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Fertilizer Management for Sustainable Rubber Plantation

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ABSTRACT

Rubber tree (*Hevea brasilliensis* Muell.) is one of economic crops of Thailand and main production is in the southern region. Nowadays the plantation areas are expanded to other parts of the country because of its high price and continuous harvesting along the year. Soil under rubber tree have developed under tropical climate which their characteristics are acid, low fertility and risk of degradation especially in case of unappropriate management. Most of plant nutrients lose from plantation area by crop removal both from latex and from timber production. However, some part of plant nutrients still recycle in plantation area by annually litter falling. Chemical fertilizer this recommended for immature phase of the old region is 20-8-20 and 20-10-12 of the new region. Whereas 30-5-18 is recommended for tapping phase. Legume intercropping can reduce chemical fertilizer application and prevent soil erosion. Fertilizer application according to soil and plant nutrient status seem like the efficiency way, but still impractical for the small holder farmers. Organic fertilizer is also important for improving soil physical properties. However integrated management for sustainable production of rubber plantation should be further investigated.

Keywords: Fertilizer management Sustainable rubber plantation
Hevea brasilliensis Muell.

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บทคัดย่อ

ยางพาราเป็นพืชเศรษฐกิจที่สำคัญของประเทศไทย แหล่งปลูกหลักอยู่ในภาคใต้ ปัจจุบันพื้นที่ปลูกขยายไปทั่วประเทศ เนื่องจากราคาดี และให้ผลผลิตตลอดปี แหล่งปลูกยางพาราอยู่ในเขตภูมิอากาศร้อนชื้น ดินเป็นกรด ความอุดมสมบูรณ์ต่ำ เสี่ยงต่อการการเสื่อมโทรมหากจัดการไม่เหมาะสม ธาตุอาหารพืชสูญเสียไปกับผลผลิตทั้งในรูปน้ำยางและไม้ยาง แต่บางส่วนหมุนเวียนอยู่ในพื้นที่ปลูกเนื่องจากยางพาราเป็นพืชผลัดใบมีอายุเก็บเกี่ยวหลายปี ในประเทศไทยปุ๋ยเคมีที่แนะนำให้ใช้ในช่วงก่อนเปิดกรีดในเขตปลูกยางเก่า คือ ปุ๋ยผสมสูตร 20-8-20 และเขตปลูกยางใหม่คือ 20-10-12 การปลูกพืชตระกูลถั่วคลุมดินช่วยลดการใช้ปุ๋ยไนโตรเจน และ ลดการเซาะกร่อนของดิน ส่วนปุ๋ยเคมีที่แนะนำสำหรับยางหลังเปิดกรีด คือ ปุ๋ยผสมสูตร 30-5-18 การใส่ปุ๋ยตามค่าวิเคราะห์ดินเป็นวิธีที่มีประสิทธิภาพมากที่สุด แต่ยังมีข้อจำกัดในทางปฏิบัติระดับไร่นา ปุ๋ยอินทรีย์ก็มีความสำคัญเช่นเดียวกันโดยเฉพาะสภาพดินที่สมบัติทางกายภาพไม่เหมาะสม อย่างไรก็ตามยังต้องศึกษาแนวทางการจัดการดินแบบผสมผสานเพื่อการผลิตที่ยั่งยืนต่อไป

คำสำคัญ : การจัดการปุ๋ย การปลูกยางพาราอย่างยั่งยืน ยางพารา

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Introduction

Rubber tree (*Hevea brasilliensis* Muell.) is indigenous to the Amazon basin of South America. During the nineteenth century, Brazil was the main supplier of hevea latex, a milky colloid produce in lactiferous tissue of the bark, which was collected through tapping of tree in the natural forest. Until now rubber tree is cultivated as economic plants (1). There are several varieties that produce latex or timber and both of two productions (2,3). Many high-yielding clones have been developed for commercial planting. These clones yield more than 2,500 kg of dry rubber per hectare per year (400 kg rai^{-1}), when they are grown under appropriate condition (4).

Rubber plantation are found in several countries in the tropic from its native habitat in Amazon basin to Guatamala and Mexico in the America; Nigeria, Liberia, Cameroon and Ivory Coast in West Africa and continental and insular Southeast Asia and The Indian sub-continent. (2). Rubber plantation areas in Asia occupy approximately 94 % of the world total, 5.1 % in Africa and 1.2 % in America (2). In Southeast Asia Thailand, Indonesia and Malaysia rang first among the world rubber cultivators, They contribute more than 90 % of the world total. Other countries in Asia with relatively minor rubber plantation are India, Vietnam, China, Sri Lanka, Philippines, Burma, Lao and Cambodia (1). Plantation area in Thailand is approximately 2.79 million hectares (17.41 million rai) in 2009 (5). The large plantation area cover 14 provinces of the South region which occupy around 76 % of the total country. Whereas it's occuptes 12 % in the East region, 11 % in the North-east and 2 % in the North region (6).

The climate conditions for optimum growth of rubber tree consist of (a) rainfall of around 2,500 mm evenly distributed without any markedly dry season and with at least 100 rainy days per year (b) temperature range about 20 °C to 34 °C with monthly mean 25 °C to 28 °C (c) high atmospheric humidity of around 80 % (c) bright sunshine amounting to about 200 hours per year at the rate of 6 hours per day throughout the year, and (d) absence of strong winds (2).

The soil requirement of the plant is generally well-drained weather soil consisting of laterite, lateritic types, sedimentary types, non-lateritic red or alluvial soils. Rubber tree is a high nutrient demand crop especially during the immature stage of its growth and development. Optimum growth and high quality latex output therefore depend largely on ability of the farmer to determine controlling factors and properly adjust them to suit rubber production. Most of rubber cultivators in Thailand are small holder. During immature state there is some money support for the replanting area. But a long 25-30 years of tapping phase the farmers have to manage rubber plantation and related activities by themselves. However, many farmers neglect

to maintain soil fertility because the rubber tree still produce the latex as if it stand on serious condition.

This paper is an overview about rubber plantation which is one of crucial economics crop of Thailand, soil properties of rubber plantation and it's limitation, nutrient cycle in plantation areas and nutrient management in immature state and tapping state. This information is useful for sustainable soil and fertilizer management of rubber production.

Rubber tree as economic plants of Thailand

Rubber tree is one of the economic plant of Thailand. Since its introduction to Thailand during the early 1900, the country has grown to become the world's largest producer and exporter of natural rubber (5). From 2008-2009 rubber plantation area and production area increase 4.13 % and 1.23 %, respectively, leading to the increasing yield of 0.28 % or about 0.3 million tons. Nearly 90 % (2.7 million tons) of Thailand' natural rubber production is for export. That consist 0.991 million tons of rubber blocks, 0.769 million tons of ribbed smoked sheet, 0.504 million tons of concentrated latex and 0.435 million tons of compound rubber, which 0.37 % increase from 2008 (5). The top five destination for Thailand rubber products in terms of export value that year were China, Malaysia, Japan, the European Union and the United state (2). Strong growth of Chinese and Indian economies and demand for rubber in the two Asian giants to feed their tire industries is still a good opportunity to planting countries (4). However the fluctuating price can occur, depending on the world economic status and the oil price.

The requirement of natural rubber within the country is around 0.370 million tons (12 % of total production), which consist of 40.8 % of ribbed smoked sheet, 33.96 % of STR and 25.24 % of concentrated latex. Vehicle industry requires the largest amount of natural rubber in Thailand (5). Rubber tree can be harvested through a year except in a rainy day, so plantation holder and latex tapping labor gradually earn money along the year, and it also helps to maintain agricultural labor in local area. That prevents agricultural labor transfer to the big city.

Properties of rubber planting soils and their limitations

Hevea or rubber tree can grow on a wide range of soil but more than 1 meter depth and well drained soils of pH below 6.5 and free from underlying sheet rocks are well suited for its performance as a commercially viable plantation crop. Soil under hevea in general, have developed either under warm humid equatorial monsoon climate with little or no dry period or under tropical wet-dry monsoon climate with variable duration of dry season, extending from three to five months. The Indonesia archipelago, Malaysia and Southern part of Sri Lanka fall under the former climatic zone, while India, north

part of Sri Lanka, Burma, Thailand , Vietnam and Philippines archipelago and the South part of Indonesia fall under the latter (7).

Physiographic features such as degree of slope, aspect, soil depth, rockiness ect., influence growth and yield of rubber (7). Rubber has extensive root system with taproots that could be as deep as 3-4 meters (8). The 5 years old rubber plantation, root concentration was seen in the top 18 cm layer. Horizontally the roots were found up to 200 cm away from the plant base (9). So that, a fairly deep, well drained soil with good physical structure on a gently sloping terrain with minimal soil erosion is required by rubber for optimum growth (8). However, the rubber tree can withstand soil physical conditions ranging from stiff clayey with impeded drainage to well drained sandy loam. Fragile soil with high clay particle such as clay loam is the most suitable texture (7), because clay particle has a high water retention and rich in plant nutrient element compare to silt and sand particles. However, the low fertility of soil can be improved by adding fertilizer in appropriate proportion of plant nutrient element and right in quantity.

Plant growth is directly affected by the presence of gravel by impeding root development and seedling emergence and indirectly through reduction of volume of soil that can be dawn upon by plant for water and nutrients (10). Shallow soils, which have gravely layer less than 100 cm restrict development of rubber tap root affecting anchorage of trees. However, the tree planting in that condition can adapt to survival by bending taproot sideways instead of growing vertically in to the soil and preponderance of extensive lateral root system that compensates for the tap root (8).

Rubber planting soil in the South of Thailand has been developed under humid tropical climate, so it is generally low fertility. Kaolinite, which low capacity of nutrient adsorption, is the dominant clay mineral. Analysis of 27 soil series samples found that it contained plant nutrient element in the range of low to medium. pH 4.1-4.7, total nitrogen 0.4-2.5 mg kg^{-1}, available phosphorus 4-25 mg kg^{-1}, exchangeable potassium 0.04-0.23 $cmol_c kg^{-1}$ exchangeable magnesium 0.15-1.37 $cmol_c kg^{-1}$ and cation exchange capacity (CEC) 3-18 cmol kg^{-1}. Chemical properties of soil under rubber plantation both in the old area (South of Thailand) and in the new area (North-east and North of Thailand), including the appropriate range, were also shown in Table1.

Table 1. Chemical properties of soil planting rubber tree (0-30 cm) in Thailand (11).

Chemical properties	Old plantation area	New plantation area	Appropriate range
Organic matter (%)	1.00-2.90	0.80-2.50	1.00-2.50
Total nitrogen (%)	0.60-0.14	0.04-0.13	0.11-0.25
Available P (mg kg^{-1})	12.00-46.00	12.00-45.00	11.00-30.00
Exchangeable K (mg kg^{-1})	20.00-77.00	20.00-69.00	>40.00
Exchangeable Ca ($cmol_c$ kg^{-1})	0.08-1.73	0.24-7.97	>0.30
Exchangeable Mg ($cmol_c$ kg^{-1})	0.10-0.85	0.21-1.67	>0.30
Fe (mg kg^{-1})	17.61-133.60	15.30-125.68	30.00-35.00
Mn (mg kg^{-1})	2.23-31.91	6.36-44.74	2.00-4.00
Zn (mg kg^{-1})	0.18-2.08	0.15-0.80	0.40-0.60
Cu (mg kg^{-1})	0.80-1.97	0.16-0.55	0.80-1.00

The results of the analysis of 50 soil samples from rubber plantation in South of Thailand showes that most of soil samples contained organic matter, total nitrogen and exchangeable Ca higher than critical value. On the other hand, exchangeable K and exchangeable Mg were lower than critical value (12). However, the criteria of chemical properties of soil for growing rubber tree is quite different, depending on the source. Another criteria of rubber growing soil other than Rubber Research Institute was summarized in Table 2.

Table 2. Criteria for soil data interpretation (8)

Soil parameter	Very poor	Low	Moderate	Good
Ca ($cmol_c$ kg^{-1})	1.0	1.0-2.3	2.3-5.0	7.0
	(200)	(200-460)	(460-1,000)	(1,400)
Mg ($cmol_c$ kg^{-1})	0.4	0.5-1.0	1.1-1.5	3.0
	(48.6)	(60.8)	(133.7-182.3)	(364.5)
K ($cmol_c$ kg^{-1})	0.01	0.01-0.2	0.2-0.4	0.4-0.8
	(3.9)	(3.9-78.2)	(78.2-156.4)	(156.4-312.8)
ECEC (cmol kg^{-1})	<4	4-9	9-12	>12
Avai.P (mg kg^{-1})	<5	5-8	8-10	>10
Total N (%)	<0.04	0.05-0.12	0.12-0.24	> 0.24

The value in the bracket are stress by mg kg^{-1}

Long-term planting with lack of appropriate soil management made soil gradually degrad. In plantation area, plant nutrients normally lose by crop removal, soil erosion and soil leaching. Slash and burn in order to clear surface land for a new planting and replanting a made short term fertile soil but loss of soil organic matter that is essential substance maintaining soil fertility for cultivation area, including rubber plantation. According to the observation of rubber plantation in Hinan Island , China during 1954 to 1995, it was found that soil organic matter, total N, available K and available P decreased by 48.2 %, 54.1 %, 56.7 % and 64.1%, respectively. The Annual average declining rate of, available K, organic matter, available P, available N and Total N were 5.3, 4.3, 3.8, 2.9 and 2.3 % respectively (Table 3.). If the complete return of litters was considered without additional fertilizer application to the soil of the rubber plantation, the consumption periods for P, N, K and Mg were only 825, 329, 94 and 65 years, respectively (13). So It is necessary to improve soil fertility in rubber plantation.

Nutrient cycle in rubber plantation

Rubber plantation area resemble to forest. Although, there is some plant nutrient loss by crop removal as latex, litter fall annually can resupply partially of nutrient element into the soil after it is decomposed by soil microorganism. In a rubber plantation the nutrients undergo in a dynamic flow, frequently suffering transformations in a cyclic fashion. The heart of nutrient cycling is the soil, which acts as a reservoir and gradually allows the removal and immobilization of nutrients, both by rubber tree and by the plant covering the soil. (14). At the first state of rubber growing (1-4 years), If legume is grown in order to prevent the out break of weed, the plantation will receive more organic matter from legume biomass and increase nitrogen from symbiotic nitrogen fixation. The leaves,

Table 3. Degradation rate of soil fertility under rubber plantations in Hainan Island (13).

Parameter	Reference system	Natural soil (%)	Rubber plantation soil	Average annual (%) declining rate (%)	
1982	1995				
O.M.	percent oversoil of > 2 %	75.50	66.20	10.3	4.3
Total N	percent oversoil of > 0.1 %	52.60	44.50	14.0	2.3
Total P	percent oversoil of > 0.14 %	3.69	2.37	0	-
Total K	percent oversoil of > 1.2 %	82.90	78.30	40.0	2.9
Avai.N	percent oversoil of > 60 mg kg^{-1}	89.90	80.10	12.2	2.9
Avai.P	percent oversoil of > 5 mg kg^{-1}	62.10	59.40	10.0	3.8
Avai.K	percent oversoil of > 50 mg kg^{-1}	88.20	82.50	14.0	5.3

Data of natural soil and rubber plantation soil in 1982 and the reference system were base on the second soil servey in Hainan (HPSSF, 1993)

Table 4. Nutrient concentrations from 6-month-rubber leaves (A) and fall leaves (B) (14).

Sample	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	g kg^{-1}						mg kg^{-1}				
A	33.1	3.6	9.3	25.0	6.8	2.8	36	12	271	130	25
B	13.1	0.9	1.1	24.0	4.8	2.4	54	9	554	170	16

branches and seeds that fall from rubber trees make up main source of nutrients returning to the soil. Production state of rubber plantation annually drop fruit and leaves to the soil 160 and 5,700 kg ha^{-1} as dry matter, respectively.

In a 4-year-old rubber plantation intercropped with *Pueraria phaseoloides*, dry matter of the legume and the rubber tree were estimated. It was found that 3,185 and 2,787 kg ha^{-1} of the legume and rubber tree litter were accumulated to the soil. Whereas the latex extracting 25, 18, 11, 5 and 2 kg ha^{-1} of N, K, Ca, Mg and P, respectively. With regard to the amounts of nutrients extracted by the rubber tree and by the legume, 59 % of N, 55 % of Ca, 54 % of Mg, 37 % of P and 22 % of K return to the soil (14).

Rain can leach plant elements to the plantation soil. It was estimated that 20, 10, 0.5 and 1.5 kg ha^{-1} of K, N, P and Mg were leached by 2,450 mm rain into the soil. However, Plant nutrient element that cyclic in rubber plantation soil also depends on soils and fertilizer managements. Increasing K fertilization rate also increased the K content in leaf litter fall. Calcium and N as macro element were the most recycled leaf nutrients to the soil via litter fall. Whereas the concentrations of B, Fe and Mn in fall leaves are higher than in 6-month-rubber leaves. (Table 4.) Potassium, followed by P was nutrients with the highest retranslocation rate. Potassium was the most export nutrient by harvested rubber, and this amount was higher than that transferred to the soil by the leaf litter fall (14).

Table 5. Estimation of amounts of nutrients in 6-month old rubber tree leaves, macronutrient retranslocation rate, amounts of nutrients remaining and translocation (14).

Estimate	N	P	K	Mg	S
Nutrients in rubber tree leaves before falling (kg ha^{-1})	56.5	6.1	14.2	11.7	4.8
Retranslocation rate (%)	59.0	73.0	86.0	27.0	9.0
Amounts of nutrients translocated from leaves (kg ha^{-1})	33.3	4.5	12.2	3.2	0.4
Amounts of nutrients remaining in the leaves (kg ha^{-1})	23.2	1.6	2.0	8.5	4.4

Nutrient managements for sustainable production

Humid tropical soil is a high weathering soil which faces a trouble of degradation cause of both natural weathering and miss using. Opening soil surface and land preparation for a new planting or replanting made soil vulnerable to surface loss. Slope land more than 15 % should be planted on terrace. The rubber tree is such a long life crop. An economic life cycle is around 30-40 years. This can be divided into two main phases, the immature period of 5-7 years from planting to tapping, and the mature period during which the tree are tapped. Suitable soil and fertilizer management both immature and tapping period affect high yield and make fertile soil for sustainable production.

Soil and fertilizer management for immature state of rubber tree

Immature state of rubber tree takes 5 to 7 years depending on varieties, climate condition, soil properties and fertilizer management. The growth rates of rubber tree grown in the South and the East region of Thailand are higher than those grown in the North-East and the North. The average trunk girth increment of an immature plant grown in the South and the East region was 8.10-8.50 cm $year^{-1}$ whereas, only 5.70-7.30 cm $year^{-1}$ of trunk girth increment in the latter regions (15).

Considering to nutrient or fertilizer management, It was found that percentage of RRIM 600 plant able for tapping was significantly affected to K fertilizer while N responses were observed in some occasions. However, plant respond to the fertilizer takes a little bit long, such as 24 months for K fertilizer. Whereas, Linear NK interaction was frequently observed after 48 months of plant age (16).

Intercropping with short harvest plants is a good choice in rubber plantation from start growing until the fourth year of planting. Covering plantation area by growing legumes is an alternative way to minimized surface soil loss, maintain soil moisture and increase soil fertility. Because of nitrogen fixation by rhizobium that infect the legume root, it can be reduced nitrogen fertilizer rate as fertilizer recommendation in Malaysia shown in Table 6. (17) Moreover, large amount of legume biomass is finally accumulated to the soil, and resulted in soil organic matter increased. In addition, rubber plantation and inter row with legume can be omitted fertilizer application for two years before tapping (6).

Table 6. Fertilizer rate recommendation from 1 to 6 years of rubber plantation in Malaysia (17).

Fertilizer and legume	Nutrients (kg ha^{-1}) from 1 st to 6 years			
	N	P_2O_5	K_2O	MgO
Low K, no legumes	640	250	170	50
Low K, mixed legumes	225	250	170	50
Low K, pure legume stand	30	250	170	50
High K, no legumes	660	260	90	50
High K, mixed legumes	225	260	90	50
High K, pure legume stand	30	260	90	50

In Thailand, two complete fertilizers; 20-8-20 and 20-10-12 have been recommended for immature state depending on region. The first fertilizer grade was recommended for the rubber grown in the South and the East of Thailand and the latter has been recommended for the new regions especially the North east and the North of Thailand. Fertilizer Application rate depends on age of the tree and soil texture shown in Table 7.

Table 7. Fertilizer rate for immature state of rubber tree (6)

Year	Age of rubber tree (month)	Fertilizer rate (g $plant^{-1}$)		
		Fertilizer 20-8-20		Fertilizer 20-10-12
		Clay loam	Sandy loam	All type of soil texture
1	2	70	100	60
	5	100	140	80
	11	130	170	100
2	14	150	200	110
	16	150	210	110
	23	150	210	120
3	28	230	320	180
	36	230	320	180
5	52	260	360	200
	59	260	360	200
6	64	270	370	200
	71	270	370	200

Soil and fertilizer management for tapping state of rubber trees

The main rubber production is latex which flows from latex vessels in the bark surrounding the trunk. Tapping of rubber tree starts in the fifth to seventh year after planting and then continues for 25-30 years. After 30 years, a decline in latex production make further tapping of the tree uneconomic. (18) In general practice, when the trunk has about 50 cm circumference at 150 cm above ground is appropriate time to start tapping. (6) In the past, after cutting the old rubber plant, they were burnt for preparing of replanting. Nowadays, the rubber timber was required for furniture industry. Both of the latex tapping and rubber wood production affect nutrient depletion in planting area by crop removal.

Potassium is the largest nutrient element contain in latex that was removed from plantation area follow by N, P, Ca, S and Mg. These elements contained in rubber latex 2.95, 2.8, 1.09, 0.84, 0.22 and 0.21 g kg^{-1}, respectively. Then, the nutrient elements were removed 5.0, 4.8, 1.9,1.4,0.4 and 0.4 kg ha^{-1} with 1,700 kg ha^{-1} of latex yield. (14) Where as Suntaree and Jintana (19) reported that the dry mass weighted average concentration for a whole tree of Ca, N, K, Mg and P were 5.9, 3.63, 3.24, 1.01 and 0.44 g kg^{-1}, respectively, and the concentrations of N, K, P, Mg and Ca in the latex were 7.30, 2.60, 0.69, 0.56 and 0.08 g kg^{-1} respectively. They also estimated that plant nutrient requirement for the growth and yield of 8-25 years of rubber tree were N = 142, Ca = 120, K = 95, Mg = 28 and P = 16 g $plant^{-1}year^{-1}$. Thus, fertilizer application along the tapping phase should be considered.

Fertilizer grade recommended for tapping phase of rubber tree planting in almost soil texture of Thailand is 30-5-18 with the rate of 1 kg/plant and should be split to 2 application times. The first time is at the early of rainy season that enough soil moisture and new leaves become mature,

Table 8. The criteria of soil fertility for rubber plantation (21)

Parameter	Soil interpretation		
	Low	medium	high
Carbon (%)	< 0.5	0.5-1.5	>1.5
Total N (%)	<0.11	0.11-0.25	>0.25
Available P (mg kg^{-1})	<11	11-30	>30
Available K (mg kg^{-1})	<40	>40	-
Exch.Ca ($cmol_c$ kg^{-1})	<0.30	>0.30	-
Exch.Mg ($cmol_c$ kg^{-1})	<0.30	>0.30	-

and the second time is at the end of rainy season (6). However, each plantation area is different in soil fertility and plant nutrient condition. Base on real time fertilizer application also promoted for rubber plantation, which application rate of fertilizer depends on plant nutrient status in its plant and soil.

Soil sample from plantation area is determined, then fertilizer rate can be recommended properly. The criteria of soil fertility for rubber plantation depicted in Table 7. And the recommendation for fertilizer application as follow; soil contain organic matter less than 1.5 g/100 g should be add 24 kg-N rai^{-1} (150 kg-N ha^{-1}). Where as the soil contain organic matter more than 1.5 g 100 g^{-1} need 12 kg-N rai^{-1} (75 kg-N ha^{-1}). Available P in soil more than 11 mg kg^{-1} need 8 kg-P rai^{-1} (50 kg ha^{-1}), less than 11 mg kg^{-1} should be added 4 kg-P rai $^{-1}$ (25 kg-P ha^{-1}). Exchangeable K in soil less than 40 mg kg^{-1} add 19 kg-K rai^{-1} (118.75 kg ha^{-1}) whereas more than 40 mg kg^{-1} add 14 kg-K rai^{-1} (87.5 kg-K ha^{-1}) (20).

Comparison of rubber fertilizer application according to plant nutrient status and traditional method in 2 provinces of Thailand ; Surat Thani and Nakornsrithammarat showed that the fertilizer application according to plant nutrient status gave 438 kg $^{-1}rai^{-1}year^{-1}$(2,737.5 kg $ha^{-1}year^{-1}$) of latex yield, 30,625 bath $rai^{-1}year^{-1}$ of income generation and 6,086 bath rai^{-1} of the net profit, whereas the conventional method gave 353 kg rai^{1} year ^{1} (2,206.25 kg ha^{-1} year, 24,693 bath rai $^{1}year^{1}$ and 5,932 bath rai^{1}.(21). This indicated that site specific nutrient management is appropriated technology for rubber plantation.

Organic fertilizer application in rubber plantation

Organic fertilizer is an alternative fertilizer application both for immature state and for tapping state, especially in poor physical properties of soil. Improper characteristics of tropical soil such as rapid decomposition of organic matter, low cation exchangeable capacity and low pH can be remedies by adding organic residue or organic fertilizer other than annually accumulated by leaf litter. Although many investigations on the use of organic fertilizer in rubber plantation of Thailand have been done since 1976, the results can not be concluded with certainty.

Rubber seedlings fertilized with 500 kg/rai (3,125 kg ha^{-1}) of organic fertilizer and a half of chemical fertilizer recommendation rate (30 kg rai^{-1} or 187.5 kg ha^{-1}) increased the trunk growth, minimized the time for preparing stock and high success of budding compare to those of only chemical fertilizer application (22). In low quantity of rain fall area i.e. The North-east of Thailand, to incorporate organic fertilizer with the soil before planting and prepared the plating hole deeper than normal (50x50x75cm) made the rubber tree grew better and more survive compare to

unapplied organic fertilizer. It was significantly affected to the growth of rubber tree until the second year of the planting (23).

Organic fertilizer application along with chemical fertilizer in high falling rain area such as the South and the East region did not show significant different from sole chemical fertilizer application (24). The results of organic fertilizer application for tapping state were variable depending on soil condition. In some case rubber tree received organic fertilizer together with chemical fertilizer have highest increment of circumference. So that it gave a high yield. However, it was not the best practice considering to economic gain.

Discussion

Rubber tree is an economic plant in Thailand especially in the South region. Recently, rubber latex still has a high price and less fluctuation. The farmer can get certainly income compare to the other plant production. According to the government policy in 1989 to grow rubber in other regions. Now plantation areas are expanded to the other parts of country which are poor in soil properties and climate conditions. Whereas, in the South region unsuitable area such as sloping land and low land or abandon paddy rice field are widely used for rubber plantation.

Native habitat of rubber tree is in the tropic that organic matter in the soil is decomposed rapidly (25). They are devoid of most nutrients and have a low CEC, a low base saturation and high aluminum saturation (17). Rubber plantation soil in south of Thailand is also low pH. According to the soil analysis results of 27 soil series growing rubber revealed that soil pH range from 4.1 to 4.7 (11). Consequently, deficiency of basidic cation, such as Ca, Mg and K were occurred. However rubber plantation soils were treated from land clearing for a new planting and annual fertilizer application. So that nutrient status is variable depending on level of soil and fertilizer management.

Nutrient element in rubber plantation also lost by crop removal especially K and N which are high concentration in rubber latex (14,20). Along 25 to 30 years of tapping period, large amount of plant nutrient is lost and should be compensated by adding fertilizer. Slightly elevated the soil pH by liming to reach a weak acid level should be investigated for elevating available form of some plant nutrient elements such as phosphorus that is always fixed by Al and Fe in acidic soil (26). At the same time the soil will receive Ca which is the most necessary for bark or trunk development (19) if $CaCO_3$ is used. Whereas if Dolomite is added to adjust pH plant will receive both Ca and Mg (27).

Economic life cycle of rubber tree is around 30-40 years. That can be separated into two phases; immature and tapping phase. Well growth and healthy tree at immature state can produce a high latex

production. Fertilizer recommendation for immature state of the old plantation area is 20-8-20 and 20-10-12 for a new region. Application rate depends on rubber age and soil texture. Nitrogen fertilizer in this phase can be reduced by legume intercropping. In tapping phase, 30-5-18 fertilizer is recommended (6). However, the farmer still apply various kinds of fertilizers which are available in their villages (28). Moreover they do not apply fertilizer every year. So the rubber tree can not produce a high latex production in the long run.

Fertilizer application according to plant nutrient status in soil and plant of each area is the most efficiency of soil and fertilizer management. Comparison of rubber fertilizer application according to soil nutrient status and traditional method in 2 provinces of Thailand ; Surat Thani and Nakornsrithammaraj showed that the former method gave 85 kg rai^{-1} $year^{1}$ higher yield than the latter method, and increase 25.64 % of the net profit (21). Fertilizer application according to soil nutrient status in corn cultivation gave higher yield than the fertilization by general recommendation whereas the cost of fertilizer was not significant different (29). In Sugar can, it was found non-significant different of the yield, but % brix (soluble solid), %pol (percent by weight of sucrose in sugar can juice) and % purity of sugar can juice were higher in fertilization by plant nutrient status considering than in general recommendation (30). In addition, the results of rice cultivation showed 18 % of yield increasing in fertilization by general recommendation whereas 23 % of yield increasing in case of fertilization according to plant nutrient status (31).

The limitation of fertilization as specific nutrient management of rubber small holder are lack of plant and soil analysis laboratory, time consumption of the process and high cost. Nowadays, they can evaluate soil fertility status quickly by using soil test kit and the fertilizer recommendation is revealed by Rubber Research Institute of Thailand. However most of the farmers still lack of knowledge about this technology.

Organic fertilizer is an alternative fertilizer application both of immature state and tapping state, especially in the poor physical properties of soil such as plantation area in the North-east of Thailand and rubber plantation in abandon paddy field that lack of organic matter. It can support the growth of rubber seedling (24). Whereas in tapping phase the research results are still not clear that should do further research. However, the information detailed in this review can lead to recommendation for a proper management of soil for sustainable rubber plantation which remain to be resolve scientifically.

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