AG:GCPF/THA/029/AGF
Terminal Report

FAO FERTILIZER PROGRAMME

INCREASED YIELDS AND SMALL FARMERS' INCOME THROUGH THE USE OF FERTILIZERS AND RELATED INPUTS

THAILAND

PROJECT FINDINGS AND RECOMMENDATIONS

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Report prepared for
the Government of the Kingdom of Thailand
by
the Food and Agriculture Organization of the United Nations

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1996

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS USED

DOA	Department of Agriculture
DOAE	Department of Agricultural Extension
IPNS	Integrated Plant Nutrition Systems
K	potassium [the element]
K_2O	potassium oxide [the usual form in which potassium as a plant nutrient is applied and calculated]
Kaset Tambon	local extension officers
MOAC	Ministry of Agriculture and Cooperatives
N	nitrogen [the element]
OM	organic matter
P	phosphorus [the element]
P_2O_5	phosphate [the usual form in which phosphorus as a plant nutrient is applied and calculated]
PI	productivity index
SMS	Subject Matter Specialist
VCR	value:cost ratio

The local currency is the baht (B)

1. INTRODUCTION

1.1 PROJECT BACKGROUND

Agriculture has been the most important sector in the economy of Thailand. Increasing population pressure on the land and diminishing soil productivity were matters of great concern to the government, and Thailand's Economic and Social Development Plans always gave high priority to programmes and projects which would raise productivity of existing lands under cultivation, thereby increasing the country's agricultural production and export earnings, while raising farmer incomes.

Over a number of years, significant changes had occurred in land use and cropping patterns in the country. In 1981, 16.5 million ha (36%) was arable land out of a total land area 51.2 million ha. About 2.7 million ha (15% of the total arable land) was irrigated. Rainfed areas were mostly used for rice and other field crops, fruits and coconut.

Average farm family holdings had been declining: from 2.7 ha per farm family in 1963, to 2.4 ha in 1975, and were expected to be only 2.0 ha per farm family in 1985.

Total fertilizer use in terms of N, P_2O_5 and K_2O had increased significantly, from 161 000 t in 1973/74 to 436 800 t in 1981/82, but that increase was much less than the rate of increase in fertilizer use in other Asian countries in the same period.

The average usage of fertilizer in Thailand was very low: in 1981, approximately 26 kg/ha of plant nutrient was used on arable land, which was less than half the average use in other Asian countries. Only India and Myanmar had lower rates.

There was also a large regional variation in fertilizer use within Thailand. In the central part it was about 50 kg/ha, but only 20 kg/ha in the northeast, indicative of the uneven degree of fertilizer use in the country.

The development of fertilizer use was affected by both economic and physical constraints. Factors of direct relevance at the small-scale farmer level included:

- lack of funds for the purchase of mineral fertilizers;
- non-availability of fertilizers at the right time and in the right place;
- uncertain rainfall and irrigation facilities in certain areas;

- unfavourable relationships between crop and fertilizer prices; and
- a lack of location-specific fertilizer recommendations which would ensure attractive economic returns from fertilizer use.

The Agricultural Development Plan of Thailand called for crop diversification and intensification schemes to increase productivity of the major crops, namely rice, maize, coconut, sugar cane, cassava, rubber and jute, covering over 90% of the cultivated land of the country. These crops were the source of 88% of total agricultural export earnings.

The Plan recognized that one element in increasing crop intensification and productivity would be the development of fertilizer use, primarily through promotion and extension activities, and improved supply and distribution.

The private sector played a vital role in fertilizer distribution, responsible for 85% of total fertilizer consumed, and there were no plans to modify the role of the private sector.

The promotion of fertilizer use was a public-sector activity, and the Ministry of Agriculture and Cooperatives was responsible for a number of activities that required strengthening, including:

- conducting fertilizer trials and demonstrations for the main crops;
- providing extension services to farmers, including holding field days and promoting yield contests among farmers; and
- training extension workers and farmers in various aspects of fertilizer use development.

The Government of Thailand recognized that it could not continue expanding its cultivated land: future needs would have to be met through increased productivity, and fertilizers would have a key role in providing that productivity increase. It consequently sought external assistance to this end, and support was arranged from the Arab Gulf Fund through the FAO Trust Fund programme.

A three-year project, FH/THA/025/IMP, *Yield increase through the use of fertilizers and related inputs*, financed by the World Phosphate Rock Institute (IMPHOS), started in October 1980, with the aim of assisting government efforts to increase production and productivity through the efficient and effective use of fertilizers and related inputs by small-scale farmers. The setting up of fertilizer trials and demonstrations, together with training of farmers and extension workers, were the main activities of the project. However, due to limited funds, much more work along these activities remained to be done, not only in establishing the basic information for fertilizer use development but also in creating consciousness on the part of the farmers with regard to the efficient use of fertilizers.

FH/THA/025/IMP was due to terminate in October 1983, but it was possible to continue the various activities to 30 April 1985 by funding the cost of the international expert post from other sources, and the operational expenses mainly from the Government contribution.

The Government of Thailand submitted a request for support from the FAO Technical Cooperation Programme to complement the Arab Gulf Fund Programme assistance and to support the follow-up project. That assistance was granted in the form of project TCP/THA/4512, *Yield increase through the use of fertilizers and related inputs*. The TCP budget of $US 100 000 provided about half of FAO's contribution to project GCPF/THA/029/AGF, reported here.

1.2 OUTLINE OF OFFICIAL ARRANGEMENTS

The Plan of Operation for project GCPF/THA/029/AGF, *Increased yields and small farmers' income through the use of fertilizers and related inputs*, was signed by the Government of Thailand on 17 April 1985 and by FAO on 16 April 1985.

The indicative donor budget was $US 200 000, from the Arab Gulf Fund through its FAO Trust Fund arrangement, with a counterpart contribution from FAO (from other sources) of $US 200 000 and government contributions-in-kind of $US 207 000 and the baht equivalent of $US 403 450.

The implementing agency of the project was the Ministry of Agriculture and Cooperatives (MOAC). The project began work on 1 May 1985, with the existing National and International Staff of the terminating project FH/THA/025/IMP. The duration was expected to be two years.

In December 1987, the project was revised, and extended until the end of December 1988, in order to cover activities such as collecting trial and demonstration data in the 1986/87 cropping season. It was further extended, until 30 June 1994.

The donor contribution, as finally adjusted, was $US 160 000.

1.3 PROJECT OBJECTIVES

The long-term objective of the project was to assist in the development of agricultural production in Thailand, especially by the small-scale field-crop farmers, both under rainfed and irrigated conditions. Efficient use of fertilizers and related farm inputs was expected to increase crop yields in the various agro-ecological zones.

The ultimate goal of the project was to raise the income of the small-scale farmers and thereby improve their standard of living.

The immediate objective was to assist in the designing and implementation of a trial/ demonstration programme in the use of fertilizers and other inputs for the priority field crops, appropriate to the various agro-climatic regions of the country. This programme was to be carried out in the farmers' fields, employing suitable fertilizer recommendations together with the use of other inputs and proper crop husbandry. Specifically:

- to conduct a programme of simple trials on farmers' fields for the purpose of determining proper fertilizer rates for each crop under the various conditions of soils and climates in the country;
- to set up demonstration plots to show the yield potential and the economic return when proper fertilization was applied. At the same time, farmers' field days and other training activities would be conducted to support the extension aspect of fertilizer use and to complement the setting up of demonstration plots;
- to prepare and implement training programmes for relevant professional staff at national and provincial levels in order to increase the effectiveness of agricultural advisory services. This training was to take the form of: (i) in-service training of counterparts under the guidance of an internationally-recruited Fertilizer Use/Plant Nutrition expert; (ii) short-term fellowships for specialized training abroad; and (iii) comprehensive short-term training courses for advisory services at various levels;
- to assist in devising improved means to make fertilizers available to the farmers at the right time and place;
- to assist in the promotion of effective communication and feedback between research institutes dealing with soil fertility matters and agricultural extension services, and through them, to the farmers, specifically: (i) to suggest problems to be included in national research programmes, especially on soil fertility/fertilizer use matters;

(ii) to convey to the agricultural extension service those practical results from soil fertility research which should be adopted by the farmers in order to increase crop production;

- to prepare, on the basis of the project's results and any other information available in the country, relevant training and teaching materials on fertilizers which could be used for extension purposes.

1.4 PROJECT IMPLEMENTATION

The operation of the project was coordinated with the Department of Agriculture (DOA), through the Director, Soil Science Division, and the Department of Agricultural Extension (DOAE) through the Director, Crop Promotion Division. These officials delegated national counterparts to be responsible for the day-to-day operations in applied research (trials) and extension (demonstrations). DOA provided some 40 field technicians on a part-time basis for fertilizer trial work. Approximately 800 Subject Matter Specialists (SMSs) and local extension officers (*Kaset Tambon*) from DOAE were detailed to the project to lay out fertilizer demonstrations and to conduct extension activities.

2. RESULTS AND CONCLUSIONS

The results of fertilizer trials and demonstrations conducted in the 1984/85 cropping season under the previous project, FH/THA/025/IMP, but processed and interpreted by GCPF/THA/029/AGF are included in this report.

2.1 FERTILITY STATUS OF FIELD TRIALS AND DEMONSTRATIONS

A total of 1 752 surface soil samples (0-15 cm depth) were taken from field trials and demonstrations during the 1984/85 to 1986/87 cropping seasons. All soil samples were analysed by the DOA soil laboratory. The soil fertility status of cultivated land where the field trials and demonstrations were conducted have been summarized in Table 1.

Table 1 Fertility status of field trials and demonstrations

Organic matter (%)		Available P_2O_5 (ppm)		Exchangeable K_2O (ppm)	
Range	% distribution	Range	% distribution	Range	% distribution
		Rice	(289 sites in the north, centre and west)		
<1.00	9	<6	15	<41	12
1.00-2.00	44	6-10	21	41-80	35
2.01-3.00	29	11-20	29	81-120	25
>3.00	18	>20	35	>120	28
		Rice	(420 sites in the northeast and east)		
<1.00	67	<6	49	<41	51
1.00-2.00	22	6-10	28	41-80	26
2.01-3.00	7	11-20	13	81-120	11
>3.00	4	>20	10	>120	12
		Rice	(20 sites in the south)		
<1.00	5	<6	45	<41	30
1.00-2.00	30	6-10	30	41-80	35
2.01-3.00	45	11-20	25	81-120	30
>3.00	20	>20	–	>120	5
		Maize	(300 sites)		
<2.00	40	<6	16	<50	13
2.01-3.00	33	6-9	17	50-100	32
>3.00	27	10-15	16	101-150	18
		>15	51	>150	37
		Sorghum	(42 sites)		
<2.00	57	<11	50	<50	31
>2.00	43	11-19	24	50-100	21
		>19	26	>100	48

Organic matter (%)		Available P_2O_5 (ppm)		Exchangeable K_2O (ppm)	
Range	% distribution	Range	% distribution	Range	% distribution
Soybean					(113 sites)
<2.00	49	<7	25	<36	9
2.00-3.00	31	7-12	16	36-55	16
>3.00	20	13-18	12	56-100	32
		>18	47	>100	43
Groundnut					(201 sites)
<1.00	34	<7	28	<36	25
1.00-2.00	36	7-12	28	36-55	19
2.01-3.00	22	13-18	14	>55	56
>3.00	8	>18	30		
Mung bean					(21 sites)
<1.00	29	<7	10	<36	24
1.00-2.00	33	7-12	33	36-55	14
>2.00	38	13-18	33	>55	62
		>18	24		
Cassava					(120 sites)
<0.50	36	<11	73	<31	41
0.50-0.92	30	11-20	15	31-50	37
0.93-1.50	17	>20	12	>50	22
>1.50	17				
Sugar cane					(57 sites)
<1.00	46	<9	24	<36	7
1.00-2.00	33	9-16	9	36-70	33
>2.00	21	>16	67	>70	60
Cotton					(41 sites)
<1.00	34	<9	56	<61	34
1.00-2.00	29	9-16	15	61-120	20
2.01-3.00	20	>16	29	>120	46
>3.00	17				
Kenaf					(128 sites)
<0.50	26	<6	41	<21	15
0.50-1.00	33	6-10	30	21-30	23
1.01-1.50	21	11-15	9	31-45	21
>1.50	20	>15	20	>45	41

Paddy soils in the northeast and east were most deficient in organic matter (OM), available phosphorus (P) and exchangeable potassium (K); 67% of paddy soils contained less than 1% OM, 77% had 10 ppm or less available P (Bray No. 2), and 51% less than 41 ppm of exchangeable K. Paddy soils in the north, centre, west and south, however, were relatively high in OM and exchangeable K.

Upland soils on which cassava was grown were most deficient in OM, followed by soils cropped with kenaf, sugar cane, groundnut, cotton and mung bean. Soils on which maize, soybean and sorghum were grown were relatively high in OM. Generally speaking, most upland soils were relatively low in available P. Soils on which cassava and kenaf were grown tended to be lower in exchangeable K, and soils sown to soybean, cotton and sugar cane tended to be higher, with soils under groundnut and mung bean being intermediate. Soils on which maize and sorghum were grown contained the highest exchangeable K, with 55% and 69% of soils containing more than 100 ppm of exchangeable K, respectively.

2.2 FERTILIZER TRIALS

Simple or unreplicated fertilizer trials were conducted in farmers' fields to refine fertilizer recommendations and to evaluate the economics of fertilizer use in terms of economic optimum rates of application in selected areas. A total of 480 N-P_2O_5-K_2O fertilizer trials on maize, sorghum, soybean, groundnut, mung bean, sesame, cassava, sugar cane, cotton and kenaf were set up, of which 396 trial results could be analysed (Table 2). The analysis of economic return and economic optimum rate was based on 1986 farm-gate prices. Economic optimum rate is the point on a yield response curve where the last baht invested in an input will provide the farmer a net return of one baht (Table 3). Fertilizer recommendations were derived from N-P_2O_5-K_2O economic optimum rates.

Table 2 Response of crops to individual plant nutrients

Crop	No. of Trials	Nitrogen		Phosphate		Potassium	
		kg/ha	PI(1) (N)	kg/ha	PI(1) (P_2O_5)	kg/ha	PI(1) (K_2O)
Maize	40	63	13.7	63	5.7	31	9.0
Sorghum	42	63	15.3	63	7.7	31	1.8
Soybean	46	19	3.1	56	5.0	38	3.7
Groundnut	57	19	10.9	56	4.0	38	5.6
Mung bean	36	19	6.5	56	4.0	38	2.5
Sesame	9	31	1.3	31	0.8	31	-
Cassava	46	75	99.5	38	58.2	50	80.1
Sugar cane(2)	19	75	121.0	38	89.1	75	51.1
Sugar cane(3)	25	75	205.8	38	32.5	75	14.1
Cotton	33	38	6.4	38	5.9	38	9.8
Kenaf	43	50	11.9	50	5.8	50	12.3

Notes: (1) PI = productivity index. (2) Planted crop. (3) Ratoon crop

Table 3 Nutrient rates at the points of economic optimum rate(1)

Crop	No. of Trials	N-P_2O_5-K_2O (kg/ha)	Estimated yield increase (kg/ha)	PI(2)	Profit (B/ha)	VCR(3)
Maize	40	44-0-19	921	14.6	1 467	3.0
Sorghum	42	55-0-0	885	16.1	1 410	3.0
Soybean	46	6-35-25	338	5.1	1 419	2.7
Groundnut	57	23-27-37	576	6.6	3 269	4.1
Mung bean	36	20-26-21	320	4.8	1 548	2.8
Cassava	38	95-30-68	13 854	71.8	8 079	4.5
Sugar cane(4)	19	78-24-47	14 653	98.3	4 052	3.2
Cotton	33	38-41-51	886	6.8	10 815	7.8
Kenaf	43	53-16-61	1 408	10.8	4 850	4.3

Notes: (1) Based on 1986 farm-gate prices. (2) PI = productivity index. (3) Value:cost ratio. (4) Planted crop.

2.2.1 Cereals

For maize, the results of 40 trials showed that the productivity index (PI) of nitrogen (N) was good, at 13.7 kg grain/kg N at the level of 63 kg N/ha. Phosphate (P) response was moderate at 5.7 kg grain/kg P_2O_5 at the level of 63 kg P_2O_5/ha. At the level of 31 kg K_2O/ha, the PI of K was relatively good at 9.0 kg grain/kg K_2O. A good relation between P response of maize and available-P content of the soil was observed. The PIs of P at the level of 63 kg P_2O_5/ha were 13.5, 9.8 and 0.0 kg grain/kg P_2O_5 for the soils with available-P content of less than 10, 10-40 and more than 40 ppm, respectively. Application of 44-0-19 kg/ha of N-P_2O_5-K_2O was needed to reach the economic optimum rate calculated from individual NPK response curves. This gave a yield increase of 921 kg/ha and a profit of B 1 467/ha with a value:cost ratio (VCR) of 3.0. In general, the recommended level was 50 kg N+25 kg K_2O/ha, with P_2O_5 application according to the available-P status of the soil (see Table 4).

Table 4 Phosphate recommendations for maize, based on available-P

Available P (Bray No. 2) (ppm)	Recommended P_2O_5 rates (kg/ha)
<10	30-40
10-40	0-20
>40	0

For sorghum, the results of 42 trials showed that the average PI of N was good at 15.3 kg grain/kg N at the level of 63 kg N/ha. There was a moderate response to P, at 7.7 kg grain/kg P_2O_5 at the level of 63 kg P_2O_5/ha. K response was negligible. A good relation between P response of sorghum and soil available P was observed. P response was high, at 15.0 kg grain/kg P_2O_5 for the soil with available P content of less than 11 ppm at a treatment of 63 kg P_2O_5/ha. However, negative response to P was observed when available P was over 19 ppm. The NPK economic optimum rate could be reached by applied 55-0-0 kg/ha of N-P_2O_5-K_2O. This gave a yield increase of 885 kg/ha and a profit of B 1 410/ha with a VCR of 3.0. In general, the recommended application was 60 kg N/ha, with no K_2O, and with P_2O_5 application according to the available-P status of the soil (see Table 5).

Table 5 Phosphate recommendations for sorghum, based on available-P

Available P (Bray No. 2) (ppm)	Recommended P_2O_5 rates (kg/ha)
<11	40
11-19	0-20
>19	0

2.2.2 Grain legumes

For soybean, the results of 46 trials indicated that the average PI of N was low, at 3.1 kg bean/kg N at the 19 kg N/ha treatment level. Response to P was moderate, at

5.0 kg bean/kg P_2O_5 at the 56 kg P_2O_5/ha level. The PI of K was relatively low at 3.7 kg bean/kg K_2O at the 38 kg K_2O/ha treatment level. The NPK economic optimum rate could be obtained from application of 6-35-25 kg/ha of N-P_2O_5-K_2O. This gave a yield increase of 338 kg/ha and a profit of B 1 419/ha with a VCR of 2.7. In general, between 0 and 20 kg N/ha was recommended, with 40 kg P_2O_5/ha and 30 kg K_2O/ha.

For groundnut, the results of 57 trials showed that the PI of N was good, at 10.9 kg nut in shell/kg N at a level of 19 kg N/ha. There was only a moderate response to P, of 4.0 kg nut in shell/kg P_2O_5 at a level of 56 kg P_2O_5/ha. A moderate response to K, of 5.6 kg nut in shell/kg K_20, was also observed at a level of 38 kg K_20/ha. Application of 23-27-37 kg/ha of N-P_20_5-K_20 was required to reach the economic optimum rate. This gave a yield increase of 576 kg/ha and a profit of B 3 269/ha with a VCR of 4.1. The general recommendation was 20-30-40 kg/ha of N-P_2O_5-K_2O.

For mung bean, the results of 36 trials showed that N response was moderate at 6.5 kg bean/kg N at the 19 kg N/ha treatment level. The PI of P was 4.0 kg bean/kg P_2O_5 with a 56 kg P_2O_5/ha treatment. K response was only 2.5 kg bean/kg K_2O at a level of 38 kg K_2O/ha. Application of 20-26-21 kg/ha of N-P_2O_5-K_2O was needed to reach the NPK economic optimum rate. This gave a yield increase of 320 kg/ha and a profit of B 1 548/ha with a VCR of 2.8. The general recommendation was 20-30-30 kg/ha of N-P_2O_5-K_2O.

2.2.3 Sesame

The results of 9 trials showed that the PI of N was low, at 1.3 kg seed sesame/kg N at the 31 kg N/ha treatment level. P response was negligible at a level of 31 kg P_2O_5/ha. Poor K response was observed. Calculation of NPK economic optimum rate was inconclusive due to the fact that NPK response curves were concave. Therefore, no fertilizer recommendation is proposed.

2.2.4 Cassava

High N and K responses and good P response were observed from 46 cassava trials. The PI of N was 99.5 kg tuber/kg N at the 75 kg N/ha treatment level. The PI of P was 58.2 kg tuber/kg P_2O_5 at the level of 38 kg P_2O_5/ha. At the level of 50 kg K_2O/ha, the PI of K was 80.1 kg tuber/kg K_2O. A good relation was found between K response and the level of exchangeable-K content of the soil based on the results of 38 trials conducted in the 1984/85 and 1985/86 cropping seasons. The PI of K at the 50 kg K_2O/ha treatment level was high at 93.1 kg tuber/kg K_2O for soils with exchangeable K of less than 31 ppm, but the response to K was low, at 19.1 and 13.1 kg tuber/kg K_2O, for soils with exchangeable

K between 31-50 and more than 50 ppm, respectively. Application of 95-30-68 kg/ha of N-P_2O_5-K_2O was required to achieve the NPK economic optimum rate. This gave a yield increase of 13 854 kg/ha and a profit of B 8 079 with a VCR of 4.5. In general, the recommended dosages were 100 kg N +30 kg P_2O_5/ha, plus K_2O at a rate determined from the soil exchangeable-K level (see Table 6).

Table 6 Potassium recommendations for cassava, based on exchangeable-K

Exchangeable K (ppm)	Recommended K_2O rates (kg/ha)
<31	70-100
31-50	30
>50	0

2.2.5 Sugar cane

For the planted crop, the results of 19 trials showed that the N response was good. Treatment with 75 kg N/ha gave a PI of 121.0 kg cane/kg N. The P response was also good, at 89.1 kg cane/kg P_2O_5 at a level of 38 kg P_2O_5/ha. K response was moderate, at 51.1 kg cane/kg K_2O at a level of 75 kg K_2O/ha. Application of 78-24-47 kg/ha of N-P_2O_5-K_2O was needed to reach the NPK economic optimum rate. This gave a yield increase of 14 653 kg/ha and a profit of B 4 052 with a VCR of 3.2. The general recommendation was 80-30-50 kg/ha of N-P_2O_5-K_2O.

For the ratoon crop, the results of 25 trials showed that the N response was very high. The PI of N was 205.8 kg cane/kg N with application of 75 kg N/ha. The P response was relatively low, at 32.5 kg cane/kg P_2O_5 at a level of 38 kg P_2O_5/ha. K response was low, at 14.1 kg cane/kg K_2O at a level of 75 kg K_2O/ha. More than 150 kg N/ha was required to reach the N economic optimum rate. However, the economic optimum rates of P and K were inconclusive, as the P and K response curves were concave. Therefore, no recommendation was proposed for the ratoon crop.

2.2.6 Fibre crops

For cotton, the results of 33 trials showed that the PI of N was relatively good, at 6.4 kg seed cotton/kg N at a level of 38 kg N/ha. The P response was also relatively good, at 5.9 kg seed cotton/kg P_2O_5 at a level of 38 kg P_2O_5/ha. The PI of K was high, at 9.8 kg seed cotton/kg K_2O with a treatment of 38 kg K_2O/ha. A good relationship was observed between K response and the exchangeable-K content of the soil. The PI of K at the 75 kg K_2O/ha treatment level was high, at 8.0 kg seed cotton/kg K_2O for soils with exchangeable K of less than 61 ppm, but the PI fell to 1.8 kg seed cotton/kg K_2O when exchangeable K was over 120 ppm. Application of 38-41-51 kg/ha of N-P_2O_5-K_2O was needed to reach the NPK economic optimum rate. This gave a yield increase of 886 kg/ha and a profit of B 10 815/ha with a VCR of 7.8.

In general, the recommendation was for 40-40-50 kg/ha of $N-P_2O_5-K_2O$, with the K_2O dose adjusted according to soil exchangeable-K levels (see Table 7).

Table 7 Potassium recommendations for cotton, based on exchangeable-K

Exchangeable K (ppm)	Recommended K_2O rates (kg/ha)
<61	70
61-120	50
>120	40

In kenaf, results from 43 trials showed that N response was good: at 50 kg N/ha, it was 11.9 kg fibre/kg N. There was a moderate response to P, of 5.8 kg fibre/kg P_2O_5 at a level of 50 kg P_2O_5/ha. The PI of K was good at 12.3 kg fibre/kg K_2O at the 50 kg K_2O/ha treatment level. Application of 53-16-61 kg/ha of $N-P_2O_5-K_2O$ was required to reach the NPK economic optimum rate. This gave a yield increase of 1 408 kg/ha and a profit of B 4 850/ha with a VCR of 4.3. The general recommendation was for 50-20-60 kg/ha of $N-P_2O_5-K_2O$.

2.3 FERTILIZER DEMONSTRATIONS

A total of 3 475 fertilizer demonstrations on rice, maize, soybean, groundnut, cassava, sugar cane, cotton and kenaf were set up in farmers' fields in 69 provinces. The results of 2 053 demonstrations were used for analysis and interpretation.

2.3.1 Effect of individual nutrients

All demonstrations in the 1984/85 cropping season and some of those in the 1985/86 and 1986/87 cropping seasons had four treatments, i.e., control, N, NP or NK, and NPK. In legume crops, control, P, PK and NPK treatments were also used. The main purpose of these demonstrations was to show to the farmers the effects of individual nutrients. The results of the evaluation are summarized in Table 8.

Results from rice demonstrations were available in the largest number (513)across the country. The responses to N ranged from 620 to 801 kg/ha, the PI from 9.8 kg grain/kg N in northeastern and eastern regions, to between 11.3 and 16.0 in the south. The VCR for N was above 2 in all cases. The yield increase due to P application was lower in terms of kg/ha, but the PI was of the same order as N, except in one series of 14 demonstrations in the southern region, where a negative response to P application was observed. Aside from one series of 14 demonstrations conducted in the southern region, the VCR for P was in the range of 2.0-2.8. The K response was again somewhat lower than the P. The PIs ranged from 5.7 kg grain/kg K_2O in north, centre and west, to 9.0 in the northeast and east. The VCR for K was between 1.9 and 3.0.

Considerable demonstration data for maize (372 sites) was obtained from northern, northeastern, central and eastern regions. The responses to N were between 615-819 kg/ha and PIs were between 9.8 and 26.4 kg grain/kg N. In one series of 207 demonstrations, the VCR for N was low, at 1.8, due to N application at higher rates. However, in another series of 165 demonstrations, the VCR for N was high, at 4.9. The yield increases due to P application at a level of 31 kg P_2O_5/ha were between 315 and 450 kg/ha and the PIs were between 10.2 and 14.5 kg grain/kg P_2O_5. The VCR for P was between 1.6 and 2.2. Response to K was relatively low, ranging between 176 and 200 kg/ha, with PIs of 5.7 to 6.5 kg grain/kg K_2O. The VCR for K was below 2.0.

For soybean, N responses ranged from 114 kg/ha and a PI of 6.0 kg bean/kg N in northern and western regions, to 211 kg/ha and a PI of 11.1 in the northeastern region. The VCR for N was high, between 3.1 and 5.7, due to low levels of N application. The response to P was low. The PIs for P were only 2.9 and 1.8 kg beans/kg P_2O_5/ha in northern and western regions and in the northeastern region, respectively. The VCR for P was at an unacceptable level. The PI for K was low, at 1.7 kg bean/kg K_2O with a VCR of 1.3 in northern and western regions, but the PI was moderate, at 4.0, with a VCR of 3.0 in the northeastern region.

For groundnut, the responses to N were between 143 and 209 kg/ha and the PIs for N were between 7.5 and 11.0 kg nut in shell/kg N. The VCR for N was high, between 4.3 and 6.3. The PIs for P were between 3.3 and 4.5 kg nut in shell/kg P_2O_5. The VCR for P was lower than that for N (1.6-2.2). The PI for K was of the same order as that for P (3.1-4.3). However, the VCR for K was above 2, which was better than the VCR for P, due to the low potassic fertilizer prices.

For cassava, N response was high. Application of 50 kg N/ha gave a yield increase of 3 703 kg/ha, or PI for N at 74.1 kg tuber/kg N with a VCR of 4.3. P response was low. A yield increase of 932 kg/ha or PI for P at 18.6 kg tuber/kg P_2O_5 with a VCR of 0.9 were obtained from applying 50 kg P_2O_5/ha. Moderate K response was observed. A yield increase of 2 219 kg/ha or PI for K at 44.4 kg tuber/kg K_2O with a VCR of 3.7 were observed at a level of 50 kg K_2O/ha.

Table 8 Response of crops to individual nutrients in demonstrations

Crop	Region	No. of Sites	Control yield (kg/ha)	Nitrogen (N)				Phosphate (P_2O_5)				Potassium (K_2O)			
				Rate (kg/ha)	Response			Rate (kg/ha)	Response			Rate (kg/ha)	Response		
					kg/ha	PI	VCR		kg/ha	PI	VCR		kg/ha	PI	VCR
Rice	N, C, W	177	3 664	63	757	12.0	2.8	25	365	14.6	2.8	25	142	5.7	1.9
Rice	NE, E	257	2 500	63	620	9.8	2.3	25	263	10.5	2.0	25	226	9.0	3.0
Rice	S	65	2 228	63	711	11.3	2.6	25	281	11.2	2.2	25	171	6.8	2.3
Rice	S	14	3 096	50	801	16.0	3.7	38	−109	-	−0.6	19	150	7.9	2.6
Maize	N, NE, C, E	207	2 597	63	615	9.8	1.8	31	450	14.5	2.2	31	176	5.7	1.5
Maize	N, NE, C, E	165	3 001	31	819	26.4	4.9	31	315	10.2	1.6	31	200	6.5	1.7
Soybean	N, W	62	1 367	19	114	6.0	3.1	56	161	2.9	1.2	38	66	1.7	1.3
Soybean	NE	6	1 280	19	211	11.1	5.7	56	98	1.8	0.8	38	153	4.0	3.0
Groundnut	N, NE, E	91	1 254	19	143	7.5	4.3	56	253	4.5	2.2	38	118	3.1	2.6
Groundnut	NE, E	44	1 340	19	209	11.0	6.3	56	182	3.3	1.6	38	162	4.3	3.6
Cassava	NE, E	65	13 116	50	3 703	74.1	4.3	50	932	18.6	0.9	50	2 219	44.4	3.7
Sugar cane	N, NE, E, W	16	30 459	75	5 598	74.6	2.3	38	5 305	139.6	3.6	38	3 233	85.1	3.8
Sugar cane	N, W	15	62 727	94	21 683	230.7	7.1	31	11 767	379.6	9.8	31	−11 022	-	−15.8
Sugar cane	NE	6	41 946	75	13 813	184.2	9.4	38	−6 247	-	−4.2	63	7 082	112.4	5.0
Kenaf	NE	100	944	50	202	4.0	1.4	50	123	2.5	0.7	75	103	1.4	0.7
Kenaf	NE	40	1 073	50	199	4.0	1.4	50	136	2.7	0.8	50	124	2.5	1.2

Notes: The regions were: N = northern, C = central, W = western, NE = northeastern, E = eastern, S = southern.
PI = productivity index. VCR = value:cost ratio

The results from a limited number of sugar cane demonstrations were extremely variable. The responses to N ranged from 5 598 to 21 683 kg/ha and PIs from 74.6 to 230.7 kg cane/kg N with VCRs from 2.3 to 9.4. The P response was lower than the N response. The responses to P ranged from negative to 11 767 kg/ha and the PIs varied from zero to 379.6 kg cane/kg P_2O_5, with VCRs from negative to as high as 9.8. The K response was again somewhat lower than the P response. The yield increases due to K application ranged from negative to 7 082 kg/ha and PIs varied from zero to 112.4 kg cane/kg K_2O, with VCRs from negative to 5.0.

For kenaf, the responses to N were between 199 and 202 kg/ha and the PI for N was 4.0 kg fibre/kg N with a VCR of 1.4. The P response was lower than the N response. The yield increases due to 50 kg P_2O_5/ha application were between 123 and 136 kg/ha and the PIs for P were between 2.5 and 2.7 kg fibre/kg P_2O_5 with VCR below 1. The K response was again somewhat lower than the P response. The PIs for K were between 1.4 and 2.5 kg fibre/kg K_2O with VCRs between 0.7 and -1.2.

2.3.2 Fertilizer rates demonstrations

Fertilizer rates demonstrations consisted of a control and three levels of either N, P or NPK. The aim was to show the effect of different fertilizer rates and grades and to calculate economics. The average results are presented in Table 9.

For rice, the results from 278 demonstrations in the north, centre, west, east and south showed that the response to NP fertilizer was relatively good. Treatment of 75-38-0 kg/ha of N-P_20_5-K_20 gave the highest PI (9.0) with the highest VCR (2.0). Another series of 7 demonstrations in the central region showed that the low-rate treatment (50-38-0) gave the highest PI (10.9) and the highest VCR, (2.3).

Results from 45 P demonstrations on soybean in the north showed that treatment 0-38-0 gave the highest PI (5.1) with the highest VCR (2.2).

For groundnut, results from 60 demonstrations in northern and eastern regions showed that the response to P was relatively good at the low level of 38 kg P_20_5/ha in the absence of NK. This gave a yield increase of 281 kg/ha and PI of 7.4 with a VCR of 3.6. The highest level of application, 113 kg P_20_5/ha, gave the highest yield increase, 596 kg/ha, but the lowest PI (5.3) and lowest VCR (2.6). Another series of 9 demonstrations in the northeastern region showed that treatment 19-56-38 gave the highest yield increase, 409 kg/ha and PI of 3.6 with a VCR of 2.1.

Table 9 Results of fertilizer rates demonstrations

Crop	Region	No. of sites	Control yield (kg/ha)	Application $N-P_2O_5-K_2O$ (kg/ha)	Response		
					kg/ha	PI	VCR
Rice	N,C,W,E,S	278	3 338	50-38-0	752	8.5	1.8
				75-38-0	1 018	9.0	2.0
				100-38-0	1 145	8.3	1.8
Rice	C	7	4 339	50-38-0	961	10.9	2.3
				100-38-0	985	7.1	1.6
				150-38-0	689	3.7	1.1
Soybean	N	45	1 378	0-38-0	192	5.1	2.2
				0-75-0	284	3.8	1.6
				0-113-0	362	3.2	1.4
Groundnut	N,E	60	1 584	0-38-0	281	7.4	3.6
				0-75-0	484	6.5	3.1
				0-113-0	596	5.3	2.6
Groundnut	NE	9		19-38-38	255	2.7	1.6
			992	19-56-38	409	3.6	2.1
				19-75-38	194	1.5	0.8
Cotton	N,W,NE	14		38-38-19	349	3.7	3.9
			1 501	75-75-38	591	3.1	3.3
				150-150-75	911	2.4	2.6
Kenaf	NE	9		25-25-25	215	2.9	1.0
			801	50-50-50	252	1.7	0.6
				94-94-94	446	1.6	0.6

Notes: The regions are: N = northern, C = central, W = western, E = eastern, S = southern, NE = northeastern. PI = productivity index. VCR = value:cost ratio

For cotton, results from 14 demonstrations across the north, west and northeast showed that 38-38-19 gave the lowest increase, 349 kg/ha, but with the highest PI (3.7) and the highest VCR (3.9). However, treatment 150-150-75 gave the highest yield increase (911 kg/ha), but with the lowest PI (2.4) and the lowest VCR (2.6).

For kenaf, results from 9 demonstrations in the northeast showed that the low rate treatment 25-25-25 gave a yield increase of 215 kg/ha, with the highest PI (2.9) and a VCR of only 1.0. Poor economic benefits from fertilizer use may be attributed to low management standards prevailing in farmers' fields. The average yield of control plots was low, at 801 kg/ha.

2.3.3 Compost and fertilizer demonstrations

As noted earlier, paddy soils in the northeast and east were generally deficient in OM, available P_2O_5 and exchangeable K_2O. In addition, upland soils on which cassava was grown were also deficient in OM. Therefore, as an application of the Integrated Plant Nutrition Systems (IPNS) approach, compost and fertilizer demonstrations were initiated in 1985 in order to complement the use of mineral with organic sources of plant nutrients and to maintain soil fertility.

For rice, results from 278 demonstrations in northeastern and eastern regions showed that the average yield of control plots was 2 560 kg/ha, reflecting the low productivity level characterizing these two regions. The response to NPK fertilizer plus compost was good. The intermediate rate of treatment (75-38-19 kg/ha of $N-P_20_5-K_20$ plus 6.25 ton/ha of compost) gave a yield increase of 943 kg/ha.

For cassava, results from 12 demonstrations in the northeast showed that response to NPK fertilizer with compost was good. Treatment 50-50-50 kg/ha of $N-P_20_5-K_20$ plus 6.25 ton/ha of compost gave the highest yield increase, 11 356 kg/ha or 85%. However, results from another series of 11 demonstrations in the eastern region showed only a moderate response to NPK fertilizer with compost. Treatment 188-188-188 with compost gave the highest yield increase: 6 778 kg/ha or 52%. The yield response for rice and cassava under the combined fertilizer and compost treatment is presented in Table 10.

Table 10 Results of demonstrations of fertilizer plus compost

Crop	Treatments		Yield	Yield increase	
	$N-P_2O_5-K_2O$ kg/ha	Compost 6.25 t/ha	kg/ha	kg/ha	%
Rice	Control		2 560	–	–
(278 sites in	50-38-19	Yes	3 213	653	26
north &	75-38-19	Yes	3 503	943	37
northeast)	150-38-19	Yes	3 633	1 073	42
Cassava	Control		13 288	–	–
(12 sites in	50-0-0	Yes	18 404	5 116	39
northeast)	50-50-0	Yes	23 332	10 044	76
	50-50-50	Yes	24 644	11 356	85
Cassava	Control		13 120	–	–
(11 sites in	31-31-31	Yes	15 911	2 791	21
east)	94-94-94	Yes	17 671	4 551	35
	188-188-188	Yes	19 898	6 778	52

2.4 TRAINING

2.4.1 Local training

Two national training seminars of three days each were organized. They were attended by about 200 SMSs from DOAE. The topics covered included fertilizer use and extension, review of the results of previous years' soil analyses activities, fertilizer promotion activities, identification of constraints and explanation of field demonstrations.

A total of 101 regional and local training seminars were conducted for about 1 436 SMSs and Kaset Tambons. The results of previous demonstrations were reviewed and the problems encountered in the implementation of the demonstrations were discussed.

2.4.2 Field days

Field demonstrations showing a visible fertilizer effect were used as teaching tools through the organization of farmers' field days. Field-day activities included: field observation, lectures on techniques of crop cultivation and fertilizer application and its economic analysis, and yield estimate contests. About 1 000 field days were organized with about 32 100 farmers attending.

2.4.3 Training abroad

External training was organized for four counterpart staff to attend the FAO/IAC (International Agriculture Centre) Joint Course on Fertilizer Use and Rural Extension in Wageningen, the Netherlands, and for two counterpart staff to attend the Course on Soil and Plant Analysis, at the University of Reading, United Kingdom. Three of the four fellowships for the FAO/IAC Joint Course were funded by the Government of the Netherlands.

Three study tours were organized to provide 22 counterpart staff with first-hand experience of fertilizer extension in other countries with similar conditions.

Full details are given in Appendix 2.

2.5 REPORTS AND PUBLICATIONS

The project produced four technical reports. Three of them covered the analysis and interpretation of the fertilizer trial and demonstration results, and were presented at various international seminars and conferences. A paper was prepared to introduce the DOAE's mineral fertilizer programme.

In addition, three handbooks were prepared in Thai: (i) Handbook of Fertilizer Demonstration Guidance; (ii) Handbook of Fertilizer Act; and (iii) Directory of Direction for Mineral Fertilizer. Full details are given as Appendix 4.

2.6 CONCLUSIONS

The results of 396 fertilizer trials on the ten field crops and of 2 053 fertilizer demonstrations on rice and seven field crops conducted on farmers' fields during the cropping seasons of 1984/85 to 1986/87 were analysed and discussed. A total of 1 752 soil samples taken from trial and demonstration sites were analysed.

For the paddy soils of the demonstration sites, soils in the northeast and east were most deficient in OM, available P_2O_5 and exchangeable K_2O, while soils in the north, centre, west and south were relatively high in OM and exchangeable K. For the upland soils of the trial and demonstration sites, soils on which maize and sorghum were grown contained the highest OM and exchangeable K contents, while soils under cassava had the lowest. Most of the soils were relatively low in available P.

The results of fertilizer trials on the ten field crops showed that good responses were obtained to low levels of N treatment on maize, sorghum, groundnut, cassava, sugar cane and kenaf, but responses to P and K varied. Yield responses to plant nutrients were affected by available P and exchangeable K contents of the soil. The NPK economic optimum rates were calculated on the basis of the yield response obtained and the farm gate fertilizer and crop prices current in 1986. Plant nutrient recommendations were proposed, derived from NPK economic optimum rates and other factors such as soil testing for nine field crops.

The emphasis of the fertilizer demonstrations was on food crops, the majority of the results representing cereals (1 076) followed by grain legumes, fibre crops, cassava and sugar cane. Yield responses and economics of fertilizer application in terms of VCRs were evaluated under various fertilizer treatments and in different regions. Economic analysis of results indicated that the current general fertilizer recommendations would only be profitable in specific areas and could not be adopted for other areas.

Successful field demonstrations were used as teaching tools through the organization of farmers' field days. Farmers were responsive to what they witnessed in the field: extensive on-the-spot trials and demonstrations in the direct environment of the farmers are clearly a vital factor in technology transfer.

3. RECOMMENDATIONS

3.1 FERTILIZER RECOMMENDATIONS

The results of fertilizer trials on the nine field crops carried out on farmers' fields in the 1984/85 to 1986/87 cropping seasons provide the basis for proposing revised fertilizer recommendations according to soil units, on the basis of fertilizer and crop prices prevailing in 1986. However, considering the varied agro-ecological conditions and crop diversification programmes launched by the Government, it is recommended that this approach be continued and expanded to cover as many representative sites as possible in order to develop more refined recommendations, and with emphasis on field crops.

3.2 LONG-TERM EXPERIMENTS

Nutrient use and efficiency should always be studied in the context of the farming system within which crops were grown. Experiments conducted over a long period on one farming system are invaluable as a guide to the major problems that may arise. Unfortunately, there appear to be very few long-term trials in which fertilizer use is managed in relation to the needs of the cropping system rather than the individual crops. It is therefore recommended that a series of long-term experiments be set up. These will require careful preliminary site selection, a continuing commitment for initially small returns, and accurate recording of crop performance and soil characteristics over several years. Such experiments are critically important to any successful programme of soil maintenance. Higher yields and more intensive cropping systems inevitably mean that more nutrients are extracted from the soil. Yields fall rapidly on upland soils when nutrients are not replaced and rather more slowly for lowland rice production systems. Such long-term trials should allow the authorities to monitor changes and so to take prompt remedial action before harmful effects become acute.

3.3 SOIL TESTING

Calibration of soil values with results of simultaneously conducted numerous field fertilizer trials on several field crops revealed a significant correlation between soil nutrient status and yield response to added nutrient. It is therefore recommended that the government consider introducing systematic soil testing as a tool in making fertilizer recommendations for some field crops. However, further development of work in soil testing will be required to determine critical nutrient concentrations in soil and other factors that may influence the interpretation of the results of soil analysis.

3.4 TRAINING

Among farmers, poor knowledge of the proper use of fertilizers was one constraint encountered in the promotion of fertilizer use. It is recommended that farmers' knowledge of fertilizers be expanded through the agricultural extension services. This presumes continued training of extension workers in basic soil and fertilizer knowledge, economic analysis of input and output relationships. Their involvement in planning and conducting field demonstrations will be a practical means to equip them with new information, skills and tools, to be transferred, in turn, to farmers.

Considering that farmers are responsive to what they witness in the field, extensive on-the-spot demonstrations in the direct environment of the farmers seem to be a most vital factor in delivering the technology. It is therefore recommended that fertilizer demonstrations showing a visible fertilizer effect should be used as teaching tools through the organization of farmers' field days.

3.5 INTEGRATED PLANT NUTRITION SYSTEMS TRIALS

While use of mineral fertilizers is the quickest and surest way of boosting crop production, cost and other constraints often deter farmers from using them in recommended quantities and in balanced proportions. It is therefore recommended that the IPNS trials initiated by DOA be expanded in order to develop plant nutrient management practices based on cropping systems and integrated use of mineral fertilizers with crop residues, green manures, biological N-fixation sources and OM of animal origin for sustainable crop production in major agro-ecological zones of the country.

Appendix 1

PROJECT STAFF

Name	Function	Dates of Service Starting	Concluding
International			
C.T. Ho	Fertilizer use specialist	May 1985	Sept. 1986
National staff (From DOA)			
Samrit Chaiwankupt	Director, Soil Science Div.	May 1985	Dec. 1988
Chote Sittibusaya	Soil Scientist	May 1985	Dec. 1988
Pairoj Somnus	Soil Scientist	May 1985	Dec. 1988
Chumpol Narkaviorj	Soil Scientist	May 1985	Dec. 1988
Prasat Kesawapitak	Soil Scientist	May 1985	Dec. 1988
Sootin Claimon	Soil Scientist	May 1985	Dec. 1988
Ring Meesawat	Soil Scientist	May 1985	Dec. 1988
National staff (From DOAE)			
Pramuan Satarath	Director, Crop Promotion Div.	May 1985	Dec. 1988
Mongkol Chuntrapen	Chief, Soil and Fertilizer Subdiv.	May 1985	Dec. 1988
Dusit Jittanoon	Subject matter specialist	May 1985	Dec. 1988
Kukiat Soitong	Subject matter specialist	May 1985	Dec. 1988
Wanakorn Intarasatit	Subject matter specialist	May 1985	Dec. 1988

Appendix 2

FELLOWSHIPS AND STUDY TOURS

A2.1 FELLOWSHIPS

Name	Purpose	Location	Dates
C. Narkaviroj A. Chareonsaksiri	Fertilizer use and rural extension	Wageningen, the Netherlands	20 May 1986 - 12 July 1986
P. Kesawapitak W. Intarasatit	Soil and plant analysis	Reading Univ., UK	18 May 1986 - 28 June 1986
R. Meesawat S. Chaivimol	Fertilizer use and rural extension	Wageningen, the Netherlands	16 May 1987 - 10 July 1987

Note: Three of the four fellowships for the Wageningen course were funded by the Government of the Netherlands.

A2.2 STUDY TOURS

Name	Purpose	Location	Dates
A. Senanarong S. Chaiwanakupt P. Satarath M. Chuntrapen	Wheat block demonstrations; fertilizer trials and demonstrations	Nepal	28 Feb. 1986 - 1 March 1986
P. Somnus N. Suanmalee P. Promsoongwong S. Suwan S. Vilaisataya B. Detsongchan M. Saevatanonta A. Dalodom M. Chuntrapen D. Jitanoonta K. Soitong A. Suriyagarn S. Yuttagasamson S. Intaprome A. Sripichitt W. Koolsing S. Srivicha	(1) Agricultural production in general and fertilizer research and extension in particular; (2) Saemaul Undong Project; (3) The Farm Management Extension Programme of the Rural Development Administration.	Republic of Korea	9-20 June 1986
C. Sittibusaya	International Conference on the Management and Fertilization of Upland Soils	Nanjing, China	7-17 Sept. 1986

Appendix 3

MAJOR ITEMS OF EQUIPMENT PROVIDED

Quantity	Item	Cost ($US)
2	Minibus (Toyota *Hi-Ace Commuter*)	18 800
3	Vehicle (Toyota *Cressida* station wagon)	27 300
5	Personal computer (IBM compatible)	11 800
4	Printer (Epson)	2 450
1	Image scanner	3 400
1	Computer screen for overhead projector	1 200
2	Uninterruptible power supply	1 000
2	Plain-paper photocopier	6 700
1	Flame photometer (Jenway PFP-7)	4 700
1	Electric typewriter (Thai + English)	1 000
2	Air conditioner	4 900

Appendix 4

DOCUMENTS PREPARED BY THE PROJECT

Chuntrapen, M. 1985. Department of Agricultural Extension's Mineral Fertilizer Programme.

Ho, C.T. 1985. FAO experience with responses to potash fertilizers. Paper prepared for: *Potassium in the Agriculture Systems of the Humid Tropics*, the 19th Colloquium of the International Potash Institute. Bangkok, Thailand, 25-30 November 1985.

Ho, C.T., & Sittibusaya, C. 1986. Responses to NPK fertilizer of maize and sorghum in Thailand. Paper prepared for: *Int. Seminar on Yield Maximization of Feed Grains through Soil and Fertilizer Management*. Bangkok, Thailand, 12-16 May 1986.

Ho, C.T. 1986. Responses of upland crops to NPK fertilizers in the Philippines and Thailand: FAO Fertilizer Programme experience. Paper prepared for: *International Conference on the Management and Fertilization of Upland Soils*. Nanjing, China, 7-11 September 1986.

Handbook of Fertilizer Demonstration Guidance (in Thai).

Handbook of Fertilizer Act (in Thai).

Directory of Direction for Mineral Fertilizer (in Thai).

D/W0679