Utilization of Vetiver Grass and Soil Analysis as a Tool for Bulk Blended Fertilization in a New Rubber Plantation on Sloping Land

Jindarat Chuenrung, Chusak Sajjapongse, Apirat Khaosawee and Thammanoon Kaewkongka

Soil ScienceResearch Group, Agricultural Production Sciences Research and Development Office, Department of Agriculture, Phaholyothin Road, Bangkok 10900, Thailand

An experiment on vetiver started in 2003 on a farmer land in Tambon Tabtao, Amphur Thoeng, Chiang Rai Province. Total land area was 0.8 ha, with 15-20% slope and approximately 700 m asl. Plants used in the experiment consisted of rubber saplings (RRIM 600) and vetiver grass, which was planted along the contour lines to conserve soil and water. Total duration of the first phase was three years (2003-2006).

The land was divided into four plots, 0.2 ha each, and a trial was done to test the use of fertilizers in newly planted rubber plantations. There were four treatments: 1) readily blended fertilizer recommended by the Rubber Research Institute (RRI) (20% N, 10% P_2O_5, 12% K_2O, at a rate of 360-400 g/plant/year), 2) fertilizer of the formula recommended by the RRI, blended just before the application time, 3) fertilizer of the formula derived from the soil analysis data, and 4) same as (3) but with an addition of 2 kg of cow dung/plant/year.

Soil analysis data indicates that soil in the experimental area is relatively deep, approx. 90 cm (0-70 cm: clay; 70-90 cm: sandy clay loam). Bulk density at various depths varies from 1.29 to 1.59 g/cu cm. Drainage in the subsoil is slow, approx. 0.04-0.06 mm/hr. Within the plow layer (0-15 cm) the soil pH is slightly acid (6.2), but it has high organic matter content (2.61%), low available phosphorus (5.15 ppm) and high available potassium (147 ppm).

Vetiver grown on the contour line could reduce soil loss by 1.9-17.8 times. Vetiver could absorb carbon dioxide to accumulate in the organic forms in the stems and leaves up to 50.7%. Phosphorus and potassium contents in the plants amounted to 0.06% and 0.93%, respectively.

Fertilizer formula derived from soil analysis data was 75-50-87.5 kg/ha N, P_2O_5 and K_2O, respectively. Six years after planting, the averaged circumferences of the rubber trees (at the height of 1.5 m) in treatments 1 and 3 were 30.67 and 30.56 cm, respectively, while those in treatments 2 and 4 were only 27.44 and 27.06 cm, respectively.

It was found that rubber trees in treatment 3 yielded as much as 59 kg of rubber sap/ha/day, while those in treatments 1 and 4 yielded 54 and 55 kg/ha/day, respectively and the trees in treatment 2 gave the lowest, 41 kg/ha/day.

It can be concluded that applying fertilizers according to the soil analysis data produced significantly more rubber sap than the blended fertilizer formula recommended by the RRI. On the other hand, the use of organic fertilizer may not be necessary, as the soil is clayey, with relatively high organic matter content.

Study was also done on the biodiversity of the soil in the root zone, including N-fixing bacteria. They will be recorded in the vetiver database, to be useful for future research and development.

Keywords: Use of vetiver grass, application of fertilizers according to the soil analytical data, newly planted rubber plantation, sloping land

Introduction

Farmers living on sloping highland practice slash-and-burn to get rid of weeds before growing cash crops such as maize, ginger and upland rice, for their food and income. After having farmed for a period, farmers will leave the land fallow and move to cultivate the crops in a new area; the practice is called 'shifting cultivation'. In 1993, the Thai Department of Agriculture (DOA) experimented by growing Para rubber (*Hevea brasilensis*) on a sloping highland at 700 m asl and found the rubber trees grew well and produced high amount of rubber sap. In 2003, the DOA started a 1-million-rai Para rubber for the North and the Northeast Project, with 300,000 rai for the North. Since then, farmers gradually grow Para rubber as an economic crop in their land.

Para rubber is an important economic crop for national development. In 2003, the total rubber cultivation area was 12.6 million rai (Thailand Rubber Research Institute, 2005). In that year the country could export 3.17 million tons of rubber that was worth 210.4 billion Baht. The revenue from exporting rubber had increased to 331.7, 331.0 and 375.6 billion Baht respectively for the years 2006, 2007 and 2008. Rubber cultivating area in 2008 was 16.7 million rai, yielding 3.17 million tons of rubber. China, United States, Japan, Malaysia and South Korea have been the major importers (Agricultural Economics Office, 2008). Rubber is therefore a very important economic crop for Thailand, which has generated a good income to farmers. Moreover, it has built a good habit to the farmers in their good attitude towards tree growing for the conservation and management of natural resources and the environment. Keeping Para rubber trees in a form similar to the forest can help preserve topsoil and alleviate certain natural catastrophes.

Due to the '1-million-rai Para rubber for the North and the Northeast Project', with 300,000 rai for the North, farmers were enthusiastic in growing this cash tree-crop. The Para rubber cultivation area in Chiang Rai province increased rapidly from 49,288 rai in 2006 to 81,936 rai in 2007 and 92,851 rai in 2008, respectively, with a relatively high yield of 278 kg rubber/rai in 2008 (Agricultural Economics Office, 2008).

Due to the high price of rubber this cash tree-crop has attracted interest from many farmers; much of the land under shifting cultivation was put under this tree-crop. The RRIM 600 Para rubber variety was brought to cultivate on the farmers' sloping highland at 700 m asl at Tambon Tabtao, Amphur Thoeng, Chiang Rai Province. As the land was formerly under shifting cultivation and had a high rate of soil erosion, vetiver grass of Sri Lanka variety was grown across the slope to reduce soil erosion and loss of plant nutrients (Tawachai et al., 2002). The practice has been known to reduce soil erosion to 1/36 and runoff to 1/6 (Tawachai et al., 1995). It was also known that, to increase rubber yield application of chemical fertilizers and compost is necessary. These fertilizers can be from the recommendation of the DOA (2005) and by self-mixing of single fertilizers (DOA, 1998), which may help reduce the investment cost.

Purpose

The purpose of this study was to establish experimental-cum-demonstration plots to show farmers how to take care of the newly planted Para rubber trees, particularly how to apply fertilizers and how to tap the rubber sap, by using self-mixed fertilizers according to the soil analytical results. This is to help save some cost as well as to increase the ability of the trees to give a higher yield. In this area, vetiver grass was planted along the contour lines during the early stage to reduce soil erosion and nutrient loss. Moreover, the investigators had studied the absorption of CO_2 by vetiver grass as a way to slow down the global warming, and also studied the biodiversity of the soil under vetiver grass.

Materials and Methods

1. Materials
   1.1 20-10-12 fertilizer ($N-P_2O_5-K_2O$)
   1.2 46-0-0, 0-46-0 and 0-060 fertilizers ($N-P_2O_5-K_2O$)
   1.3 Soil sampling tools for physical and chemical analysis
   1.4 Rainfall measuring gauge
   1.5 Instruments to analyze soil physical properties
   1.6 Tools to analyze soil microbes

The experimental plots with an area of 5 rai were constructed in the field of farmer (Mr. Tab Piraban), Tambon Tabtao, Amphur Thoeng, Chiang Rai Province, when the Para rubber trees were grown from June 2003, with vetiver grass included from the beginning. The slope gradient of the area was approximately 15-20%. The area was divided into 4 plots, 1.25 rai each, with the following treatments:

1. Application of ready-mixed fertilizer (20-10-12, as percentage of $N-P_2O_5-K_2O$) as recommended by the Thai Rubber Research Institute (1998).
2. Application of self-mixed fertilizer (20-10-12, as percentage of $N-P_2O_5-K_2O$) as recommended by the Thai Rubber Research Institute (1998).
3. Application of self-mixed fertilizer according to the soil analytical results.
4. Application of self-mixed fertilizer according to the soil analytical results, plus adding 2 kg of cow dung to each tree every year.

The Para rubber trees were planted at a spacing of 2.5 x 7.0 m. Vetiver was planted across the contour lines between rubber trees. Soil samples were collected from various depths up to 90 cm for chemical and physical analysis. The girth (at 1.5 m) of 9 trees was measured in each plot. Rubber sap was collected when the trees were 6 years old by averaging from 30 trees per plot. Sediment was collected for each year to compare soil erosion in plots with and without vetiver.

During the 3 years of the experiment (2006-2008) data related to the biodiversity of the soil grown to vetiver was collected at the soil layer of 0-30 cm in upper slope, middle slope and lower slope sites. Vetiver was sampled to analyze for the carbon absorbed in the stems and leaves, and soil samples were collected to analyze for the carbon absorbed by the soil.

Experimental Site: The field of farmer (Mr Tab Piraban), Tambon Tabtao, Amphur Thoeng, Chiang Rai Province (5 rai = 0.8 ha) (Position: Q 0643306 UTM 2191923)

Period of the Experiment: October 2006-September 2010 (4 years)

Results and Discussion

1. Soil chemical properties

From the disturbed soil samples (0-15 and 15-30 cm) collected from the Upper Slope, Middle Slope and Lower Slope at the beginning of the experiment, it was found that, soil in the plow layer is slightly acid (pH 6.2), relatively high in organic matter content (2.6% OM), low available P (5.16 mg/kg) and high available K (147 mg/kg).

Averaged values of Ca, Mg, Mn, Fe, Cu and Zn were found to be 1,520, 133, 59, 23, 1.7 and 0.84 mg/kg, respectively. Analysis of the subsoil shows that all nutrients are lower than the topsoil, with the exception of the iron (Table 1).

At the same time, disturbed soil samples were collected from a middle slope location along with those undisturbed soil samples, with the purpose to study the fertility of the soil at the depths of 0-5, 0-10, 10-20, 20-30, 30-50, 50-70, 70-90 and 90-100 cm (Table 2).

2. Soil physical properties

2.1 *Soil texture* (Table 3). Using the Pipette method, it was found that the soil in the middle slope has a depth of 90 cm, the upper part (0-70 cm) being in the category of Clay, with 15.16% course sand, 9.93% fine sand, 21.44% silt and 53.28% clay. The lower part, on the other hand, belongs to the category Sandy Clay Loam, with 38.60% coarse sand, 13.38% fine sand, 22.31% silt and 25.71% clay.

2.2 *Soil bulk density:* A metal core was used for collecting undisturbed soil samples from 0 to 90+ cm for analyzing the soil bulk density. It can be seen in Table 3 that the topsoil (0-20 cm) has a medium value of the bulk density, i.e. 1.32-1.37 g cm^{-3}. The bulk density of the subsoil (20-70 cm) was high or very high (1.46-1.59 g cm^{-3}) when comparing with other soils of the same group. Soil layers below that (70-90 cm and 90-100+ cm) were practically impermeable, with a bulk density from 1.59 to 1.74 g cm^{-3}. This may be considered a plow pan. Additionally, undisturbed soil samples collected from upper slope, middle slope and lower slope at 1-10 cm, 10-30 cm and 30-50 cm were found to have bulk densities of 1.32, 1.44 and 1.43 g cm^{-3}, respectively.

2.3 *Hydraulic conductivity*, Ko. This property was analyzed by using Falling Head Permeameter. It was found that, at the soil depth of 0-20 cm, Ko rate was fast, i.e. at 59.16-63.40 mm hr^{-1} and at the depth of 20-70 cm the rate decreased to the medium level, i.e. at 2.13-2.72 mm hr^{-1}. Below that level, i.e. at the soil depth of 70-90 and 90-100+ cm, where the bulk density was very high (1.59-1.74 g cm^{-3}), Ko was between 0.04-0.06 mm hr-1, the permeability of which is considered very slow (Table 3). Additional soil samples obtained from the Upper Slope, Middle Slope and Lower Slope at the depths of 0-10, 10-30 and 30-50 cm yielded the average permeability rates of 126.40, 66.15 and 29.86 mm hr^{-1}, respectively (Table 4).

2.4 *Plant Available Water*, PAW. PAW could be obtained by measuring the Field Capacity (FC) of the soil at the tension equal to pF 2.0 (10 kPa) by using pressure cooker apparatus and to measure the Permanent Wilting Point (PWP) at pF 4.2 (1,500 kPa) by using pressure membrane apparatus. The PAW can be obtained by deducting the Field Capacity with the PWP (PAW = FC – PWP) and can be done for each layer of the soil profile. It was found from this study that PAW for each layer of the soil at the depths of 0-10, 10-20, 20-30, 30-50, 50-70 and 70-90 cm and can be averaged to be 6.59, 5.55, 3.25, 3.54, 4.66 and 3.43% by volume, respectively, which is equal to 3.87 cm of water in the soil profile, which is considered small; it therefore needs to have uniform distribution of the rainfall for the whole year (Table 3).

2.5 *Aggregate Stability* (AS) was measured by using an aggregate analyzer. For the soil at the depth 0-15 cm, the aggregate sizes 8-2 mm, 2-1 mm, 1-0.5 mm, 0.5-0.25 mm, 0.25-0.1 mm and <0.1 mm occupied 55.31%, 19.03%, 6.33%, 4.89%, 6.71% and 7.72%, respectively, with the mean weight diameter (MWD) = 3.13 mm (Table 5). For the soil at the depth 15-30 cm, the aggregate sizes 8-2 mm, 2-1 mm, 1-0.5 mm, 0.5-0.25 mm, 0.25-0.1 mm and <0.1 mm occupied 41.22%, 19.85%, 13.80%, 10.27%, 8.97% and 5.90%, respectively, with the mean weight diameter (MWD) = 2.52 mm. These figures show that the AS of the topsoil was higher than the subsoil, which is probably due to the higher amount of organic matter of the upper strata. When comparing AS for the samples taken from all three sites, it was found the soil from the upper slope had a higher AS than those from the middle slope and the latter had a higher AS than those from the lower slope, respectively.

2.6 *Soil moisture content* was found by the oven dry method. Soil sampling was done by using an auger tube at the following levels: 0-10 cm, 10-20 cm, 20-30 cm, 30-50 cm, 50-70 cm and 70-90 cm at all 3 slope positions and it was done 17 times in 5 years (Summer during February-April, Rainy season during May-October, Winter during November-January). Table 6 shows the analytical results as follows: soil in 2006 had moisture contents (v/v) between 15.27 and 49.62% while soil in 2007, 2008, 2009 and 2010 had moisture contents between 26.78-53.34, 27.84-48.96, 23.44-47.70 and 27.31-49.04, respectively.

3. Biodiversity of the soil under vetiver. Data on soil biodiversity were collected from all slope positions at the 1-30 cm depth. Following data (Table 7) showing the presence of various microorganisms in the 1st and 2nd rows were recorded, respectively: Bacteria: 96.0x105 CFU and 90.6x105 CFU; Actinomycetes: 151.6x103 and 273.1x103 CFU; Rhizobium 0 cell/g dry soil; aerobic free-living nitrogen fixers: 73.5 x103 and 56.3x103 CFU; micro-aerophilic nitrogen fixers: 5,400-9,200 and 15 cells/g dry soil.

4. Types and amounts of N-fixing bacteria. Forty-five soil samples with vetiver roots were collected for analyzing the types and numbers of Azotobacter and Beuerinckia by using Dilution Plate Count in a specific substrate. Azospirillum was counted by using MPN method in semi-fluid substrate. N-fixing ability of the microorganism was measured by using Acetylene Reduction method. Within the vetiver rhizosphere two bacteria groups were found. The first group, Azotobacter, they were found to exist as pair, each being in oval shape. The cell has a large size, could fix N in the aerobic condition at an amount of 300-800 NMoles/108 cells/hr. The number found was 102-104 cells/g of vetiver root (Fig. 3a). The second group, Azospirillum, was found to exist as blocks, small-size cells, could fix N in low-oxygen condition at an amount of 30-120 NMoles/103 cells/hr. The number found was 102-103 cells/g of vetiver (Fig. 3b).

Marking to study and follow the bacteria. A 'Gus A' (Gus = B-Glucuronidase) mark by Jefferson and Wilson method revealed that vetiver could grow well due to the bacterium added to it. The bacterium would stay within the vetiver roots as well as their rhizosphere. This Gus A gene could change the color of the solution from colorless to light blue, and the light blue roots were thus obtained.

5. Accumulation of C in vetiver and its rhizosphere. Vetiver plant samples were collected from Upper Slope and Lower Slope areas and found 50.7% of C was absorbed in the form of organic carbon (OC), with a C:N ratio of 63.5 and with P and K as plant nutrients up to the amount of 0.06% and 0.93%, respectively (Table 8). For the accumulated C in the rhizosphere (0-30 cm) in the Upper Slope and Lower Slope, it was found there was a 1.5% carbon credit in the form of organic carbon (OC), equal to 25.7 and 26.4 g organic matter (OM)/kg soil and 3.8 and 3.9 g N/kg soil (Table 9).

6. The amount of soil lost from the plots. Eight sediment traps equipped with containers were used for measuring soil loss from the experimental site, 4 for the area without vetiver (equipment 1, 4, 6, 8) and 4 for the area with vetiver (equipment 2, 3, 5, 7). They were distributed in all slope positions, Upper Slope, Middle Slope and Lower Slope. Measurement was done during the rainy season in 2006, 2007 and 2008 and found the areas with vetiver produced 7.55, 15.71 and 9.90 kg/rai, respectively, contrasting with the area without vetiver which produced 134.27, 29.67 and 23.06 kg/rai. This means that the presence of vetiver helped lower the loss of the soil as many as 17.8, 1.9 and 2.3 times in the three years, respectively.

7. Effects of climate on the growth of Para rubber trees.

- *Air temperature.* Chiang Rai Meteorological Station reports for 2006, 2007, 2008, 2009 and 2010 show that the averaged temperatures for these respective years were 31.3, 30.9, 30.3, 31.3 and 32.0 ^{o}C and the lowest temperatures were respectively 19.6, 19.1, 19.8, 19.9 and 20.1 ^{o}C.
- *Relative humidity.* Chiang Rai Meteorological Station reports for 2006, 2007, 2008, 2009 and 2010 show that the average maximum relative humidity for these respective years were 96, 95, 95, 94 and 94% and the average minimum relative humidity were 53, 52, 55, 50 and 50%.
- *Soil temperature.* Chiang Rai Meteorological Station reports for 2006, 2007, 2008, 2009 and 2010 show the temperature of the soil at the depths of 0, 5, 10, 20, 50 and 100 cm were 26.1, 26.4, 26.5, 26.7, 27.0 and 27.1 ^{o}C.
- *Rainfall.* Data from the Thoeng Meteorological Station show the annual rainfall from 10 years (2001 to 2010) varies from 1,221 to 3,281 mm/yr. However, during the 5-year period of the experiment, the amounts of annual rainfall of 1,891.8, 1,478.7, 1,617.2, 1,194.7 and 1,693.5 mm are considered sufficient for the growth of Para rubber trees.

8. The growth of Para rubber trees. The girth of the trees was first measured on July 18, 2006 and was done at the height of 150 cm in 4 treatments, 9 trees each. The results for the averaged girth of each treatment were that:
Treatment 1. Application of ready-mixed fertilizer (20-10-12, as percentage of N, P_2O_5, K_2O) as recommended by the Thai Rubber Research Institute (1998): 20.33 cm.
Treatment 2. Application of self-mixed fertilizer (20-10-12, as percentage of N, P_2O_5, K_2O) as recommended by the Thai Rubber Research Institute (1998): 16.67 cm.
Treatment 3. Application of self-mixed fertilizer according to the soil analytical results: 20.11 cm.
Treatment 4. Application of self-mixed fertilizer according to the soil analytical results, plus adding 2 kg of cow dung to each tree every year: 22.50 cm.

The girth was measured altogether 19 times, with the result shown in Table 11, which indicates the averaged girths for the 4 treatments being 30.67, 30.71, 37.73 and 38.62 cm, respectively.

The growth of the Para rubber trees was studied by comparing the girth measured for the first time and again around 4 years later (July 15, 2010) and found the increase for the four respective treatments were 30.67, 27.44, 30.56 and 27.06 cm. It was shown Treatment 1 and

Treatment 3 resulted in the greatest increase; to be followed by Treatment 2, while Para rubber trees in Treatment 4 increased the least (Table 11).

9. Rubber yields. Six years after planning, Para rubber trees were tapped 11 times during August 2009 and July 2010. It was found that the trees in Treatment 1 gave an average yield of 8.61 kg/rai/day. Trees in Treatments 2, 3 and 4 gave respectively 6.58, 9.42 and 8.81 kg/rai/day. It is interesting to know that Treatment 3 (Application of self-mixed fertilizer according to the soil analytical results) gave the highest yield, while Treatment 1 (Application of ready-mixed fertilizer as recommended by the Thai Rubber Research Institute) and Treatment 4 (Application of self-mixed fertilizer according to the soil analytical results, plus adding 2 kg of cow dung to each tree every year) produced lower amounts and Treatment 2 (Application of self-mixed fertilizer as recommended by the Thai Rubber Research Institute) gave the lowest yield (Table 12).

10. The investment in fertilizers. In Treatment 1 (Application of ready-mixed fertilizer as recommended by the Thai Rubber Research Institute), applying 20-10-12 mixed fertilizer at a rate of 360 g/tree at the age of 3-4 years old and 400 g/tree when 5-6 years old, the total amount of money invested during the whole period of 4 years (May 2006-May 2010) was 2,949.12 Baht or 589.82 Baht a year. The corresponding investment amounts for Treatments 2, 3 and 4 were 3,757.56 and 751.51 Baht; 8,482.8 and 1,696.56 Baht; and 10,402.80 and 2,080.56 Baht. It should be noted that single fertilizers were much more expensive than mixed fertilizers. E.g. the prices of the fertilizers with formula 46-0-0, 0-46-0 and 0-0-60 (N-P_2O_5-K_2O) were respectively 800 Baht, 1,800 Baht and 1,400 Baht for a 50-kg sack.

The analysis of the investment in fertilizers shows that Treatment 4 posted the highest investment cost, followed with Treatment 3. Treatment 1 (Applying mixed fertilizers according to the Thai Rubber Research Institute), on the other hand, demanded the least amount of investment.

11. Income from the sale of rubber product. Farmers tapped the rubber trees during August-December 2009 and January-December 2010 and earned 144,126 Baht and 288,697 Baht, respectively, with the price of rubber to calculate equal to 120 Baht/kg (Table 3).

Conclusions and Recommendations

Growing Para rubber trees in the North, particularly at Tambon Tabtao, Amphur Thoeng, Chiang Rai Province, is considered a good choice, as this is a kind of ‘economic forest’ that can increase income for farmers and add the ‘forested’ areas to compensate for the encroached and slash-and-burn areas, which may cause global warming and soil erosion problems. Growing vetiver along the contour may substantially decelerate the runoff and decrease the amount of lost soil.

Growing vetiver in agricultural areas can help lower the global warming problems because this grass has an ability to absorb a high amount of CO_2, as high as 50.7% of its whole mass and store in the form of organic carbon (OC). Vetiver can also uptake P and K equal to 0.06% and 0.93%, respectively. Technically, self-mixed fertilizers are suitable to apply, as they respond to the demand of the Para rubber trees very well. Because of the high price of single fertilizers, its use may not be profitable.

Application of Research Results

Growing Para rubber trees in the North of Thailand to respond to the policy of the government needs to have vetiver grown along the contour lines to help reduce soil erosion and the loss of plant nutrients, with a result that the requirement to add external inputs in the form of chemical fertilizers is less. Besides, both the Para rubber trees and vetiver help reduce CO_2 in the atmosphere.

Extending this information to the farmers by advising them to mix the fertilizers by themselves to respond to the analytical results will enable the use of fertilizers to match the real need of the trees and the farmers will obtain the highest profits, in case the prices of single fertilizers are NOT excessively high.

References

Department of Agriculture. 1998. Training manual for mixing fertilizers, 1-25 course (February-March 1998). Division of Soil Science. 100 pp.

Department of Agriculture. 2001. Report on the role of compost in fixing N by vetiver grass. Year 1998-2000. 1 p.

Department of Agriculture. 2005. Recommendation for using chemical fertilizers for economic crops. 121 pp.

Department of Agriculture. 2005. Use of fertilizers and soil improvement in rubber plantations. Thai Rubber Research Institute. 80 pp.

Department of Agriculture. 2007. Recommendation for Para rubber varieties Year 2007. Thai Rubber Research Institute. 37 pp.

Department of Agriculture. 2009. Recommendation for Para rubber planting in new plantations. Thai Rubber Research Institute. 46 pp.

Department of Agriculture. 2010. Tapping Para rubber trees and the use of chemical stimulants. Thai Rubber Research Institute. 39 pp.

Tawachai Na Nagara, Damri Thavornmas, Seri Sukhakij, Jakranophakun Thongyai, Mongkol Panichkul, Prasop Veerakornpanich, Duangjai Choeysai, Thammanoon Kaewkhongkha. 1995. Use of vetiver grass in multiple cropping systems project. Proceedings from the Technical Meeting of the Department of Agriculture for 1995. 425 pp.

Tawachai Na Nagara and Mongkol Panichkul. 2004. Use of vetiver grass in agricultural areas. In: Knowledge about Vetiver Grass. 91 pp.

Agricultural Economics Office. 2007. Agricultural Statistics of Thailand Year 2007. 169 pp.

Agricultural Economics Office. 2008. Agricultural Statistics of Thailand Year 2008. 184 pp.

Agricultural Economics Office. 2008. Agricultural Statistics of Agricultural Trades between Thailand and foreign Countries Year 2008. 115 pp.