. After declining for several years in the late 1990, production in Malaysia recovered to reach nearly 1 million tons in 2003, about 29 per cent higher than in 1999. The higher price of natural rubber resulted in a shift in the comparative advantage of rubber production against other crops, in particular palm oil, which attracted smallholders to revive rubber tapping. Indonesia also experienced a significant increase in production in the past few years. In 2003, total output reached 1.79 million tons, which was 10 per cent more than 2002 (FAO, 2004).

There are an estimated approximately 60,000 hectares planted to rubber in Cambodia, including 44,000 hectares of rubber under 7 state-owned rubber estates (SOREs), now autonomous public enterprises: Chamkar Andong, Boeng Ket, Chup, Krek, Peam Cheang, Memot and Snoul, with a total concession area of about 72,400 hectares. All are in Kampong Cham province except Snoul which is in Kratie province, but Chup and Krek are developing 12,000 hectares of new plantation in Kampong Thom province (SOREs, 2003).

About 700 hectares in an area of 1,033 hectares were under the Rubber Research Institute of Cambodia (RRICAM), about 4,500 hectares belong to two private estates, leased from Government: Ta Peo (about 2,000 hectares of rubber) close to, and previously part of, Chup in Kampong Cham province; and Tei Seng (2,300 hectares of rubber, but much of it outside estate control) in Ratanakiri province.

An estimated 10,000 hectares of smallholder or family rubber producer are found mainly in Kampong Cham and Ratanakiri, but also some are Kratie, Kampong Thom, and Mondulkiri as well.

At this point, it can be stated that natural rubber production in Cambodia recorded 47,000 tons in 2002 higher than the past few years (ASDP, 2003).

OBJECTIVES

Natural rubber productions are not stable at any time. This is depending on many factors especially the weather factor. In dry season (February to April) the natural rubber productions are lower than at the rainy and winter seasons, due to water stress. Fertilizer is one of the factor which may increase the yield and quality of rubber. However the effect of fertilizer may be pronounced during the period where the soil moisture is ample.

It was proposed that the effect of irrigation and fertilizer must be investigated together especially as an on-farm research. Due to the high rubber prize influenced by the world market, farmers in the eastern provinces of Thailand such as those at Chanthaburi, Rayong or Trat would like to switch from fruit crop orchard into the rubber plantation due to the high input cost and the prize fructification of fruit crops. If the method of increasing the yield of rubber through the irrigation and fertilizer work and the rubber yield could be increased up to the point when the economic return achieved, rubber cultivation might be an alternative crop cultivation for the farmers in those specific areas.

Therefore the objective of this study was to investigate the effects of irrigation and fertilizer application on the yield and quality of rubber when grown under irrigation and rainfed condition. In order to evaluate the real situation of rubber growth in the natural plantation, the experiment would be conducted as an on-farm research in the existed rubber plantation. It was anticipated that the result of this experiment could be used as the practical recommendation especially in relation to the water and fertilizer management to those farmers growing rubber in the vicinity of Chanthaburi, Rayong or Trat which was the target areas of this research investigation.

REVIEW OF LITERATURE

Natural rubber production in Asia reached 7,632,000 tons in 2004, which was about 3.6 per cent higher than the record production of 7,361,000 tons set in 2003. Production in Thailand, the world's largest producer were 2,866,000 tons in 2004, slightly lower than the production of 2,876,005 tons in 2003 while natural rubber production in Cambodia increased to 48,000 tons in 2004 which was higher than the production of 47,000 tons in 2003 (FAO, 2004).

In order to increase natural rubber production, several technologies are required; such technologies must be generated by researcher and further tested them in the real farm plantation in order to develop as an appropriate technology. Technologies which are needed for the farmer in order to increase their rubber production are plenty. However, in this research report, certain technology was emphasized as technologies related to the research which would be specifically conducted. Such production technologies were as followed:

1. Rubber ecology
2. Varietals improvement
3. Cultural practices
    - 3.1. Tapping system
    - 3.2. Irrigation
    - 3.3. Nutrient status and fertilizer requirement
    - 3.4. Latex diagnosis

1. Rubber ecology

Hevea brasiliensis is a tropical crop, growing best at temperatures of 20-28 °C with a well-distributed annual rainfall of 1,800-2,000 mm. It can be grown satisfactorily up to 600 meters above sea level, and will grow well on most soil provided an adequate drainage. The required temperature and rainfall for growing rubber are those between the 10° latitudes on either side of the equator, but rubber can actually extend their growth and distribution to the greater extents of latitudes.

Excessive rainfall interferes with tapping and collection of latex although rain guards lessen this hazard. Drought is also a serious problem, although it is probable known that *Hevea* could be cultivated with irrigation. Prolonged periods of low temperature lengthen the time for trees to reach their maturity. High salinity is a problem in some drought-prone areas.

In China strong wind are generally aggravated by being accompanied by low temperatures. In that particular area it is normal to cultivate rubber in relatively small block to lessen wind damage and to grow windbreaks of Eucalyptus. *Hevea* is sensitive to high water tables and severe tree damage may result from flooding. Some clones developed on Hainan Island were capable of surviving temperatures as low as - 1 °C. Tapping panels were sealed or dressed during winter (IRRDB, 2002).

2. Varietals improvement

In Thailand, the main research has been generated by the Department of Agriculture, Ministry of Agriculture and Cooperatives for rubber production. Research on varietals improvement had been emphasized in order to provide the farmers with suitable rubber cultivars performing good growth and high yield. In the year 2003, several cultivars of rubber had been introduced to the farmers. Cultivars of rubber recommended by the Department of Agriculture are divided into three groups as followed:

2.1. High yield varieties:

Varieties of rubber considered as high yielding clones are RRIT 251, RRIT 226, BPM 24 and RRIM 600.

For the clone of RRIT 251, ten years average yield was 2,856.3 kg/ha/year (RRIT, 2000), the growth and bark thickness of this variety are medium and the recommendation for tapping system is ½ S, d/2 . Clone RRIT 251 is moderately resisted to black stripe, phytophthora, oidium, bird eye spot and pink diseases. The rubber tree has less bark dryness and medium resistance to strong wind. Clone RRIT 251 should not be planted at slope land particularly in the area which have less surface soil and high level of underground water.

For the clone RRIT 226, the eight years average yield obtained was 2,162.5 kg/ha/year (RRIT, 2000). The growth and bark thickness of RRIT 226 are considered medium before and after the tapping period. Since the trunk of this variety is rather uniform, the tapping system recommended are ½ S, d/2 (RRIT, 2000). Clone RRIT 226 is highly resistant to phytophthora, black stripe disease and moderately resistant to bird eye spot and pink diseases but susceptible to oidium disease. This clone can be planted at slope land with high humidity. However, it should not be planted at the area where top soil is thin and high underground water exist (RRIT, 2000).

For the clone BPM 24, the average yield reported was 1,950 kg/ha/year (RRIT, 2000). Yield can be slightly increased using chemical application. Variety BPM 24 performed good growth, producing a thick old bark but the new bark is rather medium. Recommendation for tapping is ½ S, d/2, however, if tapping system of ½ S, d/1 is imposed, it will resulted to the rapid dryness of the bark after tapping.

Clone BPM 24 is highly resistant to phytophthora disease and moderately resistant to black stripe, oidium, bird eye spot and pink diseases. It is considered as moderate resistace to strong wind and it does not caused fast bark dryness. According to the recommendation by the Department of Agriculture, this clone can be planted at slope land with thin surface soil, high level of underground water and high moisture area (RRIT, 2000).

Clone RRIM 600 produced the average yield of 1,806.3 kg/ha/year (RRIT, 2000). The yield can be moderately increased when the chemical is applied (RRIT, 2000). Yield is heavily reduced when the tree drops its leaves especially in cool season between December and January. The growth of this variety is medium and the old bark is much thinner than the new bark and the tapping system recommended for this variety is ½ S, d/2. Clone RRIM 600 is moderately resistant to oidium, bird eye spot disease and also moderately resistant to strong wind and has less bark dryness but very susceptible to phytophthora , black stripe diseases and susceptible to pink disease. This clone can be planted at slope land but should not be planted at the thin surface soil particularly in the area where high underground water exist.

2.2. Cultivars which have high wood quality

In Thailand very good wood quality of rubber cultivars are recommended by the Department of Agriculture. Those varieties are RRIT 402, AVROS 2037 and BPM 1, where the moderately high wood quality cultivars introduced are RRIT 401, RRIT 403, RRIT 203 and RRIT 118 (RRIT, 2000).

For the varieties processing the high wood quality of rubber, their cultivar descriptions were as followed:

Clone RRIT 402 is considered as fast growing variety. When rubber is six years old, the girth size is equal to 51.6 cm (when measured at 1.0 m high from the ground level). The branches are plenty with strong and straight trunk; therefore, the tree produces big and dense canopy. Leaves of the tree drop much early than other cultivars. At six years old, the tree produced 0.11 m^3 of wood/tree which is equivalent to 48 m^3/ha. This cultivar is highly resistant to bird eye spot, moderately resistant to oidium and phytophthora diseases (RRIT, 2000). Clone AVROS 2037 is the fast growing cultivars. When rubber tree is 6, 15 and 20 years old, its girth size is equal to 50.3, 78.5 and 87.3 cm, respectively. This cultivar of rubber produces several leaves during the period the tree is young. Branches are small but there are many in numbers and fall off easily. When mature, one or two branches are attached at the top of the tree. Because of the branching characteristic, good light penetration can be observed in the plantation where this rubber cultivar is planted. AVROS 2037 produce the straight trunk and canopy in the circular manner. At 6, 15 and 20 years old, wood yield of 0.10, 0.31 and 0.43 m^3/tree are produced which equal to 45, 144 and 180 m^3/ha respectively (RRIT, 2000). Clone AVROS 2037 is strongly resistant to bird eye spot, pink diseases and strong wind also. It is moderately resistant to oidium and susceptible to phytophthora. This clone should not be planted at slope land where the areas have thin top soil and high level of underground water.

Clone BPM 1 is also a fast growing rubber tree. At 6, 15 and 20 years the girth size is 50.1, 78.1 and 86.1 cm. Wood yield of clone BPM 1 at such respective ages are 0.1, 0.31 and 0.43 m^3/tree which are equal to 44, 143 and 180 m^3/ha (RRIT, 2000). At young stage, this rubber cultivar processes very few branches but later on, the leaves and branches increase in number and plant produce large canopy over the ground. Clone BPM 1 is resisted to phytophthora disease and strong wind. It is moderately resisted to oidium, bird eye spot and pink diseases. This clone can be planted at slope land where the top soil is thin with high level of underground water (RRIT, 2000).

2.3. High yield with high wood quality cultivars:

Several cultivars of rubber grown in Thailand are considered high wood quality as well as high yield. The first grades of those cultivars are PB 235, PB 255, PB 260 and RRIC 110 while the second grades are RRIT 312, RRIT 325, RRIT 404, RRIT 407, RRIT409 and RRIC 121 (RRIT, 2000).

In Cambodia, there are many good rubber cultivars cultivated, some of them were introduced through the French assistance and some, by Vietnamese experts. At present, the Rubber Research Institute of Cambodia (RRICAM) multiplies several rubber varieties for research and production. Zoning for rubber production is done by RRICAM in order to match the suitable rubber cultivar to its best adapted growing areas. Extension of rubber is also done by RRICAM to increase the national rubber production. Varieties of rubber which farmers choose to grow in Cambodia are GT 1, PR 107, PB 235, PB 260 and RRIM 600 (RRICAM, 2003).

3. Cultural practices

Numbers of agronomic practices are required to rubber production in order to stimulate good growth and yield both in term of quality and quantity. This section discussed only some of the important agronomic practices related to the experiment conducted in this study as follows:

3.1. Tapping system

3.1.1. Standard of tapability

Rubber trees are tapped only after they attain a standard girth. It is well known that tapping reduces growth of rubber trees. Therefore, to obtain sustained yield for a number of years, it is necessary to maintain a satisfactory rate of growth of trees under tapping. If trees are tapped before attaining the specified girth, the yield obtained will not be economical in the long run (Abraham and Hashim, 1983). Hence, a standard for tapability has been fixed after considering all these aspects. The standard is different for seedlings and budding owing to the difference in the anatomy of bark and shape of trunk.

Seedling trees are opened at a height of 50 cm, when the girth at that level is 50 cm. Often, it is preferred to open at the height of 90 cm when the girth at that level is 50 cm. However, the specified for opening subsequent panels on a seedling tree is 100 cm (Abraham and Hashim, 1983).

Budded trees are considered tapable when they attain a girth of 50 cm at a height of 125 cm from the bud union. Subsequent panels are also opened at the same height. This height has been fixed after considering the average height of tapers and the convenience in tapping. Although opening for tapping at 175 cm did not showed much variation in yield (Abraham and Hashim, 1983), it resulted in excessive wounding and spillage. In Thailand, budded trees are opened for tapping at a height of 150 cm from the bud union, when the girth at that level is 50 cm (IRRDB, 2003).

Tapability of trees is assessed using suitable girth wires. Girth wires are made by fixing a piece of wires of 55 or 50 cm length respectively on a straight stick 50 cm long for seedling trees and 125 cm long for budded trees. For assessing tapability, the stick is held against the tree with one end on the ground (for seedling trees), or on the bud union (in the case of budded plants) and the wires on the other end is wounded around the tree. If the tree ends of the wires just meet or leave a gap, it indicates that the tree has attained standard tapable girth and is marked for tapping. Alternatively measuring tapes can be used (Abraham and Hashim, 1983).

It is recommended to begin tapping when 70 per cent of the trees in a selected area attain the standard tapping girth. Generally it takes six to seven years to reach this stage. However, by planting the advanced planting materials such as the poly bag plants, the immaturity period can be reduced (IRRDB, 2003).

3.1.2. Marking

It is economic to begin tapping when 70 per cent of the trees in a selected area attain the standard tapable girth. Generally it takes six to seven years to reach this stage. However, by planting advanced planting materials like poly bag plants, the immaturity period can be reduced. Panel are marked on the trees selected for tapping, using a template and marking knife, parallel to the contour terrace or planting line to facilitate efficient tapping operation. The template is made of a strip of flexible metal, 16 to 18 cm wide for seedlings and 20 to 23 cm for budding. Separate templates are required for seedlings and budding and also should be made in such a way that when used to mark, the slope of the cut should be 25° for seedlings and 30° for buddings.

After deciding the position of the panel, a vertical line, called front channel line, is drawn. On this line, the opening height is marked. Since half spiral tapping is the standard, the half circumference of the tree at the opening is determined.

Another vertical line, called back channel line, is marked on the half spiral point above the opening height. With the aid of the template placed between these two lines, at the opening height, ensuring a high left to low right, the line for tapping cut and a few guide lines are marked through the grooves. After marking the guide lines, spout and cup hanger are fixed. Subsequent guide lines are marked every year before commencing of tapping.

3.1.3. Tapping practices:

Tapping is the process of getting latex from the bark of rubber tree, it is considered the process of controlled wounding of the bark and rubber trees are exploited by regularly removing a thin shaving of bark from the surface of the tapping cut at special specific intervals.

Latex vessels in the bark are oriented at an angle between 2 and 7° from the vertical, low left to high right. Therefore, a cut from the high left to the low right of the stem severe maximum number of latex vessels.

Tapping cut on a budded tree should bare a slope of 30° to the horizontal. Since the bark of seedling trees is fairly thick, the cut should have a slope of 25°. A very steep cut leads to wastage of bark when tapping reaches the base of the tree and too flat of cut leads to overflow (spillage) of latex. The slope should be marked annually with appropriate templates. Slopes, other than the recommended, have not resulted in any increase in yield (de Jonge, 1919). The tapping cut should have an inward slope towards cambium. Absence of such slope can also lead to spillage.

Response to different tapping systems varies from clone to clone. In general, budded trees are to be tapped on half spiral alternate daily (1/2 S d/2) system and seedlings on half spiral third daily (1/2 S d/3) system. There are, however, certain clones like RRII 105, PB 235, PB 260 and PB 28/59, which are prone to TPD under alternate daily system (Sulochanamma *et al*., 1993). The incidence of tapping panel dryness in such clones, lead into the recommendation of adoption of d/3 tapping frequency. It is preferable to resort to d/3 frequency if high incidence of panel dryness is encountered. Daily tapping of trees will lead to more incidence of panel dryness and should be avoided.

For high yield cultivars, d/3 frequency can be adopted from opening of the virgin bark (Ng *et al.,* 1965). Although the yield per hectare may be marginally lower during the initial period, the difference between d/2 and d/3 system will be narrowed in course of time and there will be an ultimate saving in the cost under d/3 system with increase in net profit. Yield varies with the clone, age of the tree, fertility of the soil, climatic condition, tapping system used and skill of the taper (Ashplant, 1942).

a. Depth of tapping and bark consumption

Tapping is a highly skilled operation. The tapping cut should be sufficiently deep but should not injure the cambium. A good taper acquires this skill through practice and will tap to the optimum depth of within 0.5 mm of the cambium to obtain optimum yield without injuring the cambium. Shallow tapping results in considerable loss of crop. To remove the plugs of coagulated latex at the cut ends of latex vessels, it is enough to cut off only a thin layer of bark at each tapping. Yield is not enhanced further with increase in thickness of the bark shaving (de Jonge and Warriae, 1965).However, under low frequency tapping systems, a slightly thicker bark shaving per tapping is to be removed. Even removal of bark along the whole of the tapping cut up to the correct depth, is important. Average annual bark consumption on half spiral cut of different frequencies are 20-23 cm for every alternative day, 16-18 cm for every three days interval and 14-16 cm for every four days interval (de Jonge and Warriae, 1965).

Bark regeneration (formation of the renewed panel) is brought about by the activity of the cambium. The rate and extent of renewal are dependent on the inherent genetic characters of the planting material, fertility of the soil, climatic conditions, tapping system, intensity and quality of tapping, planting density, disease incidence, etc. In the renewed panel, slightly higher bark consumption is allowable in view of its lower thickness.

b. Time of tapping

It is necessary to commence tapping early in the morning as late tapping will reduce latex yield due to increased transpiration leading to lower turgor pressure. Such reduction is more marked in the summer months. For pre-dawn tapping, head lights can be used. In practice, the beginning and end points of the task are changed periodically to allow comparable period of latex flow from all the trees in a block. In Thailand, most tapping systems are ½ S d/2 and the farmers have been tapping at night time for their rubber around twenty one pm at night and they collected their latex at four or five am in the morning and then transported to factory or the place for processing. In Cambodia, the tapping system is ½ S d/3 and the farmer initially tap at five to six am in early morning and they collected latex production at 11 to 12 am at the same day and transported them to factory for processing to be made as crumb of rubber and rubber smoke sheet (RRICAM, 2003).

c. Tapping task

Number of trees allotted to a taper for a day's tapping is known as tapping task. Task size is fixed on the basis of stand per hectare and topography of land. Recommended tapping task varies from 275-550 trees, in Sri Lanka it is 275 to 325, in India it is 300 and it is 500 in Malaysia, Thailand and Cambodia. In Vietnam, the task size is 400-555 trees (IRRDB, 2003).

In the small holdings there is much variation in tapping task in practice with the wide range of 200-800 trees. In India it is 200-400. In Thailand task used is very high (700-800) and in Vietnam it is 400-800. Again it is very low in Sri Lanka (200-300).

In Cambodia, the best period for opening new fields for tapping is in March to April (RRICAM, 2003). The trees that left behind for the requirement of standard girth may be considered for opening in September. The tapping cut is opened along the uppermost template marking. The markings below serve as guide lines for subsequent tapings to maintain the slope of the cut and to control bark consumption.

3.2. Irrigation

Water is an essential resource for plant life and metabolism. At the cellular level, water is used in chemical reactions as well as to differentiate membranes and organelles. At the whole-plant level, it is the main carrier for substances traveling among plant organs and tissues. Moreover, because of the large difference in water potential between the hydrated plant cell and the dry atmosphere, no other substance in plants is replaced in the same quantities as water. Thus any limitation in the availability of water generally know as water stress affects almost all plant functions, including the ability of leaves to assimilate carbon dioxide and roots to take up nutrients (Kramer,1988; Passioura,1988a; and Schulze *et al*., 1988c). Plant water use and plant water relation should not be viewed as independent parameters; they can only be understood from their interrelation with other resources at the whole-plant level. Plant water use and plant water relation can only be understood from their interaction with other processes at the whole-plant level, particularly with plant nutrition. Internal circulation of elements through phloem and xylem may not only determine the range over which water potentials and transpiration vary during the day, but also mediate hormonal signals from the root during soil water stress (Schulze, 1991). Phloem transport may play a much larger role in mediating root signals. Long distance transport of water from the soil through the plant occurs in the xylem (vessels or tracheids) under tension (Cochard *et al*., 1992). Plant water uptake change the physical properties of the soil. Thus, by its very existence, the plant alters the availability of water in the soil, which may affect plant survival in the long run, especially if the availability of water is low.

Plantations of rubber *Hevea brasiliensis* are traditionally raised under rainfed condition except in nurseries where essential irrigation is given. Ideally, monthly rainfall should be sufficient to meet the water requirements of the plantation. In the tropical monsoon climate, the potential evapotranspiration rate is around four mm a day (Montieth, 1977) and rainfall of 125 mm a month evenly distributed through the year is considered essential to maintain optimum gaseous exchange (Sanjeeva Rao and Vijayakumar, 1992).

Though the traditional rubber growing belt in Asian countries received an average annual rainfall of 2,500 mm, only a few rains are received during the summer season (November to April). A moderate water stress is experienced during this period. Rubber plantations in these areas are usually raised under rainfed conditions with the plants growing on the residual soil moisture during the summer season. Under rainfed conditions, rubber plants have an immaturity period up to seven years. Irrigation during summer season can enhance the growth and reduce the unproductive period (Pushparajah and Haridas, 1977; Omont, 1982; Jessy *et al*., 1994).

Severe growth reduction and longer immaturity periods have been reported (Chandrashekar *et al*., 1990; Mohankrisshna *et al*., 1991; Chandrashekar *et al*., 1994; RRII, 1995-1996). While time taken to attain tappable girth by the trunk (50 cm girth at 125 cm above bud union) was usually six-seven years in the southern part of the west coast of India where rainfall was sufficient, it was more than 10 year in North Konkan which was in the area where drought and high summer temperature had occurred (Mohankrishna *et al*., 1991). These situation quantified stomatal closure of rubber and simultaneously reduced CO_2 assimilation and transpiration in both rainfed and irrigated young *H. brasiliensis* plants in that particular two regions.

In Thailand, it has been reported that rubber growth was vigorous and latex yield was high when plants were grown in the region where rainfall amount was from 2,000 to 2,500 mm.

All year distribution seemed much better for rubber growth however 5 – 6 wet months per year was found sufficient. At least 1,500 mm of rainfall was needed for good rubber growth when grown in Thailand (DOA, 1999).

3.2.1. Effect of irrigation

Irrigation results in highly significant increase in growth. The biomass of irrigated rubber tree was 2.8 times more than those of the rainfed tree (Vijayakumar *et al*., 1988). More than 50% of the trees under irrigation treatment attained tappable girth. Irrigated plants showed considerable growth in the summer months. While the rainfed growing tree showed negligible growth even though it also received some rainfall. Irrigated rubber trees showed the increase in relative growth rate (RGR) than the rainfed trees, the different in growth was due to irrigation treatment (Vijayakumar *et al*., 1988).

a. Water requirement

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

Evapotranspiration of immature rubber was measured using lysimeters in Central Kerala. The mean evapotranspiration was 2.60, 4.24 and 4.98 mm per day during the first, second and third year respectively, during the summer season when the plants were sufficiently irrigated to avoid any moisture stress. In another experiment, the mean evapotranspiration of two years old rubber plants was measured as 4.97 mm per day during the summer season (Jessy *et al*., 1992). The quantity of water required by a plant could be estimated as 6, 19, 44, 82, and 99 l per day during the first, second, third, fourth and fifth year respectively (assuming that the canopy coverage increase from 10 per cent in the first year to 90 per cent in the fifth year). From the fifth year, the water requirement was fairly constant. The irrigation requirement, during dry months, of a mature rubber tree was estimated as 10,000 l (Vijayakumar *et al*., 1988).

In the non-traditional areas, prolonged drought coupled with high temperature, low relative humidity and dry winds restrict the growth of rubber. In these areas, the water requirement was high compared to the traditional areas. In the Konkan region (Maharashtra, India), the irrigation requirement of rubber tree was estimated to be around 33,500 l per tree at a planting density of 400 trees per ha (Vijayakumar *et al*., 1998).

b. Irrigation in nurseries

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

c. Effect on immature rubber

Under rainfed conditions, rate of growth in terms of girth increment is very low during the summer season. Irrigation during this period enhances the growth and helps to reduce the immaturity period. In the traditional belt, summer irrigation could reduce the immature period by six months to one year (Jessy *et al*., 1994). Irrigation at 50% of the crop evapotranspiration was sufficient to enhance the growth (Jessy *et al*., 1996a). In some of non-traditional areas like North

Konkan (India), plants require more than 10 years to attain tappable girth. A significant increase in growth was observed with summer irrigation in this region (Mohankrishna *et al*., 1991). Irrigation at 50% of the estimated crop water requirement could reduce the immature period from ten years to six years (Vijayakumar *et al*., 1998).

Response of a few *hevea* clones to irrigation during immature were PB 235, RRII 300, GT 1, RRIM 501, G1 1, RRIM 612, Tjir 1, PR 107 and RRIM 600. During wet periods clones Tjir 1 and RRIM 501 showed highest RGR followed by PB 235, G1 1 and RRIM 612. RRIM 600 showed the lowest growth rate. During dry periods, RRIM 600 was leading in mean RGR, RRIM 501 maintaining the same rate and Tjir 1 was in the sixth position. The last position was of PB 235. In the subsequent unirrigated dry periods also, RRIM 600 was leading in RGR followed by PR 107 and RRIM 612. Clones GT 1, RRIM 501 and Tjir 1 occupied the last three positions (Chandrashekar *et al*., 1990).

During irrigated dry periods RGR of clone RRIM 600 was comparable with that of most of the clones. But in unirrigated periods, it was significantly higher and was not comparable with the rest. In the 1989-90 unirrigated periods, RGR of clones RRIM 600, PR 107 and RRIM 612 were significantly different from each other while the remaining clones formed a comparable group. Response of all clones, except PB 235, to irrigation was similar while that of PB 235 was significantly lower. Girth increment of the clones during wet periods ranged from 3.2 to 7.1 cm. In the subsequent irrigated dry season, the girth increment of clones ranged from 1.5 to 4.1 cm. Girth increment of clones in the irrigated dry season was comparable. During the unirrigated dry periods, growth response of clone RRIM 600 was significantly higher than that of the other clones. The climate of North Konkan though benefiting from rather high rainfall (> 2,500mm/year) has particularly long and severe dry period extending from December to May. In summer months vapor pressure deficits and temperatures are also high (Chandrashekar *et al*., 1990; Mohankrishna *et al*., 1991). The continuous rainless period results in water deficits of about 1,070 mm whereas it is around 350 mm in the traditional region (RRII, 1988). The soil moisture depletion in the region is more than what has been observed in the traditional region during an unusual drought experienced in 1987 (Vijayakumar *et al*., 1988).

Clonal variation in response to irrigation was also observed. Comparison of the RGR during irrigated and unirrigated dry period indicated better response of clones RRIM 501, GT 1 and Tjir 1. These clones had higher RGR in wet seasons.

During unirrigated dry periods, clones RRIM 600, RRIM 612 and PR 107 performed better than the others. It was found that these clones maintained better afternoon leaf water potentials and higher stomatal conductance than other clones during stress period. Induction of deeper and probably denser roots might be responsible for higher plant moisture status (Chandrashekar *et al*., 1990).

Under the rainfed conditions of Konkan region in India, clones RRIM 600, RRIM 612 and RRIM 501 performed better, which indicated that their physiological superiority in growth was better than the other clones. From the data it was clear that the growth of plants was limited primarily by water and hence providing irrigation during immaturity period would reduce the pay back period and the ill effects of drought stress.

3.2.2. Choice of irrigation method

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

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

3.3. Nutrient status and fertilizer requirement

3.3.1. Soil and nutrient requirement of rubber

Soil requirement of rubber are lower than those of coffee, cacao, oil palm, manila hemp, etc. Consequently, the majority of rubber soils are poor in plant nutrients, although often of good physical condition. Another point is that the amount of nutrients removed in the latex is relatively low, particularly for the old types of low yielding seedling trees. Both points may be held responsible for the fact that, in the past, the interest in fertilization for rubber growing was generally less than for many other tropical crops. That such situation has changed and that interest in fertilizers application has increased considerably. This was due to many of the following factors: Realization that the amounts of nutrients removed in the yield of latex are only a small fraction of those required for the growth of the tree, the profits involved in advancing tapping stage and the importance of fertilizers for maintaining vigour and yield of high producing rubber trees (Shorrocks, 1965). Also, the amount of nutrients removed in the yield depended on crop level.

When replanting, the manner of disposal of the old rubber trees it would markedly affected the nutrient content of soil. Complete removal of the timber from the land would result in a further depletion of nutrients from the general poor soils. If the timber was stacked and burned, most of the nitrogen and sulphur would be lost to the atmosphere, while other nutrients would be concentrated at the burned sites giving and enriched soil in some places and impoverished the soil over the rest of the area. The best management method of timber disposal was to let the timber decomposed on the ground in the interrow areas, thus returning the nutrients slowly to the soil, rather than to waste large quantities of nitrogen by burning or removing all nutrients with the timber from the land. It can be generally stated that the soil in the replanting area would be poorer than those of new clearing of forest land and that replanted rubber will be more in need of fertilizers.

From the time of planting a sufficient amount of well-balanced nutrients should be available to stimulate growth, so that the tapping stage is reached at as early date as possible. If by means of judicious fertilizing has been done and the tapping stage is reached one year earlier, therefore, the profit is equal to the value of one year's production at the full production capacity of the tree. Moreover, under certain conditions and in particular for genetically identical material, a correlation has been found between growth and yield. The growth rate can also have repercussions on yield in the form of better or poorer renewal of the tapped bark. The use of fertilizer on immature rubber has been done in order to create optimum growing conditions from planting to tapping as it has been a common practice nowadays. This leads to the increase in growth which is reflected in yield when the trees come into tapping. If girth is the main determining factor for yield from any particular clone, it is far easier to increase the girth during immaturity when the trees are growing at a rate of 10 - 13 cm. per annum than after tapping when the girth increments are reduced to less than 2.54 cm (Shorrocks, 1965).

3.3.2. Fertilizing rubber in Thailand

a. Fertilizer application before tapping

The application of NPK fertilizer of 20-8-20 formulation for the old land (land has been planted with rubber) and the NPK of 20-10-12 formulation of new land (land has never been planted with rubber). In the new land the organic manure or composed should be applied at the rate of two kg/tree with chemical fertilizer (RRIT, 2000).

There are two methods of fertilizer application, the first method of application is placing the fertilizer around the young trees by digging holes and after the fertilizer has been placed, then the hole are covered. Second method is to apply along the interrow of the rubber trees by digging the land between the rows of rubber planted and after fertilizer has been applied, the land is covered completely. If the area of planting is a slope land, then the banding methods of fertilizer application between rows of rubbers which is planted in the contour manner is practiced. Fertilizer application should be done when the soil is wet and it should not be applied during the dry season or during the high raining period (RRIT, 2000).

b. Fertilizer application after tapping

Fertilizer application of NPK should be done by soil analysis. Generally, the fertilizer application of NPK can be changed depended upon moisture in the soil. In Thailand, it is also practices that the farmers mixed their own fertilizer for their rubber plantation (using diamonium phosphate (18-46-0), urea (46-0-0) and potassium chlorite (0-0-60)). The fertilizer application of NPK at 30-5-18 of one kilogram/tree/year were split in to the twice application. The first application was at early rainy season and the second was before the end of the rainy season.

3.3.3. Recommended fertilizer practices

Since field nurseries and bud-wood nurseries are generally sited on the best soil locally available, therefore, management is directed towards obtaining good growth of rubber. In Malaysia, at the time of establishment, the basic dressings of limestone and rock phosphate are used and incorporated into the soil. Thereafter, regular dressings of complete fertilizer incorporating with soluble phosphate are applied (Haridas, 1981).

In polybag nurseries, the polybags are filled with a good class soil, preferably with a fairly heavy clay loam texture with added rock phosphate. In this case, complete fertilizer is applied as the young seedling develops. In all cases, care must be taken to avoid scorching the young plants. Soluble fertilizers should not be placed in contact with the stems, and fertilizers containing nitrate should not be used for fear of damaging roots.

With optimum management, advanced planting material such as stump buddings can reach 10-12 cm girth for transplanting by about 15-18 months after budding, or 20-22 months after nursery establishment. Large polybag plants at six-seven whorls can be transplanted by seven months after budding or 12 months from the establishment. Bud wood nurseries should be able to yield reasonable bud-sticks by about five-six months after cut-back.

3.4. Latex diagnosis

As latex yield indicated the growing condition and yield potential of rubber tree. The physiological parameter of latex in relation to yield potential may be of high interested to rubber grower (Jacob *et al.,* 1989). Scientists have been using the method of latex diagnosis in determining the condition of growth and production potential of rubber tree. In analyzing latex samples, four important components, the total solid content (TSC), thiol (R-SH), sucrose and inorganic phosphate (Pi) are measured. TSC reflect the percentage of dry rubber content in the sample, which thiol neutralize various form of toxic oxygen which may be increasingly produced when trees are subject to stress. High sucrose content may indicate the strong potential of growth and production and level of Pi also show the metabolic condition of tree which is also related to growth. Theoretically, latex diagnosis may be used to detect the effect of input factors such as irrigation and fertilizer as it may affected to the growing condition of rubber tree (Jacob *et al.,* 1989).

MATERIALS AND METHODS

The study on the effect of irrigation and fertilizer experiment in rubber (*Hevea brasiliensis*) was conducted as an on-farm research in the rubber plantation of Sindane Thai Rubber Co., Ltd. at Tambon Klong Phou, Kitechagoot district of Chanthaburi province, Thailand for the duration of 16 months which was between October 2004 to January 2006. .

1. Experimental design and treatments

The experimental design used in this study was a split plot design with irrigation and non-irrigation as main plots and there were three formulas of fertilizer treatments as subplot in both irrigation main plot and non-irrigation main plot. Three fertilizer treatments were factorially arranged within each main plot. There were three replications in this study. Fertilizer treatments were composed of the following formulas:

1.1. Fertilizer formula of 15-7-18 of NPK (low N level). This formula was recommended to farmers by the Rubber Research Institute of Thailand (RRIT) in 1982.

1.2. Fertilizer formula of 30-5-18 of NPK (high N level) which was recommended to farmers by the RRIT in 1998.

1.3. Fertilizer formula of 23-5-18 of NPK. This fertilizer formula was used mainly by the farmers at Chanthaburi.

In mixing the following fertilizer formulas, the mixed fertilizer formula of 18-46-0 (Diammonium phosphate) were used, with citrate soluble P_2O_5 weighed 10 kg as the source of P. Additional source of N was provided by urea of 46-0-0 (NPK) approximately 60 kg and also 0-0-60 of potassium chlorite water soluble K_2O of approximately 30 kg as the source of K. Each mixed fertilizer formula was prepared approximately 100 kg. Fertilizer was applied to each rubber tree at 500 g/tree at each time and it was given two times in a year. Fertilizers were given to the irrigated block and non irrigated block in October 2004, similar application was done in May 2005 and October 2005 during the period where soil moisture was ample.

Irrigation was given by sprinkler irrigation in irrigation block at every four days intervals. During irrigation, water was given at 40 minutes each time. The irrigation water given each time was approximately 92 liters/28.26 m^2 of raindrop. In non irrigation plot, only rainfall was the source of water.

2. Plot layout

Each individual plot size was 42 m × 32 m (1,344 m^2) composed of 56 rubber trees. The tapping area size was 30 m × 24 m (720 m^2), within the plot composed of 30 tappable trees in which the girth was at 170 cm. Spacing between row and interrow of the plot was 6 m × 4 m. All the trees used in this experiment were planted in 1996. The variety of rubber used in the study was clone BPM 24. Approximated area for irrigation level was 1.21 ha and total area of study was 2.42 ha or 15.125 rai.

3. Data collection

Two sets of data were collected in this study.

3.1. At the starting of the experiment

During October 19th – 22nd, 2004 which was the beginning period of the study, lay out of the experiment was conducted; the initial measurement of girth at 170 cm height from the ground was done. Soil sample and leaf sample were collected for laboratory analysis. In each individual block, 18 soil samples were collected at random and mixed together to form a composite sample which was used for nutrient analysis. Leaf samples were collected in the similar manner. Soil and leaf samples were sent for analysis at the Office of Agricultural Research and Development, Region 6, Chanthaburi.

3.2. Data collected during experimentation

a. Girth measurement

Apart from the beginning of the study, the measurements of girth were done in October 2004, January 2005, October 2005 and January 2006. Girths were measured to all trees from each plot. First measurement was done during the rest period for tapping in January 2005 while the second measurement will be done during the tapping peak period which was in October 2005 and the third measurement was also done at the final experiment. Girth measurement was done at the height of 170 cm from the ground.

b. Tapping panel dryness (TPD)

Bark dryness was observed for all trees within each plot at the end of the experiment using the roller for measurement along the cutting slope.

c. Dry rubber content (DRC)

Dry rubber content was determined at every tapping. Tapping was done at one day interval during the tapping period. Tapping period was not done during the beginning of the experimentation, drought period and severe wet period.

After tapping, latex which had been collected was taken from the field to the shade where weighting the latex was done followed by the coagulation process using acetic acid 2 %. Coagulating latex sample was washed with water in order to remove serum and acid before placing in the oven at the temperature of 70 $^{\circ}$C for 24 hours where the dry weight was taken and dry rubber percentage was calculated using the formular as follow:

Percentage of dryrubber content (%DRC):

$$(\%DRC) = (Wr / Wlf) \times 100$$

Wr = weight of dry coagulum (g)

Wlf = weight of fresh latex (g)

(Source: Gohet and Chantuma, 1999)

d. Rubber yield

Yield of rubber was collected and measured by weighting the latex from each plot at every tapping which was done in the early morning and the method for yield calculation were done by weighting of total latex and multiply by %DRC and divide by 100.

e. Latex diagnosis

Samples of latex collection from the experimental plots were further analyzed to determine the physiological parameters such as analysis of sucrose (Suc) (Ashwell, 1957), inorganic phosphorus (Pi) (Taussky and Shorr, 1953) thiol (R-SH) (Boyne and Ellman, 1972) and total solid content (TSC). Latex analysis was done during the period between October 2005 through January 2006 towards the end of experimentation.

Numbers of samples for latex analysis collection were done as follow: In one plot size, ten tree selected and one tree collected the following 10 drops of latex put in a small bottom after the first two drops of latex are eliminated (unstable and contaminated latex). From this small bottom, 1 ml of latex was picked up into a weighed pill for TSC measurement and other one ml of latex was sucked off (using an automatic pipette) and added in a numbered pill containing nine ml of TCA 2.5% + 0.01% EDTA. This sample can be kept 48 hr at 4^0C. Then, each samle was filtered and the clear serum obtained was used for the measurement of the physiological parameters Suc, Pi and R-SH.

4. Duration of the study

The experiment was conducted on October 2004 and continued until the end of January 2006, duration of the experimentation was 16 months.

RESULTS AND DISCUSSION

1. Climatic and edaphic growing conditions

Figure 1 showed the rainfall pattern at Chanthaburi province between October 2004 to December 2005 during most of the period when the experiment was conducted. Rainfall at Chanthaburi increased considerably from April and decreased heavily from October to December. Total amount of rainfall was 3,637.8 mm for the whole period shown. In this figure, it can be seen that tapping were not done in every month, tapping were not done in October 2004 during the initial period of the trial, it was not done in January 2005 to March 2005 due to the dryness and also it was not done in June 2005 and August 2005 due to high rainfall and the wetness of the plantation.

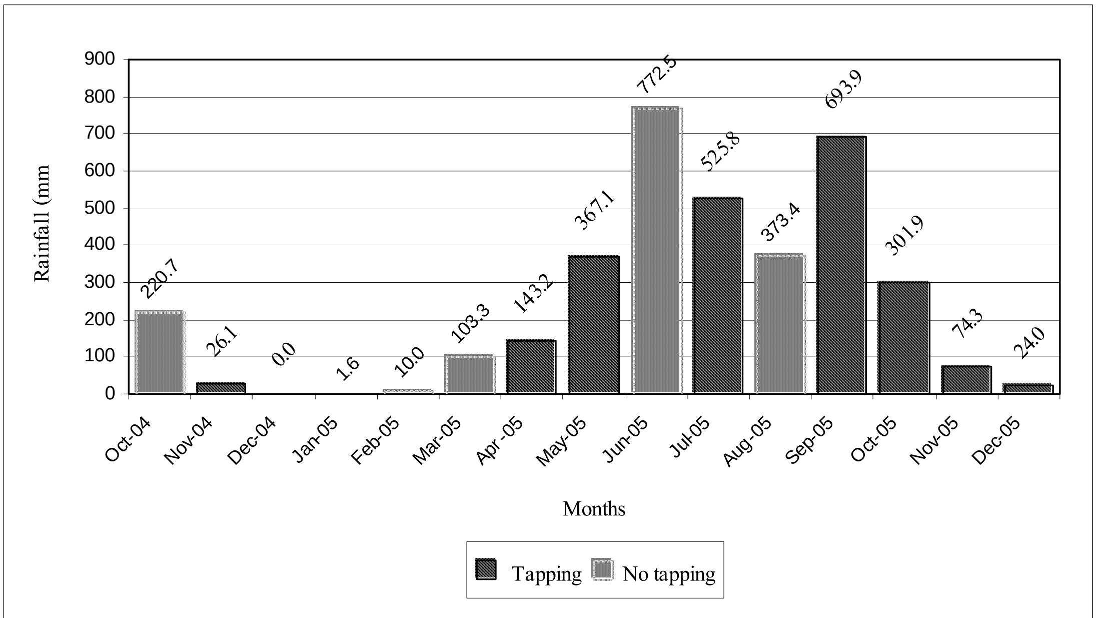

Figure 1 Amount of rainfall (mm) and pattern at Chathaburi province between October 2004 to December 2005 during most of the period when the experiment on irrigation and fertilizer on rubber tree was conducted.

Table 1 Soil analysis of the experiment on irrigation and fertilizer on rubber production showing the initial and final values of pH, organic matter, P and K in which the data were taken on October 2004 and January 2006.

Soil component	Initial soil sample	Irrigation			Mean Irrigation	Non irrigation			Mean Non irrigation
		Trt 1	Trt 2	Trt 3		Trt 1	Trt 2	Trt 3	
pH (1:1)	5.0	5.9	5.9	5.7	5.9	4.8	5.5	5.4	5.2
OM (%)	1.6	1.1	1.2	1.2	1.2	1.9	1.7	1.6	1.7
P (ppm)	103.9	164.4	112.5	136.6	137.8	98.2	281.0	125.4	168.2
K (ppm)	134.0	115.1	94.2	77.0	95.4	84.9	128.4	78.3	97.2

Table 1 showed some components of soil analysis such as pH, organic matter (OM), P and K taken during the initial period (October 2004) and final period (January 2006). Analysis of variance was not conducted for these data, while the result obtained revealed that the pH at the final stage of the experiment had been increased as compared to the initial sample and irrigation treatment tend to increase the pH value than in the non irrigated plot. Organic matter was slightly decreased in irrigation, perhaps due to leaching and higher rate of decomposition as hasten by irrigation water when compared to non irrigated plot. The value of P were both higher during the termination period in irrigated and non irrigated plots as compared to the initial phase, however, P value was lower at the final stages of irrigated plot than the non irrigated plot. The K value were both lower in the irrigated and non-irrigated plots at the final stage than at the beginning. Result of the soil analysis shown in Table 1 did not reflected any effect derived from fertilizer treatment.

Table 2 Leaf analysis of the experiment on irrigation and fertilizer on rubber production showing the initial and final values of N, P and K in which data were taken on October 2004 and January 2006.

Leaf component	Initial leaf sample	Irrigation			Mean Irrigation	Non irrigation			Mean Non irrigation
		Trt 1	Trt 2	Trt 3		Trt 1	Trt 2	Trt 3	
N (%)	2.5	3.1	3.2	3.0	3.1	3.0	2.7	2.6	2.8
P (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
K (%)	1.2	1.5	1.6	1.4	1.5	1.2	1.0	1.1	1.1

Data shown in Table 2 revealed that the percentage of N, P and K taken at the initial phase and at the final phase of the experiment (October 2004 and January 2006) were not differed with regarded to the effect of fertilizer or irrigation. Only the percentage of N at the irrigated plot during the final phase was slightly higher than the value at the initial phase. Percentage of P and K were similar when compared between the initial phase and the final phase when the plot received or not receiving irrigation. Again, data in Table 2 did not reflected any effect of fertilizer treatment upon the percentage of N P and K in the leaf analysis component.

2. Component of yield and production

2.1. Yield and production of rubber tree

Table 3 and 4 showed the average yield of rubber as expressed as yield per tree per tapping (g/tree/tapping) and production of rubber per month of tapping and also total production during the entire experimental period respectively. The data from both Tables showed similar results as reflected to the effect of irrigation and fertilizer. Both yield per tree per tapping and the production per month of tapping were significantly higher in irrigated plot as compared to the non-irrigation ($P<0.05$) in most of the tapping month except in October and November 2005.

Table 3 Average yield of rubber as expressed as yield per tapping (g/t/t) in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2004 to January 2006.

Months Irrigation treatment	Nov 2004	Dec 2004	Apr 2005	May 2005	Jul 2005	Sep 2005	Oct 2005	Nov 2005	Dec 2005	Jan 2006
Irrigation	55.4	67.1	47.5	72.0	87.4	76.9	87.2	85.6	71.5	56.8
Non irrigation	50.6	53.0	26.8	42.3	66.7	89.3	87.8	84.5	63.2	65.7
Mean	53.0	60.1	37.2	57.1	77.0	83.1	87.5	85.0	67.4	61.3
cv(%)	0.20%	0.40%	0.80%	0.70%	4.70%	1.30%	0.10%	0.50%	0.30%	0.90%
F test	*	**	**	**	*	*	ns	ns	*	*
$LSD_{0.05}$	3.4	5.2	2.3	8.5	14.5	8.9	-	-	5.3	7.6

The yield per tree was between 87.4 – 47.5 g in the irrigated block while in the non-irrigated treatment, the yield per tree were between 89.3 – 26.8 g. The average production of rubber tree per month was between 354.4 – 62.0 kg/ha regardless of irrigated or non-irrigated treatments. Total production in irrigation block was 2469.4 kg/ha which was significantly higher than in non-irrigated block (P<0.05). There is no effect of fertilizer shown in the data on yield and production of rubber. Also, it was shown that seasonal variation such as the rainy and dry seasons put certain impact to the yield and production of rubber tree. Both yield and production of rubber were obviously high during the rainy season as compared to the dry season.

Table 4 Production of rubber per month of tapping and total production collected for the entire experimentation (kg/ha) in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2004 to January 2006.

Months Irrigation trt	Nov 2004	Dec 2004	Apr 2005	May 2005	Jul 2005	Sep 2005	Oct 2005	Nov 2005	Dec 2005	Jan 2006	Total yield
Irrogation	323.2	335.7	79.2	300.1	72.8	128.1	290.7	356.5	417.4	165.7	2469.4
Non irrigation	295.3	264.8	44.7	176.1	55.6	148.9	292.6	352.2	368.6	191.7	2190.5
Mean	309.2	300.3	62.0	238.1	64.2	138.5	291.6	354.4	393.0	178.7	2329.9
cv(%)	3.20%	4.30%	3.10%	7.50%	9.40%	5.30%	0.80%	4.60%	3.90%	6.20%	2.10%
F test	*	**	**	**	*	*	ns	ns	*	*	**
$LSD_{0.05}$	19.5	25.8	3.8	35.5	12.1	14.8	-	-	31.0	22.2	95.6

2.2. Dry rubber content (DRC) and latex yield

Table 5 and 6 showed the average percentage of dry rubber content and latex yield per month of tapping and also the total amount of latex collected during 16 months of experimentation. For percentage of DRC, it was shown that the values were high in non-irrigated plot than the irrigated plot and significant different were obtained ($P<0.05$) in most of the month except December 2004, July and December 2005. Fertilizer treatment did not give any significant effect to the percentage of DRC at all.

For latex yield in which data were shown in Table 6, it can be seen that production of latex was higher in irrigated plot than those of non irrigation. Since latex yield was mainly composed of water, analysis of variance has not been done. Obviously, latex yield was plenty in the rainy season such as May and October to December 2005 (it was still raining in December in the year of 2005). However, data did not reflected any effect of fertilizer application at all.

As the percentage of DRC is nearly 90% of total solid content (TSC) in the latex (Jacob *et al*., 1989). More percentage of DRC resulted in viscosity increase in latex and limit the flow of latex, therefore, it was found in this experiment that %DRC was negatively correlated with latex yield (Figure 2) and also negatively correlated with the dry rubber yield (Figure 3). Jacob *et al*. (1989) also found the same results on the relationship between %DRC, latex yield and rubber yield. In this experiment, it was found also that positive correlation was obtained between rubber yield and latex yield in which R^2 value was 0.979 which was highly significant (data not shown).

Table 5 Average dry rubber content (%DRC) per month of tapping in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2004 to January 2006

Irrigation trt	Nov 04	Dec 04	Apr 05	May 05	Jul 05	Sep 05	Oct 05	Nov 05	Dec 05	Jan 06
Irrigation	32.2	31.7	43.9	37.6	32.1	33.6	32.7	32.7	29.9	31.8
Non irrigation	34.2	32.5	45.2	41.5	33.7	36.2	33.4	34.3	30.4	33.3
Mean	33.2	32.1	44.6	39.5	32.9	34.9	33.1	33.5	30.1	32.6
cv(%)	1.60%	3.30%	0.40%	0.10%	3.90%	2.40%	1.00%	0.20%	1.20%	2.20%
F test	*	ns	**	**	ns	*	*	**	ns	*
$LSD_{0.05}$	1.0	-	0.3	0.9	-	1.7	0.7	0.2	-	1.4

Table 6 Average of latex yield per month of tapping and total latex collected for the entire experimentation (kg/ha) in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2004 to January 2006

Irrigation treatment	Fertilizer treatment	Nov 2004	Dec 2004	Apr 2005	May 2005	Jul 2005	Sep 2005	Oct 2005	Nov 2005	Dec 2005	Jan 2006	Total Latex
Irrigated	15-7-18	961.6	1022.2	163.0	776.9	222.2	381.9	872.7	1089.8	1386.1	504.2	7380.6
	23-5-18	1083.8	1126.4	196.3	802.8	226.9	384.3	912.0	1138.4	1441.2	551.4	7863.5
	30-5-18	961.6	1020.8	182.4	813.0	231.5	377.3	884.3	1047.2	1356.9	511.6	7386.6
Mean		1002.3	1056.5	180.6	797.5	226.9	381.2	889.7	1091.8	1394.8	522.4	7543.5
Non irrigated	15-7-18	950.0	905.6	100.9	428.7	170.8	421.3	893.5	1063.0	1261.1	594.9	6789.8
	23-5-18	795.4	742.6	94.4	408.8	166.2	388.9	838.0	976.9	1142.1	556.9	6110.2
	30-5-18	848.6	800.9	100.9	436.6	157.9	425.9	893.5	1041.7	1235.2	574.5	6515.8
Mean		864.7	816.4	98.8	424.7	165.0	412.0	875.0	1027.2	1212.8	575.5	6471.9

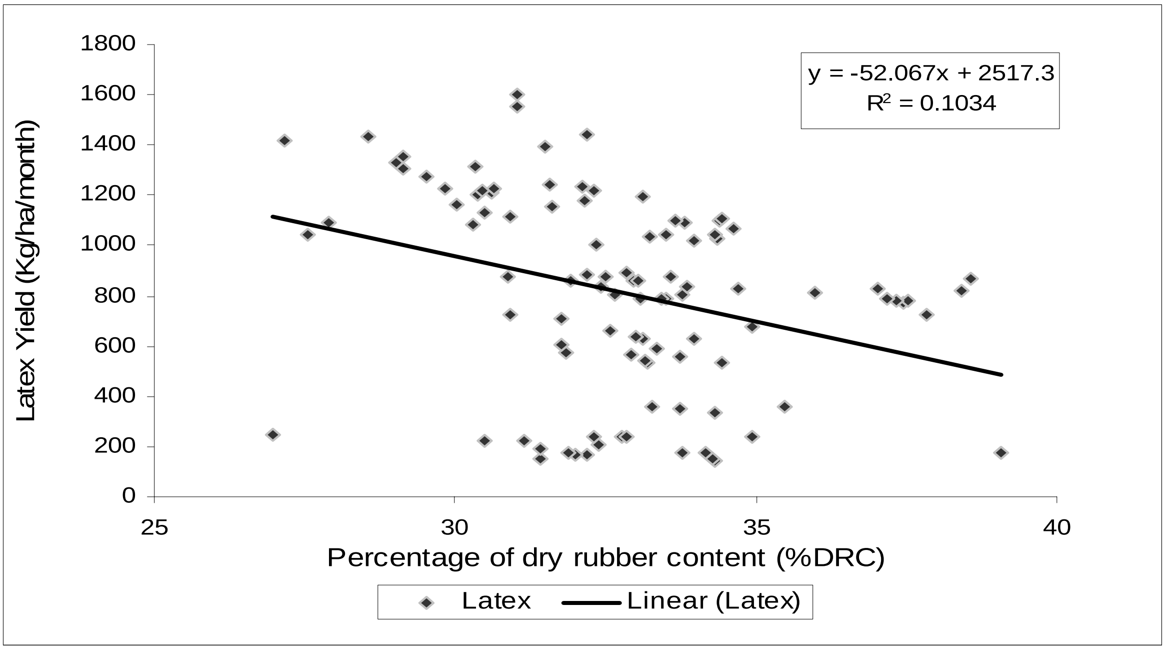

Figure 2 Correlations between Latex Yield and %DRC

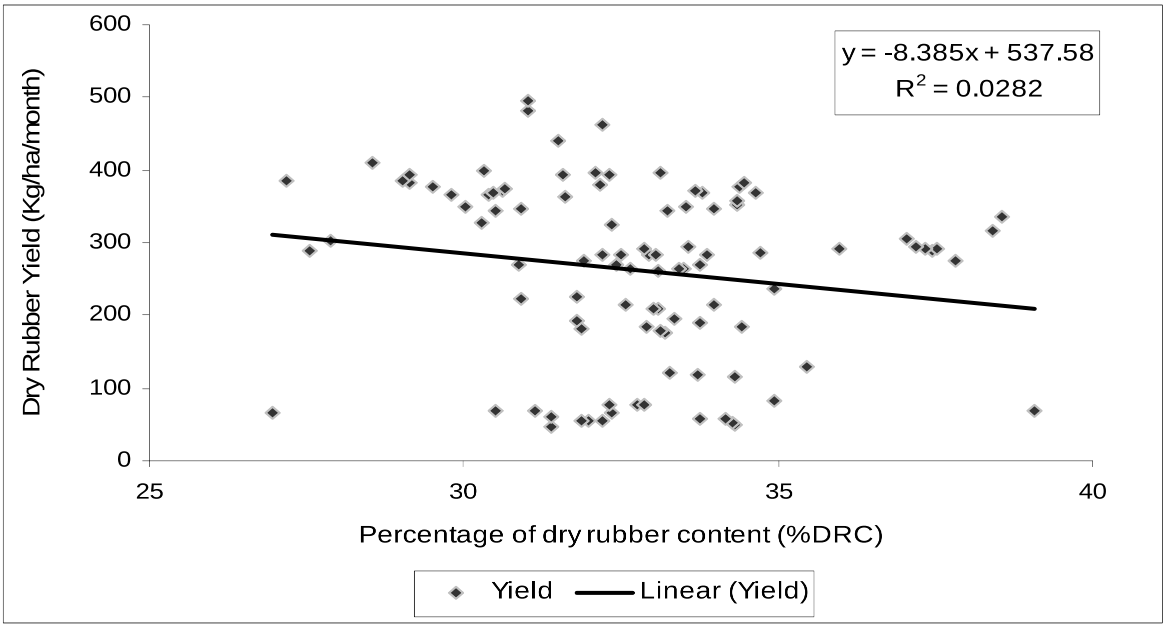

Figure 3 Correlation between %DRC and dry rubber yield

3. Latex diagnosis component

As discussed previously, the important latex diagnosis component compose of sucrose, inorganic phosphate (Pi), Thiol (R-SH) and total solid content (TSC). Latex samples were collected for diagnosis between October 2005 to January 2006 towards the termination of the trial. Data on sucrose, inorganic phosphate, thiol and total solid content of rubber trees in the experiment on the effect of irrigation and fertilizer were shown in Table 7, 8, 9 and 10 respectively.

Both sucrose (Table 7) and total solid content (TSC) (Table 10) of latex samples neither showed any difference between irrigation nor fertilizer application. However, in the inorganic phosphate component (Table 8) value of Pi in the irrigation treatment were higher than in the non-irrigation in every samples collected although significant different were not obtained. Furthermore, fertilizer application did not inserted any impact on the level of Pi.

In Table 9 where the average of thiol [R-SH]mM of latex samples were demonstrated, it was found that the level of thiol were higher in the irrigated plot as compared to the non-irrigation in the October, November and December 2005 samples. Still the thiol value of irrigation treatment in January 2006 sample was higher than in the non-irrigated plot although the thiol content in latex samples taken from the irrigated plot was significantly higher than non irrigated plot.

Since latex thiol consist of cysteine, methionine and above all glutathione (Mullen, 1960) and thiol is used to neutralize various form of toxic oxygen which is normally exist when metabolism is normal. Jacob *et al*., (1989) also stated that there are positively significant correlation between the thiol content and production. Since irrigation give positive beneficial effect to the growth and production of rubber, therefore rubber tree growing under favorable irrigated condition may produce higher value of thiol as compared to the non irrigated condition.

Table 7 Average of sucrose per month of latex analysis [Suc]mM in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2005 to January 2006

Irrigation trt[(a)]	Fertilizer trt[(b)]	13-Oct-05	12-Nov-05	15-Dec-05	23-Jan-06
Irrigated	15-7-18	4.9	8.1	4.6	4.7
	23-5-18	5.0	6.8	4.8	4.9
	30-5-18	5.3	8.3	5.1	4.1
Mean		5.1	7.8	4.8	4.6
Non irrigated	15-7-18	4.5	8.4	4.5	3.9
	23-5-18	4.8	8.0	4.4	5.6
	30-5-18	5.3	7.9	4.6	3.4
Mean		4.9	8.1	4.5	4.3
$cv_{(a)}$%		10.20%	15.00%	12.40%	29.10%
$cv_{(b)}$%		15.30%	17.50%	8.10%	24.00%

Table 8 Average of inorganic phosphorus [Pi]mM per month of latex analysis in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2005 to January 2006

Irrigation trt[(a)]	Fertilizer trt[(b)]	13-Oct-05	12-Nov-05	15-Dec-05	23-Jan-06
Irrigated	15-7-18	26.0	24.8	26.8	22.4
	23-5-18	26.0	24.0	24.4	22.2
	30-5-18	24.0	23.5	24.5	21.9
Mean		25.3	24.1	25.2	22.2
Non irrigated	15-7-18	19.8	19.5	23.4	18.7
	23-5-18	19.6	20.0	23.8	20.3
	30-5-18	21.5	20.2	23.8	18.1
Mean		20.3	19.9	23.7	19.0
$cv_{(a)}$%		17.90%	16.70%	13.00%	20.30%
$cv_{(b)}$%		26.00%	20.80%	26.00%	22.60%

Table 9 Average of thiol [R-SH]mM per month of latex analysis the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2005 to January 2006

Irrigation trt[a]	Fertilizer trt[b]	13-Oct-05	12-Nov-05	15-Dec-05	23-Jan-06
Irrigated	15-7-18	0.4	0.3	0.5	0.5
	23-5-18	0.4	0.3	0.5	0.6
	30-5-18	0.4	0.3	0.5	0.6
Mean		0.4	0.3	0.5	0.6
Non irrigated	15-7-18	0.3	0.2	0.4	0.4
	23-5-18	0.3	0.3	0.4	0.4
	30-5-18	0.4	0.2	0.4	0.4
Mean		0.3	0.2	0.4	0.4
$cv_{(a)}\%$		4.00%	10.40%	2.30%	17.90%
$cv_{(b)}\%$		11.70%	3.70%	5.20%	17.30%
$LSD_{0.05}(a)$		0.027	0.056	0.023	-

Table 10 Average of total solid content (TSC) per month of latex analysis in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between November 2004 to January 2006

Months / Irrigation treatment	13-Oct-05	12-Nov-05	15-Dec-05	23-Jan-06
Irrigation	43.6	30.9	38.5	46.2
Non irrigation	45.2	28.3	36.7	47.7
Mean	44.4	29.6	37.6	46.9
cv(%)	2.10%	3.10%	0.70%	1.30%

4. Other parameters of growth

4.1. Girth increase

Table 11 showed the increase in rubber girth (cm) from the beginning of the trial (October 2004) until the termination of experimentation. During 16 months period, girth was measured four times starting from the initial girth measurement of 50.2 cm. It was found that girth increased significantly in the irrigated plot as compared to the non-irrigation ($P<0.05$). Increment of girth in the irrigation plot was 7.6 cm in 16 months period as compared to non-irrigation where girth increased during 16 months was only 3.4 cm ($P<0.05$), while irrigation application inserted positive effect to girth development, fertilizer treatment did not showed any effect on girth increase.

4.2. Tapping panel dryness

Percentage of tapping panel dryness (TPD) when measured at the termination of the trial was shown in Table 12. Data obtained reveal that the percentage of TPD was more in the non irrigated plot as compared to irrigation application. Again, fertilizer did not showed any effect on the percentage TPD. Significant different were not obtained between irrigation and fertilizer treatment for the percentage of tapping panel dryness.

Table 11 Girth measurement of rubber (cm) during the entire experimentation in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between November 2004 to January 2006

Months	11-Jan-05	19-Oct-05	11-Jan-06	Increment during
			Final	16 months of
Irrigation trt	2nd measurement	3rd measurement	measurement	growth
Irrigation	54.3	55.7	58.0	7.6
Non irrigation	50.3	51.6	53.4	3.5
Mean	52.3	53.7	55.7	5.5
cv (%) =	2.30%	2.40%	0.4	13.60%
F test	*	*	**	**
$LSD_{0.05}$	2.443	2.567	0.498	1.509

Table 12 Percentage of tapping panel dryness measured at the end of experimentation in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand on January 2006

Irrigation treatment	Fertilizer treatment	Percentage of tapping panel dryness (%TPD)
	15-7-18	0.80
Irrigated	23-5-18	3.24
	30-5-18	4.00
Mean		2.68
	15-7-18	6.73
Non irrigated	23-5-18	3.65
	30-5-18	3.26
Mean		4.55

CONCLUSIONS

Data obtained from 16 months trial on the effect of irrigation and fertilizer on growth and production of rubber tree variety BPM 24 grown at Chanthaburi province of Thailand revealed that irrigation treatment increased the yield per tree per tapping, monthly production and also total production of rubber yield. Latex yield also increased as the result of irrigation treatment. Seasonal variation excerted certain effect on rubber yield and latex production in which both rubber yield and latex were more in the rainy season.

For the percentage of dry rubber content, it was found that under non-irrigation, the percentage of DRC was higher than those of irrigation treatment. Percentage of DRC was negatively correlated with both rubber yield and latex yield.

By performing latex diagnosis in order to determine the effect of irrigation and fertilizer, it was found that sucrose and total solid content of samples were not related to either irrigation or fertilizer treatment. Inorganic phosphate increased in the irrigation plot than those of non-irrigation but was not significantly differed. Thiol (R-SH) content in latex samples taken from the irrigated plot were significantly higher than non irrigated plot as thiol was produced in higher amount in the tree growing under favorable condition and high thiol content indicated better potential for production.

For girth increase and tapping panel dryness of rubber, data also showed that irrigation inserted beneficial effect of these parameters. As girth increase indicated the increase in growth and development, therefore, potential production will be increased. However, irrigation resulted into less percentage of tapping panel dryness and may decrease the plugs at the cut of latex vessels.

The overall result of this experiment indicated the beneficial effect of irrigation on growth and yield of rubber. However, results did not showed the effect of fertilizer treatment in any of the parameter measured. It may be possible that it would take a longer time than the experimentation period before the effect of fertilizer will be pronounced.

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APPENDIX

Appendix Table 1 Components of soil analysis of the experiment on irrigation and fertilizer on rubber production showing the initial component taken on October 2004 and final soil component analysis in which sample were taken on January 2006.

Soil component	Initial	Irrigation			Mean	Non irrigation			Mean
	soil sample	Trt 1	Trt 2	Trt 3	Irrigation	Trt 1	Trt 2	Trt 3	Non irrigation
pH (1:1)	5.0	5.9	5.9	5.7	5.9	4.8	5.5	5.4	5.2
EC (1:5)	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
OM (%)	1.6	1.1	1.2	1.2	1.2	1.9	1.7	1.6	1.7
P (ppm)	103.9	164.4	112.5	137.0	137.8	98.2	281.0	125.4	168.2
K (ppm)	134.0	115.1	94.2	77.0	95.4	84.9	128.4	78.3	97.2
Ca (ppm)	455.5	763.5	1156.4	445.0	788.2	47.8	641.7	291.2	326.9
Mg (ppm)	75.4	87.3	69.5	63.0	73.3	27.4	60.3	36.8	41.5
Fe (ppm)	100.1	61.2	42.7	59.7	54.5	144.2	75.8	83.6	101.2
Mn (ppm)	5.3	9.7	5.3	3.9	6.3	4.0	10.6	7.7	7.4
Zn (ppm)	0.4	0.3	0.4	0.5	0.4	0.2	0.3	0.3	0.2
Cu (ppm)	0.2	1.5	0.2	0.2	0.7	0.3	0.3	0.4	0.3

Appendix Table 2 Component of leaf analysis of the experiment on irrigation and fertilizer on rubber production showing the initial component taken on October 2004 and final leaf component analysis in which sample were taken on January 2006.

Leaf component	Initial	Irrigation			Mean	Non irrigation			Mean
	leaf sample	Trt 1	Trt 2	Trt 3	Irrigation	Trt 1	Trt 2	Trt 3	Non irrigation
N (%)	2.5	3.1	3.2	3.0	3.1	3.0	2.7	2.6	2.8
P (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
K (%)	1.2	1.5	1.6	1.4	1.5	1.2	1.0	1.1	1.1
Ca (%)	1.1	321.0	0.9	1.0	107.6	1.0	1.0	1.1	1.0
Mg (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Fe (mg/kg)	254.6	170.2	139.9	136.4	148.8	166.4	144.1	145.9	152.1
Mn (mg/kg)	355.6	236.0	237.3	246.9	240.1	375.3	428.3	434.6	412.8
Zn (mg/kg)	21.3	24.2	25.5	19.4	23.0	22.9	19.9	26.2	23.0
Cu (mg/kg)	9.1	7.1	7.2	6.5	7.0	6.7	5.4	5.9	6.0

Appendix Table 3 Yield of rubber as expressed as yield per tree per tapping (g/t/t) in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between November 2004 to January 2006.

		Irrigation								
Months	Tapping	Treatment 1			Treatment 2			Treatment 3		
	day	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Nov-04	14	53.6	54.5	52.1	58.5	50.0	67.8	59.3	47.1	55.8
Dec-04	12	60.8	76.0	57.7	63.6	55.9	92.6	79.0	56.8	62.0
Apr-05	4	44.0	37.7	47.4	46.7	52.1	55.9	46.5	47.8	49.7
May-05	10	73.3	66.1	70.0	72.5	69.7	75.8	80.5	70.4	69.9
Jul-05	2	83.0	91.5	80.9	91.4	73.3	92.8	93.1	99.0	81.3
Sep-05	4	72.1	83.5	74.2	80.2	84.3	68.6	80.4	71.7	76.7
Oct-05	8	89.5	78.9	88.8	91.1	89.5	85.3	90.7	81.1	89.9
Nov-05	10	95.4	78.3	88.9	89.8	82.9	88.2	84.7	74.3	87.5
Dec-05	14	70.4	75.3	66.0	71.7	65.5	85.0	82.5	60.0	67.6
Jan-06	7	54.4	62.5	47.4	54.8	48.9	76.4	65.8	47.5	53.7
Total	85	696.5	704.3	673.5	720.2	672.0	788.4	762.6	655.7	694.2

Appendix Table 3 (Cont'd)

		Non irrigation								
Months	Tapping day	Treatment 1			Treatment 2			Treatment 3		
		Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Nov-04	14	49.3	56.2	63.2	52.6	36.7	48.6	54.7	40.4	53.8
Dec-04	12	57.5	56.8	65.1	53.9	37.1	53.0	54.1	45.0	54.2
Apr-05	4	24.9	26.5	30.8	26.5	21.9	28.4	24.6	29.3	28.4
May-05	10	39.4	43.8	45.8	43.4	40.9	37.6	43.0	41.6	44.8
Jul-05	2	64.9	70.6	69.8	65.0	67.5	62.9	57.6	81.4	60.6
Sep-05	4	96.2	104.5	84.5	89.7	82.0	76.8	91.2	96.0	83.0
Oct-05	8	90.1	88.1	93.5	93.2	78.6	79.4	87.6	85.4	94.0
Nov-05	10	90.5	81.2	91.6	84.5	79.0	81.2	83.8	82.8	86.1
Dec-05	14	67.3	64.3	68.5	63.4	56.1	59.1	64.5	62.8	62.6
Jan-06	7	63.3	73.7	67.3	71.7	61.6	57.0	64.8	60.6	71.7
Total	85	643.4	665.7	680.2	643.9	561.4	584.1	625.7	625.3	639.2

Appendix Table 4 Yield of rubber per month of tapping and total yield collected for the entire experimentation (kg/ha) in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between November 2004 to January 2006.

		Irrigation block								
Months	Tapping day	Treatment 1			Treatment 2			Treatment 3		
		Rep 1	Rep 2	Rep 3	Rep1	Rep 2	Rep 3	Rep 1	Rep2	Rep3
Nov-04	14	312.8	318.1	304.1	341.1	291.5	395.3	346.0	274.8	325.4
Dec-04	12	303.9	379.8	288.5	317.8	279.4	463.1	394.8	284.0	310.2
Apr-05	4	73.3	62.8	79.0	77.9	86.9	93.2	77.6	79.7	82.8
May-05	10	305.6	275.3	291.8	302.1	290.3	315.7	335.3	293.4	291.4
Jul-05	2	69.2	76.3	67.4	76.1	61.1	77.3	77.6	82.5	67.8
Sep-05	4	120.1	139.2	123.7	133.7	140.6	114.3	134.0	119.5	127.9
Oct-05	8	298.3	263.1	296.1	303.7	298.3	284.4	302.3	270.3	299.7
Nov-05	10	397.4	326.2	370.3	374.4	345.6	367.6	353.1	309.7	364.4
Dec-05	14	410.5	439.4	385.1	418.0	381.8	495.6	481.5	350.0	394.5
Jan-06	7	158.7	182.3	138.1	159.7	142.7	222.9	192.0	138.5	156.6
Total	85	2449.7	2462.4	2344.2	2504.4	2318.0	2829.4	2694.2	2202.4	2420.7

Appendix Table 4 (Cont'd)

		Non irrigation block								
Months	Tapping day	Treatment 1			Treatment 2			Treatment 3		
		Rep 1	Rep 2	Rep 3	Rep1	Rep 2	Rep 3	Rep 1	Rep2	Rep3
Nov-04	14	287.4	328.1	368.9	307.0	214.2	283.5	318.8	235.8	313.6
Dec-04	12	287.3	283.8	325.6	269.3	185.6	265.2	270.4	225.1	271.1
Apr-05	4	41.5	44.1	51.4	44.1	36.6	47.4	40.9	48.8	47.4
May-05	10	164.4	182.7	190.8	180.7	170.5	156.6	179.3	173.3	186.5
Jul-05	2	54.1	58.8	58.2	54.2	56.2	52.4	48.0	67.8	50.5
Sep-05	4	160.3	174.2	140.9	149.5	136.7	128.1	151.9	160.1	138.4
Oct-05	8	300.3	293.8	311.8	310.7	261.9	264.8	292.1	284.5	313.3
Nov-05	10	377.2	338.2	381.8	352.0	329.3	338.5	349.1	345.1	358.6
Dec-05	14	392.7	375.1	399.4	370.1	327.2	344.9	376.3	366.3	365.3
Jan-06	7	184.6	214.9	196.3	209.0	179.5	166.2	188.9	176.7	209.2
Total	85	2249.7	2293.7	2425.0	2246.6	1897.6	2047.5	2215.8	2083.5	2253.9

Appendix Table 5 Dry rubber content (%DRC) per month of tapping in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between November 2004 to January 2006.

		Irrigation block								
Months	Tapping day	Treatment 1			Treatment 2			Treatment 3		
		Rep 1	Rep 2	Rep 3	Rep1	Rep 2	Rep 3	Rep 1	Rep2	Rep3
Nov-04	14	31.9	34.0	31.4	31.3	30.1	33.1	34.0	31.9	32.4
Dec-04	12	31.1	32.2	31.8	30.3	31.3	32.2	32.3	32.2	32.4
Apr-05	4	44.0	44.3	43.8	43.5	43.7	44.1	44.3	43.5	43.9
May-05	10	37.0	37.8	37.5	37.2	37.5	38.4	38.6	37.2	37.3
Jul-05	2	31.1	32.3	32.4	30.5	31.4	32.8	32.9	34.9	30.5
Sep-05	4	33.3	34.0	33.0	33.2	33.7	34.3	33.3	33.7	34.1
Oct-05	8	32.3	32.7	33.3	32.2	32.5	32.5	33.5	32.4	32.7
Nov-05	10	32.1	35.0	33.7	30.9	30.9	33.8	34.4	32.2	31.6
Dec-05	14	28.6	31.5	29.0	29.5	29.2	31.0	31.0	30.0	29.1
Jan-06	7	31.7	31.9	31.4	32.8	32.0	30.9	31.8	32.2	31.3

Appendix Table 5 (Cont'd)

Months	Tapping day	Non irrigation block								
		Treatment 1			Treatment 2			Treatment 3		
		Rep 1	Rep 2	Rep 3	Rep1	Rep 2	Rep 3	Rep 1	Rep2	Rep3
Nov-04	14	34.7	34.3	34.6	33.4	34.0	33.8	33.7	34.9	33.9
Dec-04	12	32.1	33.0	33.9	30.9	32.9	33.5	30.3	31.8	33.8
Apr-05	4	43.9	45.4	46.2	45.4	45.4	44.9	46.0	45.0	44.9
May-05	10	41.1	42.0	42.3	41.4	41.3	41.5	41.9	40.5	41.1
Jul-05	2	32.2	34.2	33.8	32.0	31.9	34.3	31.4	39.1	34.3
Sep-05	4	35.0	40.5	37.6	35.9	35.1	35.5	34.2	34.9	36.9
Oct-05	8	33.3	33.6	34.5	33.4	33.1	33.4	32.9	33.0	33.7
Nov-05	10	34.4	34.4	34.4	34.3	35.3	34.8	33.5	33.2	34.3
Dec-05	14	31.6	30.7	30.3	30.5	30.3	30.5	29.5	30.4	29.8
Jan-06	7	34.4	32.6	33.3	33.0	33.1	33.5	33.7	33.2	33.1

Appendix Table 6 Sucrose levels per month of latex diagnosis for the entire experimentation [Suc]mM in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2005 to January 2006.

Irrigation treatment	Fertilizer treatment	October 13th, 2005			November 12th, 2005			December 15th, 2005			January 23rd,2006		
		Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Irrigated	15 – 7 – 18	5.2	5.3	4.4	6.6	11.5	6.3	4.9	4.3	4.4	4.0	5.5	4.4
	23 – 5 – 18	4.9	4.9	5.1	6.2	7.1	7.3	5.0	5.0	4.4	6.4	4.6	3.8
	30 – 5 – 18	5.2	5.3	5.4	8.5	8.6	7.7	5.1	4.7	5.6	3.9	3.7	4.6
Mean		5.1	5.2	4.9	7.1	9.1	7.1	5.0	4.7	4.8	4.8	4.6	4.3
Non irrigated	15 – 7 – 18	4.2	4.5	4.9	7.9	8.3	8.9	4.5	3.7	5.2	4.9	3.4	3.4
	23 – 5 – 18	6.1	4.1	4.1	8.1	7.9	8.1	4.2	4.3	4.7	8.3	3.9	4.6
	30 – 5 – 18	4.5	5.1	6.3	8.1	8.1	7.4	4.2	4.4	5.1	3.9	3.1	3.2
Mean		4.9	4.5	5.1	8.0	8.1	8.1	4.3	4.2	5.0	5.7	3.5	3.7

<u>Appendix Table 7</u> Inorganic phosphorus [Pi]mM values per month of latex diagnosis for the entire experimentation in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2005 to January 2006.

Irrigation treatment	Fertilizer treatment	October 13th, 2005			November 12th, 2005			December 15th, 2005			January 23rd,2006		
		Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Irrigated	15 – 7 – 18	30.1	16.0	31.9	26.9	18.0	29.5	28.2	17.6	34.7	20.3	15.9	30.9
	23 – 5 – 18	30.3	27.3	20.3	28.3	25.9	17.9	29.4	27.1	16.7	29.9	18.7	17.9
	30 – 5 – 18	18.2	25.1	28.5	20.1	22.6	27.8	17.9	24.1	31.4	19.6	20.3	26.0
Mean		26.2	22.8	26.9	25.1	22.2	25.1	25.1	22.9	27.6	23.3	18.3	25.0
Non irrigated	15 – 7 – 18	20.9	22.5	15.9	21.4	19.8	17.2	23.6	21.8	24.8	18.2	19.3	18.7
	23 – 5 – 18	15.1	22.2	21.4	17.1	22.6	20.3	20.8	25.5	25.3	21.7	18.8	20.3
	30 – 5 – 18	21.4	20.2	23.0	18.6	21.8	20.1	19.0	25.0	27.6	15.9	19.1	19.3
Mean		19.1	21.6	20.1	19.0	21.4	19.2	21.1	24.1	25.9	18.6	19.1	19.4

Appendix Table 8 Thiol [R-SH] mM values per month of latex diagnosis for the entire experimentation in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2005 to January 2006.

Irrigation treatment	Fertilizer treatment	October 13th, 2005			November 12th, 2005			December 15th, 2005			January 23rd,2006		
		Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Irrigated	15 – 7 – 18	0.4	0.4	0.4	0.3	0.3	0.3	0.5	0.5	0.5	0.4	0.6	0.5
	23 – 5 – 18	0.4	0.4	0.4	0.3	0.3	0.3	0.5	0.5	0.5	0.6	0.5	0.7
	30 – 5 – 18	0.3	0.4	0.4	0.3	0.3	0.3	0.5	0.5	0.5	0.6	0.5	0.6
Mean		0.4	0.4	0.4	0.3	0.3	0.3	0.5	0.5	0.5	0.6	0.5	0.6
Non irrigated	15 – 7 – 18	0.4	0.3	0.3	0.2	0.2	0.2	0.4	0.3	0.4	0.3	0.4	0.4
	23 – 5 – 18	0.3	0.3	0.3	0.3	0.3	0.2	0.4	0.4	0.4	0.5	0.5	0.3
	30 – 5 – 18	0.4	0.3	0.3	0.3	0.3	0.2	0.4	0.4	0.4	0.4	0.3	0.4
Mean		0.4	0.3	0.3	0.3	0.3	0.2	0.4	0.4	0.4	0.4	0.4	0.4

Appendix Table 9 Total solid content (TSC) levels per month of latex diagnosis in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2005 to January 2006.

Irrigation treatment	Fertilizer treatment	October 13th, 2005			November 12th, 2005			December 15th, 2005			January 23rd,2006		
		Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Irrigated	15 – 7 – 18	41.7	45.0	42.0	31.0	27.7	32.7	38.5	42.3	41.1	44.6	46.1	46.9
	23 – 5 – 18	40.6	43.9	45.5	32.0	32.4	30.7	36.7	38.5	36.4	45.0	46.9	44.4
	30 – 5 – 18	47.9	43.3	42.4	29.8	31.5	30.0	39.8	36.8	36.0	50.0	45.4	46.4
Mean		43.4	44.0	43.3	30.9	30.5	31.1	38.3	39.2	37.8	46.5	46.1	45.9
Non irrigated	15 – 7 – 18	46.9	44.0	43.9	27.0	30.9	25.1	31.8	42.3	31.7	47.9	47.5	49.5
	23 – 5 – 18	45.2	45.8	46.2	28.6	26.5	30.1	43.2	35.4	35.0	47.2	48.5	46.9
	30 – 5 – 18	45.4	44.9	44.6	27.0	28.1	31.3	34.9	35.4	41.0	47.5	47.7	46.9
Mean		45.8	44.9	44.9	27.5	28.5	28.8	36.6	37.7	35.9	47.5	47.9	47.8

Appendix Table 10 Girth measurement of rubber (cm) during the entire experimentation in the irrigation and fertilizer experiment conducted at Chanthaburi, Thailand between October 2004 to January 2006.

Irrigation treatment	Fertilizer treatment	October 19th, 2004	January 11th, 2005			October 19th, 2005			January 11th, 2006		
		Initial measurement	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
	15 – 7 – 18		54.6	52.8	55.0	56.2	54.2	56.0	56.6	58.0	58.3
Irrigated	23 – 5 – 18		58.8	53.8	54.4	60.4	54.8	55.9	60.8	55.2	60.4
	30 – 5 – 18		52.2	52.7	54.8	53.9	53.8	56.0	56.3	58.3	58.4
Mean		50.2	55.2	53.1	54.7	56.8	54.3	56.0	57.9	57.2	59.0
	15 – 7 – 18		49.4	50.2	52.5	51.3	51.4	54.1	54.4	51.8	54.8
Non irrigated	23 – 5 – 18		50.1	50.0	50.1	50.7	50.2	51.1	52.7	52.0	55.5
	30 – 5 – 18		50.7	49.4	50.6	52.7	51.2	51.9	53.2	53.9	52.2
Mean		50.2	50.1	49.9	51.1	51.6	50.9	52.4	53.4	52.6	54.2

Appendix Table 11 Percentage of tapping panel dryness measured at the end of experimentation in the irrigation and fertilizer experiment conducted at Chanthaburi, on January 2006.

Irrigation treatment	Fertilizer treatment	Percentage of tapping panel dryness (%TPD)			
		Rep 1	Rep 2	Rep 3	Average
Irrigated	15 – 7 – 18	1.3	0.7	0.3	0.8
	23 – 5 – 18	1.4	0.3	8.0	3.2
	30 – 5 – 18	3.7	5.0	3.3	4.0
Mean		2.1	2.0	3.9	2.7
Non irrigated	15 – 7 – 18	5.4	4.4	10.1	6.7
	23 – 5 – 18	0.0	2.1	8.9	3.7
	30 – 5 – 18	0.4	4.2	5.2	3.3
Mean		1.9	3.6	8.1	4.6

Appendix 12 Bio-data

Sopheaveasna Mak was born on 12 July, 1972 in Phnom Penh, Cambodia. He completed his B.S. Agriculture degree from the Royal University of Agriculture in 1996, after that, he worked as researcher at the Cambodia Rubber Research Institute, Ministry of Agriculture, Forestry and Fisheries. He was appointed as Vice Chief of Rubber Research and Development Center, under the Cambodia Rubber Research Institute in 2000.

Sopheaveasna Mak is a first son of Chhean Mak and Somapheavy Pegn. He has three younger brothers (Pichpisiddh Mak, Sokheng Mak and Pichsocheat Mak) and a younger sister (Pichpisey Mak) but one of younger brothers (Pichpisiddh Mak) died during the Pol Pot regime.

Sopheaveasna Mak was awarded the fellowship for pursuing his M.S. degree in 2004 from Department of Technical and Economic Cooperation (DTEC), Thailand. At present, this particular department changed its name as Thailand International Development Cooperation Agency (TICA). He started his graduate study leading to the Master degree in Tropical Agriculture in 2004 at Kasetsart University in Bangkok, Thailand and completed his M.S. degree in Tropical Agriculture (Agronomy) in 2006.