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Effect of organic fertilizer and organic fertilizer plus chemical fertilizer on growth and yield quality of Kamphaeng Phet emperor banana

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The study was laid out in a randomized complete block design, which had 9 treatments with 4 replications, and each replication consisted of 4 plants. The treatments were: 1) controlled, 2) 20 kg/plant of swine manure, 3) 20 kg/plant of cow manure, 4) 20 kg/plant of chicken manure, 5) 20 kg/plant of swine manure + 250 g/plant of 16-16-16 fertilizer, 6) 20 kg/plant of cow manure + 250 g/plant of 16-16-16 fertilizer, 7) 20 kg/plant chicken manure + 250 g/plant 16-16-16 fertilizer, 8) 20 kg/plant of cow manure + 1 kg/plant of fine rock phosphate, and 9) 20 kg/plant of chicken manure + 200 g/plant of KCl. Growth of the banana plant and its yield were recorded on the 8th and 12th month of the experiment, respectively. The results showed that under the 7th treatment, banana plant growth had the highest plant height, pseudostem circumference, leaf number/plant and sucker number/plant; followed by the 5th and the 4th treatments. As for the yield quality, the 7th, the 6th and the 5th treatments had the highest yield quality. It could be concluded that the emperor banana applied with 20 kg/plant of chicken manure + 250 g/plant of 16-16-16 fertilizer had the highest plant growth. The most appropriate application to a quality production of emperor banana was found to be organic fertilizer with balanced formula of chemical fertilizer as the said mixture had the most adequate nutrients uptake.

Keywords: emperor banana ,organic fertilizer, chemical fertilizer

Introduction

Emperor banana (*Musa* (AA group) "Kluai Khai") (Silayoi, 2002) is a popular crop that producers like to grow due to its ability to produce all year round. The emperor banana growing area in Thailand is 11,876 hectares with 172,587 tons of total yield production in the year of 2008 – 2009. This yield has increased compared with its total yield in the previous year. The main

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growing areas for emperor bananas in Thailand are in the provinces of Trat, Kamphaeng Phet, Nakornsawan, Chanthaburi, and Phetchaburi. The total export quantity of emperor banana in the first seven months of the year 2009 was 5,799.5 tons with export value of 32.8 million baht (Chanthaburi Provincial Agricultural Extension Office, 2009) .Major export markets of Thailand are China and Hongkong; Vietnam and Japan are newly market; and although there is only a small export value, it is however a good indicator for exporting emperor banana to the new markets (Department of Agriculture, N.D.(.

The emperor banana export requires a high yield quality; hence soil, water and fertilizer management are factors that could improve its quality (Nuntagij, 2009). Emperor banana is a crop that requires a high quantity of fertilizer for every growth stage. Generally, farmers apply a chemical fertilizer as the main fertilizer for its growth, or apply the chemical together with organic fertilizers. The application of chemical fertilizer results in a high yield; consequently environment deteriorates, soil becomes infertile, farmers health suffers, and production of costs go high which then are not worthy with their investment. Eventually, farmers' debt increases.

On the other hand, the use of organic fertilizer helps in the soil improvement. It also helps in improving the physical, chemical, and biological soil properties which are suitable to plant growth in the long term, reduce the cost of production, and in accordance with the philosophy of the sufficient economy as well (Sanyakamthon, 2009). The use of organic fertilizer could reduce the use of chemical fertilizer, which is more environment-friendly, more suitable to the farmers' health, and safer for consumption.

At present, the farmers are encountering various problems in producing the emperor banana due to soil deterioration and soil infertility as results of high use of chemical fertilizer to increase the quantity of yield. Consequently, problems occur to the environment coincide with the increasing cost of chemical fertilizer thus resulting to increase in production cost as well.

Although the price of the crop has been reduced and there is an excessive supply of it, problem occurs in the market as the product quality does not meet the export standard. Notably, these various problems are related to each other as a chain. The solution to this problem is to use organic fertilizer to remedy soil deterioration. Organic farming in accordance to the determined organic farming standard, however, is difficult and takes a long time to achieve.

Thus, management in using in the various organic forms will play an important role to solve the different problems such as soil improvement, reduction in the use of chemical fertilizer, reduced cost of production, and increase in the quality of product according to market's needs (Lertmongkol, 2007).

There are many kinds of organic substances that are used to soil improvement such as animal manure, compost, green manure, etc. Farmers can choose from these organic fertilizers considering its suitability to the plants, or the use of local materials that farmers can easily find. Aside from the benefit of providing nutrients to the plants, it is also a source of hormone or pesticide and insecticide (Mala, 2003).

Boonnap *et al*. (1985) found that the application of 12,500 kg/ha of animal manure and 625.0 kg/ha of lime plus 312.5 kg/ha of chemical fertilizer (15-15-15) yielded the highest corn production ranged from about 2.00 – 2.96 tons/ha while the plot that had no application of fertilizer and lime yielded only 0.39 tons/ha.

Jin (1993) found in his study that the response of the plants to the use of animal manure in low fertile soil was better than those plants grown in intermediate and high fertile soils.

Nakviroj *et al*. (2002) found that the application of chemical fertilizer (complete compound fertilizer; 3 main elements (NPK)) together with animal manure contributed to high yield of cassava which increased by 56.4% compared with that had only chemical fertilizer. This is associated with Wargiono and Ispandi (2002) who reported that the application of chemical fertilizer plus animal manure gave the highest yield of cassava due to the microelements (S and other) that the organic fertilizer provided for the plants' growth.

Suddhiyam *et al*. (2011) studied the use of various kinds of fertilizer in producing the aromatic fresh leguminous soybean. He found that the use of animal manure together with chemical fertilizer resulted in higher standardized soybean product than that with chemical fertilizer only in both wet and dry seasons.

The animal manure is a kind of organic fertilizer, derived from the pet animals which are brought to use widely in agriculture for a long time. Aside from it giving the organic matter, macronutrient and micronutrient elements can also be found. These elements are essential to plant growth as they improve the soil structure, good drainage, and good aeration. They also help aggregate soil particles that could prevent the loss of soil surface through leaching and erosion (Mala, 2003).

The popular emperor banana varieties grown for commercial purposes in Thailand that consists of 2 varieties are found in Kamphaeng Phet and Pratabong provinces. The Kamphaeng Phet emperor banana variety was used in this study; with brown or chocolate-like leaf sheath color, open petiole canal and expanded leaf margin, light-yellow leaves, short hair on peduncle, thin skin, small fruits, yellow flesh and sweet taste (Department of Agriculture, N.D.).

The banana plant is an herbaceous flowering plant and can grow well in the tropical wet climate. The precipitation should not be less than 1,200 millimeter per year. Or it should grow in the irrigated area because it requires a lot of water for the entire growing period. Low wind speed is also required in the growing area as leaves may be torn and the plant may be broken by the wind. The suitable soil textures for growing emperor banana plant should be loam, clay loam, or sandy loam soils. The soil pH should be at 4.5 – 7. High soil fertility and good soil drainage are required to grow the emperor banana (Noppan, 2009). As of date, there has been no study on the use of organic fertilizer and organic fertilizer plus chemical fertilizer on growth and yield quality in particular to Kamphaeng Phet emperor banana. For this reason, the objective of this study was to compare the growth and yield quality of Kamphaeng Phet emperor banana under the use of organic fertilizer, and organic fertilizer plus chemical fertilizer.

Materials and methods

The experiment was laid out in a Randomized Complete Block Design (RCBD). There were nine treatments (Table 1), replicated four times. Each replication consisted of 4 plants of banana. The 144 new suckers of Kamphaeng Phet emperor banana were grown in the fruit field of Department of Crop Production and Landscape, Faculty of Agro-Industrial Technology at Rajamangala Unversity of Technology Tawan-Ok, Chanthaburi Campus from December 10, 2010 to January 30, 2012.

Table 1. Quantity of fertilizer applied per banana plant for the nine treatments

Treatments	Quantity of fertilizer (unit per plant)
T1	No fertilizer applied
T2	Swine manure (20 kg)
T3	Cow manure (20 kg)
T4	Chicken manure (20 kg)
T5	Swine manure (20 kg) + 16-16-16 chemical fertilizer (250 g)
T6	Cow manure (20 kg) + 16-16-16 chemical fertilizer (250 g)
T7	Chicken manure (20 kg) + 16-16-16 chemical fertilizer (250 g)
T8	Cow manure (20 kg) + rock phosphate powder (1 kg)
T9	Cow manure (20 kg) + KCl fertilizer (200 g)

In this study, the emperor banana suckers were grown under Puket soil series. Soil properties composed of pH 5.06, 2.22% organic matter, 20.27 ppm available phosphorus, 24.09 ppm exchangeable potassium, 204.49 ppm exchangeable calcium, and 8.75 ppm exchangeable magnesium.

The experimental field was plowed then sun-dried for 14 days. The weed residues were then picked up and removed out of the field. The prepared area was measured for the planting distance using a space of 2 m x 2 m, with block spaces of 3 meters each. Then, the prepared bamboo sticks were placed on the measured planting position; these marked positions were dug to make the planting holes with each having the size of 50 cm x 50 cm x 50 cm. Half of the amount of determined rate of fertilizer was incorporated to the soil at the bottom of the holes for each treatment. The prepared banana suckers were planted in the prepared planting holes at the depth of 40 centimeters from the soil surface then were covered by the soil. The irrigation water system (sprinkler) was set immediately after planting so the banana suckers could recover rapidly. Afterward, holes (50 cm in diameter and 50 cm deep) were made again beside all the planted banana suckers; the rest of the amount of fertilizer was then applied for each treatment, covered by the soil, and then the irrigation water was applied.

Growth parameters were collected and recorded on August 30, 2011, eight months after planting. The banana plant height was measured from the base of the plant, or the soil surface level up to the collar of the flag leaf and was recorded in the unit of centimeter (cm). The pseudostem (mother plant) circumference was measured at 30 cm high from the soil surface in the unit of centimeter. The number of leaves was counted in the unit of number per plant. The number of sucker was also counted in the unit of number per plant.

Ten months after planting, data on yield were collected by cutting the banana branch at 45 days after bearing female bud .Parameters on yield were collected in October of 2011. Banana branch was cut at the first node of peduncle then weighed in the unit of kilogram. The number of tiers per branch was counted. The fresh weight of the 2nd tier was taken and weighed in the unit of kilogram. The fruit number of the 2nd tier was counted and recorded in the unit of number per tier. Then, average weight per fruit for the 2nd tier was calculated and recorded in the unit of gram (g). The analysis of yield quality at the ripening phase of the fruits was done using the hand refractometer to measure the sweetness of the fruits 7 days after cutting the banana branch and was recoded in the unit of $^{\circ}$Brix. Data on all parameters were analyzed based on randomized complete block design using Statistical Analysis System (SAS) program. Treatments means were compared using the Duncan's Multiple Range Test (DMRT) at the 0.01 probability level.

Results

Growth of the Kamphaeng Phet emperor banana plant as influenced by the different 9 treatments is presented in Table 2. The banana plant height was very significantly different in the nine fertilizer treatments as the banana plant was tallest at 237.1 cm under the 7th treatment (chicken manure with 20 kg/plant + 16-16-16 chemical fertilizer (250 g/plant)); followed by the treatments of the 5th at 208.6 cm, 4th at 198.4 cm, 2nd at 188.8 cm ,3rd at 171.9 cm) ,9th at 163.2 cm, 8th at 158.1 cm ,6th at 144.38 cm, and 1st at 92.4 cm.

The pseudostem circumference differed very significantly among the treatments as the banana plants under the 7th treatment (chicken manure with 20 kg/plant + 16-16-16 chemical fertilizer (250 g/plant)) was longest at 49.6 cm; followed by the plants under the 5th ,4th ,8th ,3rd ,9th ,2nd ,6th, and 1st treatments with values of 47.2 cm ,46.8 cm ,42.2 cm ,41.4 cm ,40.9 cm ,40.7 cm, 35.6 cm, and 24.8 cm, respectively.

The leaves number of the mother plant (pseudostem) was very significantly different among the nine treatments. The highest number of leaves with 7.9/plant was found under the 5th treatment (swine manure with 20 kg/plant + 16-16-16 chemical fertilizer (250 g/plant)); followed by the treatments of the 2nd with 7.5/plant, 4th with 7.2/plant, 7th with 7/plant, 3rd with 6.9/plant, 8th with 6.7/plant, 6th with 6.3/plant, 1st with 6.1/plant, and 9th with 6.0 /plant.

The sucker number was very significantly different among the nine treatments as the banana plants had the highest number of suckers with 5.4/plant under the 7th treatment or chicken manure (20 kg/plant) + 16-16-16 chemical fertilizer (250 g/plant) followed by the treatments of 4th ,2nd ,5th ,3rd ,9th , 8th ,6th, and 1st treatments with values of 5.3/plant ,4.9/plant ,4.6/plant ,4.3/plant , 3.9/plant ,2.9/plant ,2.2/plant, and 0.3/plant, respectively.

Table 2. The growth of Kamphaeng Phet emperor banana plant at 8 months after planting

Treatments	**Growth**			
	Plant height (cm)	Pseudostem circumference (cm)	Leaves number (no/plant)	Sucker number (no/plant)
T1	92.4^{e}	24.8^{c}	6.1	0.3^{d}
T2	188.8^{bcd}	40.7^{ab}	7.5	4.9^{ab}
T3	171.9^{bcd}	41.4^{ab}	6.9	4.3^{abc}
T4	198.4^{abc}	46.8^{a}	7.2	5.3^{a}
T5	208.6^{ab}	47.2^{a}	7.9	4.6^{ab}
T6	144.4^{d}	35.6^{b}	6.3	2.2^{cd}
T7	237.1^{a}	49.6^{a}	7.0	5.4^{a}
T8	158.1^{cd}	42.2^{ab}	6.7	2.9^{bc}
T9	163.2^{cd}	40.9^{ab}	6.0	3.9^{abc}
CV. (%)	12.96	12.97	13.59	30.88
F-test	**	**	ns	**

Means of growth parameters in the same column with the same letter are not significantly different at the 0.01 probability level.
**: significant difference at the 0.01 probability level
ns: not significant difference

The yield quantity and quality of the Kamphaeng Phet emperor banana plant at maturity stage, 12 months after planting, is presented in Table 3. The branch weight of banana plant had a very significant difference among the nine treatments as the plants under the 7th treatment (5.91 kg), 5th (5.86 kg), and 6th (5.68 kg) had higher branch weights; followed by the treatments of the 4th (3.23 kg), 2nd (2.34 kg), 3rd and 8th (2.22 kg), 9th (2.16 kg), and 1st (0.34 kg).

The number of tiers was found to be very significantly different among the nine treatments as the plants under the 7th and 4th gave the highest number of tiers with 5.81 no/branch and 5.75 no/branch, respectively; followed by the treatments under the 5th and 6th both with 5.56 no/branch, 8th and 9th both with 5.31 no/branch, and 2nd with 5.06 no/branch. However, these values were very significantly different to the values under the treatments in the 3rd (4.88 no/branch) and the 1st (3 no/branch).

Table 3. Yield quantity and yield quality of the Kamphaeng Phet emperor banana plant at harvest, 12 months after planting

Treatments	Yield quantity and yield quality					
	Branch weight (kg/branch)	Number of tiers (no/branch)	Tier weight (kg/tier)	Number of fruits (no/tier)	Fruit weight (g/fruit)	Fruit sweetness (°Brix)
T1	0.34^{d}	3.00^{c}	0.13^{d}	13.28^{c}	9.7^{d}	18.28^{e}
T2	2.34^{c}	5.06^{ab}	0.52^{bc}	19.00^{b}	27.2^{bc}	19.53^{de}
T3	2.22^{c}	4.88^{b}	0.47^{c}	20.03^{ab}	23.7^{c}	20.00^{cd}
T4	3.23^{b}	5.75^{a}	0.61^{b}	20.08^{ab}	30.3^{b}	21.25^{c}
T5	5.86^{a}	5.56^{ab}	1.21^{a}	20.60^{a}	60.0^{a}	23.85^{ab}
T6	5.68^{a}	5.56^{ab}	1.18^{a}	20.75^{a}	56.8^{a}	22.57^{b}
T7	5.91^{a}	5.81^{a}	1.25^{a}	20.23^{a}	60.8^{a}	24.43^{a}
T8	2.22^{c}	5.31^{ab}	0.46^{c}	19.88^{ab}	23.1^{c}	20.08^{cd}
T9	2.16^{c}	5.31^{ab}	0.46^{c}	19.88^{ab}	21.8^{c}	22.96^{b}
CV.(%)	15.34	10.67	12.51	3.95	10.76	4.07
F-test	**	**	**	**	**	**

Means of growth parameters in the same column with the same letter are not significantly different at the 0.01 probability level.
**: significant difference at the 0.01 probability level

The tier weight was found to have a very significant difference among the nine treatments. The plants grown using the fertilizers obtained the highest weight of a tier; the treatment in the 7th had 1.25 kg, 5th had 1.21 kg, and 6th had 1.18 kg; followed by the tiers weight under the 4th (0.61 kg), 2nd (0.52 kg), 3rd (0.47 kg), 8th and 9th (both 0.46 kg), and 1st (0.13 kg).

There was a very significant difference in the number of fruits under the nine tests treatments as the plants gave the highest number of fruits under the 6th treatment (20.75 per tier), 5th (20.60 per tier), and 7th (20.23 per tier); these values were not significantly different from each other. These were followed by the treatments in the 4th (20.10 per tier), 2nd (20.03 per tier), 3rd (19.88 per tier), 8th (19.88 per tier), 9th (19 per tier), and 1st (13.28 per tier).

The fruit weight had a very significant difference under the nine tests treatments as the plants contributed to having the highest fruit weight were under the treatments in the 7th (60.78 g), 5th (60 g), and 6th (56.8 g). This was followed by the treatment under the 4th (30.3 g), 2nd (27.2 g), 3rd (23.7 g), 8th (23.1 g), 9th (21.8 g), and 1st (9.70 g).

The fruit sweetness also had a very significant difference in the nine tests treatments; the plants in the 7th treatment gave the sweetest fruits at 24.43 °brix followed by the treatments in the 5th with 23.85 °brix, 9th with 22.96 °brix, 6th with 22.58 °brix, 4th with 21.25 °brix, 8th with 20.08 °brix, 3rd with 20 °brix, 2nd with 19.53 °brix, and 1st with 18.28 °brix.

Discussions

Based on the results of the effect on the use of organic fertilizer, and organic fertilizer plus chemical fertilizer on the growth and yield quality of the Kamphaeng Phet emperor banana plant, its growth under the 7th treatment (chicken manure with 20 kg/plant + 16-16-16 chemical fertilizer (250 g/plant)) had higher growth than the other treatments in terms of plant height, pseudostem circumference, number of leaves per plant, and the number of sucker per plant. The treatment contributed to having higher yield quality of the banana plant were under the 5th treatment (swine manure with 20 kg/plant + 16-16-16 chemical fertilizer (250 g/plant)), and 6th treatment (cow manure with 20 kg/plant + 16-16-16 chemical fertilizer (250 g/plant)). Feungchan (1995), reported that the application of 8.25 tons/ha animal manure for every 4 or 6 months could lead to an increase of yield from 15.71 tons/ha to 15.64; the animal pen washing water at 6 gallons per hill for every 2 weeks could increase to 16.10 tons/ha, respectively. This application rate of animal manure increased yield of the new suckers for the other 4 growing seasons (note that 1 growing season is approximately one year). Thus, the total yield accounting for the 5 growing seasons without applying animal manure was 56.33 tons/ha; while with animal manure was 85.85 and 81.30 tons/ha, respectively. Still yet, the organic fertilizer plus chemical fertilizer increased the number of fruits per tier, plant height, and pseudostem circumference as well.

Sinchai et al. (2012) who studied the effect of nitrogen (N), phosphorus (P), potassium (K), and animal manures on growth, yield, and nutrient uptake of cassava found that the application of the 3 macronutrient elements (N, P, K) plus animal manures contributed to a better growth in terms of plant height, leaf area, total plant weight, and yield compared with those that had application of the chemical fertilizer only.

For the trees, Kamkod and Lakhawipat (2011) studied the comparison between the application of chemical fertilizer plus organic fertilizer, and the application of the chemical fertilizer only in Para rubber field in the Northeastern region of Thailand. In the 5-year experiment, it was found that the chemical fertilizer plus organic fertilizer contributed to having highest latex yield.

However, Santasap (2009) reported that applying the fertilizer to the plants could cause the loss of some nutrients through the soils, and some were available in the soils accounted by 70% available N, 30% available P and 70% available K. The quantity of nutrients required by the emperor banana plant for the entire growing season is presented in Table 4.

Table 4. The quantity of nutrients required by the emperor banana plant and the recommended rate of the fertilizer applied to grow the emperor banana plant for the producers (Santasap, 2009)

Nutrient	**Nitrogen (g/plant)**	**Phosphorus (g/plant)**	**Potassium (g/plant)**
Quantity of nutrients required by the banana plant	60 – 85	15 – 50	190 – 270
Recommended rate of the fertilizer (chemical fertilizer formula)	130 – 185 (46-0-0)	33 – 109 (0-46-0)	317 – 450 (0-0-60)

As mentioned above, the quantity of nutrients presented in the organic fertilizers only is not sufficient to the growth of emperor banana plant (Table 5).

Table 5. Chemical properties of the animal manures derived from the different provinces in Thailand (Office of Science for Land Development, 2005)

Animal manure	**Derived from province**	**%N**	**%P_2O_5**	**%K_2O**	**%CaO**	**%MgO**	**%S**	**pH**	**C/N ratio**
1. Swine	Nakhon Ratchasima	2.95	8.69	0.47	-	-	-	6.8	8
2. Cow	Kanchanaburi	1.66	0.73	0.79	-	-	-	4.1	21
3. Chicken	Sa Kaeo	1.28	8.06	2.6	23.45	1.97	0.93	8.35	11
4. Chicken 1	Bangkok	2.11	1.35	6.42	-	-	-	-	-
5. Chicken 2	Bangkok	2.93	1.28	3.55	-	-	-	-	-

Conclusion

Growth of the Kamphaeng Phet banana plants under the 7th treatment or chicken manure (20 kg/plant) + 16-16-16 chemical fertilizer (250 g/plant) gave better plant growth than the rest of the treatments in terms of plant height, pseudostem circumference, number of leaves per plant, and number of suckers per plant; followed by the 5th treatment or swine manure (20 kg/plant) + 16-16-16 chemical fertilizer (250 g/plant), and the 4th treatment or chicken manure (20 kg/plant).

In terms of the yield quality, the 7th treatment or chicken manure (20 kg/plant) + 16-16-16 chemical fertilizer (250 g/plant), the 5th treatment or swine manure (20 kg/plant) + 16-16-16 chemical fertilizer (250 g/plant), and the 6th treatment or cow manure (20 kg/plant) + 16-16-16 chemical fertilizer (250 g/plant) gave higher yield quality than the other treatments.

In conclusion, the application of the chicken manure (20 kg/plant) + 16-16-16 chemical fertilizer (250 g/plant) to the Kamphaeng Phet emperor banana could contribute significantly both to higher growth and yield quality than other fertilizer management. Moreover, the use of animal manures (20 kg/plant) such as chicken, swine and cow together with the 16-16-16 chemical fertilizer (250 g/plant) is suitable for the adequate nutrient uptake in producing the Kamphaeng Phet emperor banana.

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References

Boonnap, T., Tontipiban, V., and Namsai, Y. (1985). Testing and demonstration of the use of the animal fertilizer and lime plus chemical fertilizer for increasing maize and groundnut yields in Korat soil series (soil group 35). Manual report in the Year of 1992 – 1995. Land Development. Bangkok, Thailand. pp. 96.

Chanthaburi Provincial Agricultural Extension Office (2009). Statistics of Chanthaburi Provincial Kluai khai Cultivation. Banana Plantation Year 2009.

Department of Agriculture. (n.d.). Kluai Khai. Retrieved from http//www.it.doa.go.th/vichakan/news.php?newid=1 [June 25, 201].

Feungchan, S. (1995). Horticultural plant nutrition. Department of Horticulture. Faculty of Agriculture, Khon Kaen University. Khon Kaen, Thailand. pp. 604.

Jin, W. (1993). Organic manure: new developments, nutrient and new application methods in China. In Report of the Expert Consultation of the Asian Network on BIO and Organic Fertilizer RAPA Publication 13:102–109.

Kamkod, T. and Lakhawipat, N. (2011). The use of chemical fertilizer plus organic fertilizer in the Para rubber field, Northeastern Region in Thailand. The 7th year Electronic Para Rubber Journal. October – December 2011.

Lertmongkol, T. (2007). Handbook of Thai Farmers for self-reliance accordance with royal project of “sufficient economy”. Electronic book developing and producing program. Non-formal and Informal Education Center of Eastern Region. Chachoengsao, Thailand.

Mala, T. (2003). Organic fertilizer and biofertilizer: Producing technique and application. Department of Soil Science. Faculty of Agriculture, Kasetsart University Kamphaeng Saen Campus. Nakom Phathom, Thailand.

Nakviroj, C., Paisancharoen, K., Boonsang, O., Wongwiwatchai, C., and Roongruang, S. (2002). Cassava long term fertility trials in Thailand. In Proceedings of the Seventh Regional Workshop held in Bangkok, Thailand. pp. 212 p.

Noppan, K. (2009). Handbook of quality kluai khai production: Kluai Khai production in the central region of Thailand. Quality kluai khai producing program for exportation. The Thailand Research Fund (TRF). Division of Agriculture (Division 2). Nopburee Press Company Printing Ltd. Chiangmai, Thailand. pp. 29–46.

Nuntagij, I. (2009). Handbook of quality kluai khai production: Fertigation to kluai khai. Quality kluai khai producing program for exportation. The Thailand Research Fund (TRF). Division of Agriculture (division 2). Nopburee Press Company Printing Ltd. Chiangmai, Thailand. pp. 47–60.

Office of Science for Land Development (2005). Handbook of soil, water, fertilizer, plant, soil amended material analysis and monitoring the goods standardized certifying of the 1st book number .Land Development. Bangkok, Thailand.

Santasap, C. (2009). Handbook of quality kluai khai production: Soil and fertilizer management for growing emperor banana. Nopburee Press Company Printing Ltd. Chiangmai, Thailand.

Sanyakamthon, W. (2009). Critical recovery using the sufficient economy. Network of Agri-nature. Life Return Exhibition to the Land .March 17 – 18 2009. Agri-nature Foundation. pp. 120.

Silayoi, B. (2002). Banana. Department of Horticulture .Faculty of Agriculture, Kasetsart University. Bangkok, Thailand. pp. 357.

Sinchai, K., Pontanee, A., Katawatin, R., Nawata, E. and Yanai, J. (2012). Effect of N, P and K fertilizers and cattle manure on growth, yield and nutrient uptake of cassava grown on Yasothon soil series. Agricultural Academic Conference in January 2012. Faculty of Agriculture, Khon Kaen University, Thailand (11):416–420.

Suddhiyam, P., Witee, K., Sangla, L., and Tungmunkongworakul, N. (2011). Integrated fertilizer application in aromatic vegetable soybean production. Khon Kaen Agriculture Journal 39(3):132–145.

Wargiono, J. and Ispandi, A. (2002). Cassava agronomy research and its contribution to a secure food system in Indonesia. In Proceedings of the Seventh Regional Workshop held in Bangkok, Thailand. October 28 – November 1, 2002. pp. 174.

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