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APPRAISAL REPORT NO. 24
FERTILIZER SITUATION IN THAILAND

BY

TOLGAY CAVUSOGLU

ECONOMIC EVALUATION GROUP

ASRCT, BANGKOK 1970

not for publication

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FOR.

The main aim of this report is to s. and potential in Thailand. It attempts to a. formation on the historical development of ferti. fertilizer consumption.

The last section of the report is a preliminary econom. tion study on the possibilities of establishment of a fertilizer . dustry in Thailand. However, this section should be treated as a first step towards future studies.

FERTILIZER SITUATION IN THAILAND

By Tolgay Cavusoglu*

SUMMARY OF FINDINGS

(1) Chemical fertilizers were introduced to Thailand in the early years after World War II. During the following years until 1965, use of fertilizers spread rather moderately. Between 1963 and 1965 the annual fertilizer consumption, in terms of nutrient content, averaged only 30,000 tonnes. Starting with 1966, however, demand for fertilizers soared, and in 1968 it reached 80,000 tonnes. The bulk of the fertilizers used in the country is imported; local production is limited to one nitrogen factory in Mae Mo with a capacity of 25,000 tonnes of nutrients.

(2) Analyses of the available data suggest three main reasons for this recent upsurge:

(a) Starting from the early sixties the Government intensified research and fertilization. Their cumulative impact became more pronounced after 1965.

(b) New measures for providing fertilizer credit to farmers were introduced in 1966. The volume of credit reached 50 million baht (equivalent to 28,000 tonnes of fertilizers) in 1969.

(c) Parallel to demand increases for fertilizers, big companies started to pay more attention to the fertilizer trade. A keen competition sprang up between these companies, resulting in lower fertilizer prices and more favourable credit terms. The available data suggest almost a 20 per cent drop in the retail price of fertilizers since 1965. Also the average price mark up on credit sales, which amounted

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* Economic Evaluation Group, ASRCT.

to over 40 per cent before 1966, has been significantly reduced during the more recent years.

Among these reasons the last one appears to be the main contributor.

(3) The fertilizer consumption in Thailand, on the other hand, is still extremely low in relation to its potential or as compared with the consumption of other comparable countries. The current use of fertilizers in Thailand constitutes only 12 per cent of the optimum level application. In 1968 the average nutrient use came to 8.0 kg/ha.

(4) The strong competition among the importers which constitutes the main impetus for rapid increase in fertilizer demand cannot be expected to go on indefinitely. Some smaller firms have already been forced out of the field. Sooner or later, at some stage, the remaining bigger firms have to come together and fix the prices of fertilizers. This may cause a stagnation in fertilizer consumption. Therefore, action should be taken to prevent the premature levelling of the consumption trend.

(a) Feasibility studies of the local production of fertilizers should be encouraged. However, apart from lignite, which is already being fully tapped, no other potential raw material deposits for fertilizer production are known in the country. Therefore, fertilizer industries in Thailand have to be limited to blending plants producing mixed fertilizers. The effective demand for mixed fertilizers has already reached 250,000 tonnes in 1969. The projected demand will be of the order of 500,000 tonnes around mid-seventies. At this magnitude the demand is large enough to justify the establishment of blending plants. Full production capacity of existing fertilizer plant can be absorbed by the blending plants. In fact present production capacity of the fertilizer plant will not meet the total N requirement of the blending plants. More nitrogenous as well as phosphoric and potassic fertilizers will be imported. Suitable fillers can be selected from the available local materials. To determine the size, location, and other aspects of the blending plants detailed studies are needed.

(b) It appears that there is a tendency among farmers to regard chemical fertilizers as some kind of wonder drugs which can increase the yield of their crops and hence their incomes miraculously. Consequently, they are applying fertilizers without taking other complementary steps such as using insecticides. Also at present large amount of farmers are using fertilizers without really knowing the optimum application ratios, this leads to waste and disappointment. Fertilizers produce the expected results only when they are applied properly. This aspect of fertilizer use should be repeatedly demonstrated to farmers.

I. INTRODUCTION

Thailand depends heavily on agriculture. Agricultural products amount to 40 per cent of the country's national income while more than 80 per cent of its population derives their livelihood from farming or farm crops. Furthermore, export of agricultural crops, by comprising 70 per cent of its total exports, constitutes Thailand's principal source of foreign currency earnings.

It is estimated that more than 80 different crops are successfully produced in Thailand, with approximately half of these having commercial importance. However, the yields of almost all the crops are considered very low in relation to the prevailing climatic and soil conditions. Larger crops could be achieved rapidly by the increased use of fertilizers, resulting in a higher yield per rai.

The present level of fertilizer use by farmers in Thailand falls far below what might be expected. In 1968 total consumption of chemical fertilizers in terms of nutrients amounted to 90,000 tonnes. Since the farm holdings in Thailand cover an area of approximately 69 million rai (Division of Agricultural Economics 1967), the average nutrient use comes to 1.3 kg per rai or 8.0 kg/ha. This is a low average as compared with other developing countries in south-east Asia or elsewhere (Table 1).

TABLE 1
CONSUMPTION OF CHEMICAL FERTILIZERS
IN TERMS OF NUTRIENT CONTENT (N, P_2O_5, AND K_2O)
(1966/67 average)

	Total consumption (10^6 tonnes)	Consumption per hectare arable land (kg)
Western Europe	13.9	134
Eastern Europe and USSR	11.2	39
North America	13.5	61
Oceania	1.6	41
Japan	2.1	350
Developed countries[1]	42.7	64
Latin America	1.8	17
Far East[2]	2.7	10
of which		
Thailand[3]	0.05	4.7
China (Taiwan)	0.24	302
Korea	0.42	222
Malaysia (West)	0.06	80
Pakistan	0.06	3
Near East	0.7	16
Africa	0.4	2
Developing countries	5.6	9
World total	48.3	36

[1] Including Israel and South Africa.

[2] Excluding Japan, including India and Pakistan.

[3] Corresponding figures for 1968 were: total consumption 30,000 tonnes and consumption per ha arable land 8.0 kg.

Sources: FAO (1968); United Nations (1968).

In addition to chemical fertilizers, large quantities of organic fertilizers from vegetable and animal wastes are used in the country; they include barn-yard manure and products of the Bangkok garbage compost factory.* Their nutrient values, however, are low and cannot be adjusted according to the varying needs of different crops. Therefore, organic fertilizers appear to be good only for preventing further deterioration of the present soil fertility.

In a country which has never had a scarcity of food and which is presently exporting large quantities of food and agricultural products to the world markets, it is difficult to present a case for increasing fertilizer use. But the data indicate that a tremendous untapped potential for increasing agricultural production exists in Thailand (Table 2). Furthermore, the crop-bearing areas in Thailand—especially

TABLE 2
YIELDS OF PADDY IN SELECTED COUNTRIES
(1963-1967)

Country	Yield (quintals/ha)
Far East	
Cambodia	11.4
Ceylon	19.3
China (Taiwan)	36.8
Hong Kong	18.3
Japan	51.8
Malaysia	25.8
Thailand	16.3
Near East	
Iran	23.1
Syria	21.0
Turkey	41.9
Oceania	
Fiji	19.9
Australia	65.1
Europe	
France	36.8
Greece	46.3
Italy	48.9

Source: FAO (1969).

* The plant, completed in 1961, has a maximum capacity of 120,000 tonnes of organic fertilizers. Nutrient contents of its products are: N 1-2%, P_2O_5 1-2.5%, and K_2O 1-1.2%.

land suitable for paddy—have almost reached their maximum limits. At present only some marginal land is still left uncultivated*, thus any significant increase in crop production is achievable either by reducing the area of the vital forest lands or by increased crop yields. Substantial reductions in the forest land may cause serious ecological, climatic, and soil problems; therefore, if Thailand aims to maintain agricultural exports at their present level as well as providing adequate food for its fast growing population, then radical increases in fertilizer use in Thailand become necessary.

On the other hand, use of fertilizers is profitable only when they are applied at proper rates according to varying soil and climatic conditions. Agronomic research on fertilization in Thailand is still at an early stage. Although a group of well-trained personnel have already initiated programmes exploring soil conditions and fertilizer-crop relationships, up to the present only some preliminary data have been gathered. Much work in this field must still be done to determine the optimum fertilization for each crop in different districts. The future development of fertilizer consumption in Thailand depends heavily on the outcome of these research programmes.

II. HISTORICAL DEVELOPMENT OF FERTILIZER USE

The bulk of the chemical fertilizers used in the country is imported. Local production of chemical fertilizers is limited to one nitrogen factory at Mae Mo, Changwat Lampang, which was completed in 1966. The plant has an annual production capacity of about 25,000 tonnes of N nutrients (or 60,000 tonnes of ammonium sulphate and 30,000 tonnes of urea); however, its present output is much below its capacity.

Chemical fertilizers were introduced to Thailand in the early years after World War II. During the following fifties and in the first part of sixties, the use of fertilizers spread rather moderately among the

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* Farm holdings amount to almost 20 per cent of the total area of Thailand, of which annually cultivated land comprises over 16 per cent. The remaining less than 4 per cent uncultivated farm holdings mainly consist of marginal lands or land necessarily left fallow.

Thai farmers. The annual fertilizer consumption, in terms of nutrient content, averaged only 30,000 tonnes between 1963 and 1965. Starting with 1966, however, demand for fertilizers soared; between 1965 and 1968 consumption of fertilizers tripled. According to partial evidences* this new trend has continued also in 1969. Tables 3 and 4 focus on the different aspects of the historical development of fertilizer use in Thailand.

TABLE 3
CHEMICAL FERTILIZER CONSUMPTION IN THAILAND
(in tonnes)

Year	Nitrogen group			Phosphate group	Potassium group	NP group	NPK group	Total 1/
	Imports	Local production	Total					
1950	8,700	-	8,700	555	60	14	10	9,353
1951	5,880	-	5,880	250	227	14	39	6,443
1952	15,260	-	15,260	335	140	10	80	15,881
1953	8,158	-	8,158	480	300	-	250	9,250
1954	13,661	-	13,661	882	164	-	630	15,385
1955	19,594	-	19,594	3,029	514	216	840	24,287
1956	16,781	-	16,781	2,849	980	1,320	1,480	23,570
1957	24,651	-	24,651	3,801	930	6,315	4,272	40,020
1958	20,391	-	20,391	615	418	7,219	2,687	31,361
1959	23,656	-	23,665	1,272	1,279	13,119	8,458	47,899
1960	32,706	-	32,706	1,513	941	8,816	10,112	54,555
1961	34,485	-	34,485	1,622	675	10,867	7,950	56,112
1962	35,897	-	35,897	4,078	1,647	16,679	10,417	69,407
1963	49,218	-	49,218	4,950	1,801	29,297	14,090	99,883
1964	39,342	-	39,342	3,249	1,240	41,412	22,594	108,283
1965	34,916	-	34,716	2,794	2,439	27,053	16,606	84,937
1966	51,189	-	51,189	3,946	2,094	49,617	24,470	132,074
1967	55,588	8,188	63,776	2,341	3,259	95,118	37,686	202,480
1968	46,550	26,716	73,269	6,792	3,857	142,397	42,778	269,954
1969	21,000 2/	35,500	56,500 2/	9,300 2/	1,700 2/	222,000 2/	......	....

1/ Including unspecified fertilizer imports.

2/ Based on January-October import figures.

Sources: Annex I (Table 12), and (for 1969 figures) Chemical Fertilizer Co.Ltd., Customs Department and fertilizer importers (personal communications).

* Data obtained from fertilizer importing firms and Chemical Fertilizers Co.Ltd. (personal communications).

TABLE 4
CONSUMPTION OF CHEMICAL FERTILIZERS IN THAILAND
IN TERMS OF NUTRIENT CONTENT
(in tonnes)

Years	N	P_2O_5	K_2O
1950	1,833	152	33
1951	1,243	99	129
1952	3,217	136	83
1953	1,741	210	192
1954	2,939	359	196
1955	4,252	1,002	431
1956	3,806	1,310	778
1957	5,916	2,795	1,239
1958	3,958	1,938	682
1959	8,171	3,983	2,126
1960	9,835	3,246	2,231
1961	10,119	3,440	1,515
1962	11,846	5,707	2,653
1963	17,165	8,833	3,498
1964	17,966	12,210	4,509
1965	14,305	8,998	4,136
1966	20,426	12,746	5,294
1967	33,897	24,621	8,085
1968	46,378	35,122	9,092

Source: Annex I (Tables 13, 14, 15).

Analyses of the available data suggest several interrelated reasons for the recent upsurge in fertilizer consumption. They are summarized below.

Extension of governmental research on fertilization

Up to 1960 fertilization experiments were conducted only at state agricultural stations. These experiments, although significant results were obtained, inevitably produced little effect on the actual use of fertilizers by the farmers. In the absence of a large and well-organized agricultural extension network, the bulk of the farmers were not made aware of the results of the experiments carried out in a few stations.

Since 1960, however, a great number of experiments were actually conducted in privately-owned farmlands by researchers from the Ministry of Agriculture. In this way the favourable results of the experiments were demonstrated more widely. The first effects of these experiments on the fertilizer consumption were felt in the early sixties, but after 1965 their cumulative impact became more pronounced.

State assistance

Since 1955 the Thai Government has helped farmers by providing them with fertilizers at a single fixed price (currently 2 baht/kg) throughout the country. The necessary funds came from the rice premium revenue. The fertilizers thus purchased were sold or loaned to farmers at the beginning of each planting season. Farmers who have received fertilizers on credit pay back after the crop is harvested. This assistance has proved to be helpful, especially to farmers located in the north and north-east regions where the retail prices of fertilizers are higher due to high transportation costs.

From 1955 to the present, the assistance continued in every year except 1957 and the amount of fertilizers provided through this programme has gradually increased, but it has never reached a sizable magnitude relative to total fertilizer consumption in Thailand. Therefore, this assistance may be regarded as special assistance to farmers living in the less fertile lands of the north and north-east regions to ease their financial burden rather than to encourage the spread of fertilizer use. Table 5 gives the magnitude of the assistance in relation to total fertilizer consumption in Thailand.

TABLE 5
IN KIND FERTILIZER ASSISTANCE BY THE GOVERNMENT

Year	Amount of assistance	
	In tonnes	As percentage of total consumption
1955	2,450	10.0
1956	296	1.2
1957	-	-
1958	198	0.7
1959	180	0.5
1960	213	0.4
1961	304	0.6
1962	274	0.4
1963	625	0.6
1964	890	0.8
1965	1,138	1.3
1966	1,200	0.9
1967	1,500	0.8
1968	1,100	0.4

Sources: Phaisan Anusassananand, paper submitted to the Seminar on fertilizers sponsored by the Agricultural Society of Thailand, October 1969; Table 3.

In 1966 a new farmer assistance project was launched. The aim was to provide credit to farmers to purchase fertilizers. Recently the credit was preferably made available to farmers' cooperatives in lump sums rather than given to individual farmers. The credit thus received was divided among the members by themselves, and cooperatives were held responsible for the repayment of the credit. Highly commendable results were obtained in this way. First of all the members knew each other's needs better than the official administrators, and also collection of the loans was improved due to collective responsibility. Secondly, cooperatives purchased the fertilizers in bulk directly from importers or wholesalers, thus obtaining them cheaper. Cooperative movements among farmers have accelerated since the new policy was introduced.

Since the establishment of this fund, great enthusiasm and ever increasing demand for credit—much higher than the available resources—have been encountered. In 1969 the total applications for credit amounted to the equivalent of approximately 81,000 tonnes of fertilizers, but only 34 per cent of them was provided. Table 6 shows the amounts of credit provided from 1966 to 1969.

TABLE 6
CREDIT FOR FERTILIZER PURCHASES

Year	Amount of credit (million baht)	Fertilizer equivalent (tonnes)	As percentage of total consumption
1966	11.8	6,200	4.7
1967	30.0	16,300	8.9
1968	23.0	15,200	6.0
1969	50.0	28,000	...

Sources: Rice Department, Ministry of Agriculture (personal communication); Phaisan Anusassananand, paper submitted to Seminar on fertilizers sponsored by the Agricultural Society of Thailand, October 1969.

The fertilizer credit scheme is much larger than in kind fertilizer assistance programme and also its operation is more effective in encouraging farmers to use fertilizers. This programme appears to be one of the main reasons for accelerated consumption of fertilizers.

Competition among the fertilizer importers

Parallel to demand increases for fertilizers, big companies started to pay more attention to the fertilizer trade. In more recent years several big firms entered the fertilizer market. A keen competition started between these firms in order to hold a bigger share in the extending fertilizer trade.

Due to this competition two significant developments, which are particularly favourable to the farmers, have taken place: several companies have established their own extension services and lower prices together with better payment facilities were offered to farmers.

Most of the big companies now have their own extension teams. These teams are demonstrating the technique of fertilizer applications, giving advice to farmers and also making direct sales. With the establishment of these teams the role played by the middle-men is being restricted.

Previously the average price mark up was approximately 11 per cent from importer to dealer for credit sales and 29 per cent from dealer to farmer (Bond *et al*. 1966).* At present, these rates appear to be significantly reduced. Furthermore, a sizable portion of the fertilizer transactions is now being made in bulk from importer through extension service to farmers' cooperatives, thus eliminating the importer-to-dealer price mark up. Some companies even abandoned the practice of price mark up for credit sales up to four months (personal communications). Moreover, competing firms during the last 3-4 years have gradually reduced the fertilizer prices.

Table 7 shows the approximate magnitude of this reduction.

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* In 1965 the average interest rate paid by dealers was 1 per cent per month and by farmers just over 2 per cent per month. The average credit period for dealer was eight months and for farmers 6 months.

TABLE 7
FERTILIZER PRICES

Name of fertilizer	Wholesale price 1965 (baht/t)	Wholesale price 1969 (baht/t)	Wholesale price Change (%)	Price to farmers[1/] 1965 (baht/t)	Price to farmers[1/] 1969 (baht/t)	Price to farmers[1/] Change (%)
Single fertilizers						
Ammonium sulphate	1,400	1,200	-8	1,700	1,300[3/]	-23
Urea	2,650	2,300	-13	2,800[2/]	2,400[3/]	-14
Superphosphate (20%)	1,155	.....	-	1,600	1,360	-15
Potassium chloride	1,470	.....	-	2,000	1,510[4/]	-24
Compound fertilizers						
16 - 20 - 0	2,150	1700-1900	-19 to -12	2,800	2,300	-18
20 - 20 - 0	2,150	2,000	-7	2,800	.....	-
13 - 13 - 13	2,300	1,950	-15	3,200	2,600	-18
13 - 13 - 21	2,050	.....	-	2,800	2,300	-18
14 - 14 - 14	2,200	.....	-	3,200	2,400	-25
15 - 15 - 6 - 4Mg	2,250	1,900	-16	3,100	.....	-
12 - 12 - 20	2,350	1,950	-17	3,000	.....	-
12 - 24 - 12	2,300	1,900	-17	2,900	2,800	-4

1/ Sales on credit.

2/ Sold for cash only.

3/ Credit or cash at the same price.

4/ Three months credit; cash price is 1,465 baht/tonne. The price mark up in this case is equal to one per cent per month interest.

Sources: 1965 prices—Bond *et al.* (1966); 1969 prices—personal communication.

The available data suggest almost a 20 per cent drop in the retail prices of fertilizers since 1965.

From the above analysis it may be concluded that the competition that flared up in the mid-sixties appears to be the most important contributor to the rapidly increasing fertilizer use among the farmers. The competing firms are at present really pushing hard to expand the fertilizer market and their share in that market. It seems that they will persist on these lines for some time to come; therefore it is expected that the present trend of fertilizer consumption will continue in the near future. But recurrent price cuts, more generous credit conditions and increasing importance of bulk sales from importers directly to farmer's cooperatives affect the composition of fertilizer firms in the market. Some of the second-hand dealers and some smaller importers are disappearing. This eventually will lead to domination of the market by a few stronger companies. But, even these big firms cannot afford to go on with the price reductions indefinitely. At some stage they have to come together and fix the prices of fertilizers, probably at a higher level than the prices prevailing at that time.

This may cause a stagnation in fertilizer consumption. As was discussed above, it appears that the main impetus for the accelerated fertilizer consumption is the decreasing cost of fertilizers to the farmers. The Government's help is very appropriate, but it is not large enough to sustain the trend in the absence of the primary incentive.

The fertilizer consumption in Thailand is still extremely low in relation to its potential (see next section) or as compared with world consumption rates. Therefore action should be taken to prevent the premature levelling of the fertilizer consumption trend. Two sets of measures may be taken to stimulate fertilizer consumption even after the cutthroat competition among the firms is stopped:

(1) Fertilizer experiments are still at a preliminary stage and extension officials can advise farmers effectively on a very few crops only.* The main objective of the demonstration teams established by the fertilizer firms is to boost the consumption of their own brands; therefore their experiments are always biased. The experiments conducted by the Ministry of Agriculture should be intensified; various experiments should be coordinated towards pin-pointed targets; and experiments should be extended as much as possible to the private fields to increase their demonstration effect.

Furthermore, it seems that there is a tendency among farmers to regard chemical fertilizers as some kind of wonder drugs which can increase the yield of their crops and hence their incomes miraculously.+

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* This is due to lack of funds and small number of trained men in the field. During the last years, however, more money and personnel became available and correlation of different research works (e.g. soil analyses and fertilization) has started.

+ Most of the persons contacted maintained this view.

Consequently, they are applying fertilizers without taking other complementary steps such as using insecticides and fungicides, or adjusting their farming methods to facilitate fertilizer use. Fertilizers produce the expected results only when they are applied properly. This aspect of fertilizer use should be repeatedly demonstrated to farmers.* On the other hand, even if the farmers are willing to use them, the cost of insecticides, etc. is prohibitively high in relation with the incomes which farmers derive from the yield increase. Currently, except for a few mixing plants which are blending imported materials, all these protective chemicals are imported. Feasibility studies of the local production of these materials should be encouraged.

(2) In spite of substantial price decreases, current costs of fertilizers are still higher than prices prevailing in neighbouring countries with high fertilizer consumption, such as Taiwan and Japan. These high prices are due to the fact that, except ammonium sulphate and urea, all the fertilizers are imported. All the possibilities for local production of fertilizers should be researched. (See Section IV.)

Shifting demand in consumption of fertilizers

In addition to the marked increase in fertilizer consumption, a definite shift in fertilizer preference in favour of mixed fertilizers has started since the early sixties. Between 1955 and 1968 the relative shares of single and mixed fertilizers consumed in Thailand have completely reversed. This phenomenon is mainly due to rice farmers' increasing choice of ammophos as against single fertilizer. However, it also partly reflects the vigorous expansion in the use of NPK fertilizers.+ These fertilizers are mostly used for fruits and vegetables. Producers of fruits and vegetables appear to be the most progressive of all the farmer groups due to their educational levels and financial status.

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* The fertilizer waste due to improper use appears to be significant for almost all kind of crops; the rate of waste, however, is not quantifiable. The improper use of fertilizers is developing a negative effect on the expansion of fertilizer consumption.

+ Since 1965 NPK fertilizers have increased almost 50 per cent annually.

The highly profitable yield increases and quick returns on investment encouraged more farmers to use more fertilizers on these crops.

Although they are not necessarily cheaper than single fertilizers of equivalent nutrient value, mixed fertilizers are preferred by most farmers. They are relatively less bulky and they have the advantage of being homogeneously mixed, which enables farmers to apply them more accurately and easily than combining the single fertilizers.

Consequently, consumption of mixed fertilizers has been recommended by the Ministry of Agriculture and advertised by importing firms. Under the impact of these advices and also depending on their own experiences, farmers shifted from using single fertilizers to mixed fertilizers. Therefore, the above mentioned expansion in fertilizer consumption was solely produced by the increased demand for mixed fertilizers. Consumption of single fertilizers in 1968 was only five per cent above the 1963 level.

On the other hand, there are some crops which need only one kind of fertilizer,* thus stagnation of single fertilizers reflects the lack of development in the fertilizing of these crops. Even though a great deal of the conducted research was directed to these crops, their actual fertilization rates are still very low. This is primarily due to excessive price fluctuation. Excessively depressed prices in the years when there is a good harvest discourage farmers from using fertilizers. In most cases the extra income due to fertilization does not off-set the cost of fertilizers. Unless the marketing problems of these crops are solved, using fertilizers on them will not become profitable.

III. OPTIMUM FERTILIZER NEED IN THAILAND

To estimate the potential fertilizer market in Thailand, the optimum amount of fertilizer applicable to main crops is calculated in Annex II. The optimum amount of fertilizers is defined as "the amount which will produce the maximum net income for the farmer." Unfortunately,

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* See Annex II. Some food crops need mostly nitrogenous fertilizers while some oil crops need only phosphate fertilizers.

for the majority of crops the optimum amount has not yet been determined, or it has been determined only for certain locations. Variations due to soil types are not yet known for any crop. Therefore, the results which are summarized in Tables 8 and 9 are quite approximate and depend mainly on generalizations of the results of too few experiments.

TABLE 8
OPTIMUM NEED FOR NPK NUTRIENTS IN THAILAND
(in kilotonnes)

Nutrient	Region				
	Central plain	North-east	North	South	Total
N	150.2	93.2	40.2	34.7	336.3
P_2O_5	90.6	61.6	22.5	19.8	212.2
K_2O	29.6	42.5	17.7	8.9	123.4

Source: Annex II (Table 29).

TABLE 9
OPTIMUM NEED FOR IDENTIFIABLE[1/] FERTILIZERS

Kind of fertilizer	Optimum need (kilotonnes)
Single fertilizers	
Ammonium sulphate	645,3
Urea	9,1
Double superphosphate	87,1
Mixed fertilizers	
Ammophos (16-20-0)	616,2
4-24-12	53,8
13-13-13	188,5
10-8-10	110,9
10-5-5-5 (Mg)	6,5
Formulas for rubber	18,5

1/ For definition see Annex II.

Source: Annex II (Table 30).

TABLE 10
COMPARISON OF PRESENT LEVEL OF FERTILIZER CONSUMPTION WITH THE OPTIMUM NEED

Nutrient	Present use (1968) (tonnes)	Optimum need (tonnes)	Potential demand increase (%)
N	46,378	336,300	720
P_2O_5	35,112	212,200	600
K_2O	9,092	121,400	1,330

Sources: Tables 4 and 8.

Furthermore, our definition of optimum amount is a function of prices (fertilizers and crop) as well as the extra yield obtained due to fertilizing. Thus changes in either of these prices will cause variations in the calculated optimum amount. Under present conditions, changes in fertilizer prices during one year are slight but crop prices are fluctuating considerably. The optimum amounts calculated in the Annex are strictly valid only when these basic prices remained unchanged, but this is unimportant since the aim is just to find out the order of magnitude.

Realization of these hypothetical potentials will probably take a long time, especially in some marginal areas where fertilizers may produce limited returns even at significantly lower fertilizer prices. Unless irrigation facilities are improved and new rice variaties are introduced, this may be so for some of the rice growing areas in the north-east. It may be true also for such upland crops as maize, cassava, etc. Under present marketing conditions, obtaining substantially higher yields through fertilization may depress the selling prices of these crops to such an extent as to make uneconomical the use of fertilizers up to full potential.

Therefore, cheaper fertilizer supply and dependable comprehensive research data will not be enough to boost fertilizer consumption up to its optimum level. This will become possible only if all the other complementary factors such as irrigation, marketing, farming methods, use of protective sprays, etc. are radically improved.

IV. THE POTENTIAL OF FERTILIZER PRODUCTION IN THAILAND

Nitrogenous fertilizers

In the early days of the fertilizer industry, organic materials were generally the cheapest source of nitrogen for use in fertilizer. Now, however, they are the most expensive. Modern methods of synthesis provide cheaper ammonia, nitrates, and amides. Plants do not distinguish between nitrogenous fertilizer obtained from organic or inorganic source (Sauchelli 1963).

Production of synthetic ammonia was originally based on solid feedstocks such as coke or lignite, but was gradually changed over to raw materials derived from oil processing. Ammonia can be produced also by synthesis from air and water.*

The existing lignite deposits at Mae Mo were originally used to generate steam. The power was supplied to Lampang, Chiang Mai and Yanhi for construction of Bhumibol Dam. The hydroelectric facilities at Yanhi went into service in May 1964 essentially eliminating the need for the steam generating facilities at Mae Mo. Consequently, construction of a fertilizer complex to utilize the steam generating facility and the reserves of lignite was proposed and accepted by the Government. The plant was completed and started to produce in 1967 under the name of Chemical Fertilizer Co., Ltd.

Later another proposal was made to produce nitrogenous fertilizers based on petroleum feedstocks obtained from Si Racha refinery. However, it seems that at the refinery no suitable feedstocks are available and will not be available unless refining capacity is greatly expanded.+

The third method of producing ammonia is not widespread in the world because it requires the use of enormous amounts of electricity. In Thailand, where the cost of electricity is high, this production method is uneconomical.

The above analysis shows that Thailand's present potential to produce nitrogenous fertilizers is limited to one source: utilization of lignites at Mae Mo, which is already being tapped.

During the first year of its operations the Mae Mo plant faced temporary power shortage resulting in low production (Thate 1967). However, the level of production continues to be low due to difficulties

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* For the production of one tonne of ammonia roughly 8,000 kWh of electricity is required, no other raw materials other than water and air being necessary (Thate 1965).

\+ A small amount of hydrogen is flared from the cat cracker and naptha is not produced in the refinery (Bond et al. 1966).

encountered in marketing (Table 11). When Mae Mo plant was set up its prices were competitive with the prices of the imported comparable fertilizers. However, after the plant went into operation importers of foreign-made fertilizers, especially from Japan, slashed their prices.*

TABLE 11
SALES OF FERTILIZERS PRODUCED AT MAE MO PLANT

Year	Ammonium sulphate (tonnes)	As % of designed capacity	Urea (tonnes)	As % of designed capacity
1967	7,229	12	859	3
1968	19,221	32	7,242	24
1969	26,200	43	9,300	31

Source: Chemical Fertilizer Co., Ltd. (personal communication).

Furthermore, profit margins and credit terms offered by importers to dealers were more favourable than those offered by the Chemical Fertilizer Co., Ltd. Therefore many of the dealers have not engaged in selling the local fertilizer.

By June 1968 unsold stocks of the plant reached over 35,000 tonnes of fertilizers and the factory ceased its production activities. In the same month the Government banned the imports of ammonium sulphate and urea. This measure proved to be effective only to a certain limit. The plant has succeeded to reduce its oversize stocks to managable proportions; however, its sales and production have not reached full capacity even in 1969. But liquidating its excess stocks the factory started to produce again at the beginning of 1970.

* Ammonium sulphate imported from Japan was sold at 1,250 baht per tonne at the end of 1966. Mae Mo marketed its output at the same price in 1967. The price of the imported ammonium sulphate was cut to 1,050 baht per tonne, which was met by the Mae Mo factory. But by mid-1967 the price of imported fertilizer was reduced further to 900 baht per tonne, which was lower than the production cost of indigenous ammonium sulphate.

There are two main reasons for the continuing difficulties in the sales of their products. First of all, the present effective demand for ammonium sulphate and urea together appears to be less than the total output of the plant (90,000 tonnes per annum). Farmers are progressively preferring to apply mixed fertilizers against single fertilizers; therefore the impact of the soaring demand for fertilizers is small on the single nitrogenous fertilizers. The current demand for single nitrogenous fertilizers is estimated as only 70,000 tonnes per annum.

Secondly, since the imports of ammonium sulphate and urea were banned, companies switched to imports of other nitrogenous fertilizers. According to available statistics, import of nitrogenous fertilizers other than ammonium sulphate and urea has increased to 440 per cent between January and October 1969 as compared with the imports in the first ten months of 1967. They are sold to farmers by dealers or extention teams of the importers as substitutes for ammonium sulphate, leading to a reduction of the relative share of ammonium sulphate and urea in the total consumption of single nitrogenous fertilizers.

The potential demand for ammonium sulphate is about ten times larger than the present capacity of the Mae Mo plant, and its application on various crops is being recommended by the Ministry of Agriculture (see Annex II). On the other hand, use of urea by farmers is facing more reservations for various reasons. Consequently, it appears that an effective demand build-up, equal to the capacity of Mae Mo plant, will take at most another two to three years for ammonium sulphate but a longer period for urea. Since switching from one product to another is possible only to a limited extent, it will take a longer time for the Mae Mo plant to produce at full capacity.

However, the surplus urea could be utilized in mixed fertilizers. At present only one small blending plant exists in Thailand. If other blending plants will be established, the available urea may be used in these plants. The high content of N in urea reduces its cost of transportation from Mae Mo to blending plants.

Phosphoric fertilizers

At present all phosphoric fertilizers are imported. There are no known phosphate rock reserves in Thailand. Although in 1965 phosphate rock was found in Prachuap Khiri Khan province, its phosphate content was only about 18 per cent and the estimated magnitude of the reserve is not more than 100 tonnes (Poothai 1968). The Second Five Year Development Plan included a fertilizer raw materials exploration project which is particularly oriented towards phosphate discovery.

It does not appear to be economically feasible to produce any of the phosphate fertilizers from imported raw materials at present.

Potassic fertilizers

Potash deposits have received initial attention in Thailand but so far only traces have been found (Poothai 1968). Provisions for further investigations were included in the Second Development Plan under the fertilizer raw materials exploration project.

Production of potassic fertilizers from imported materials does not appear to be economically feasible.

Blending of mixed fertilizers

The effective demand for mixed fertilizers has already reached 250,000 tonnes in 1969. The projected demand will be of the order of 500,000 tonnes around mid-seventies. This total includes all formulas of NP and NPK mixed fertilizers, but demand for 16-20-0 (assuming that the recommendation of the Rice Department remains the same during that period) will constitute at least 70 per cent of the total.

At this magnitude the demand for mixed fertilizers is large enough to justify the establishment of blending plants. These plants may be built primarily for blending 16-20-0 but they may blend NPK fertilizers according to the demand.

Full urea production capacity of Mae Mo plant then can be absorbed by the blending plants to produce mixed fertilizers. In fact, present urea production capacity will not meet the total N requirement of the blending plants. More nitrogenous as well as phosphoric and potassic fertilizers will be imported. Suitable fillers can be selected from the available local materials, e.g. clay, limestone etc.

However, to determine the size, location, and cost of blending plants, and to select materials for mixing which will yield best technical and economical results, detailed technical feasibility studies are needed. A further economical feasibility study should be prepared to determine the profitability of the venture.

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ANNEX I

TABLES

TABLE 12
FERTILIZER IMPORTS
(in tonnes)

Kind of fertilizer	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Nitrogen group										
Ammonium sulphate	8,640	5,840	15,165	8,118	13,545	19,498	16,454	23,963	17,779	22,538
Ammonium sulphate nitrate	-	-	-	-	-	-	5	-	70	140
Urea	-	-	-	-	-	11	70	493	310	469
Calcium ammonium nitrate	-	-	30	-	56	60	61	180	30	220
Calcium cyanamide	-	-	5	-	-	5	-	-	-	23
Nitrate of soda and others	60	40	60	40	60	20	198	15	2,192	266
Total	8,700	5,880	15,260	8,158	13,661	19,594	16,781	24,651	20,391	23,656
Phosphate group										
Superphosphate	313	230	235	400	300	690	783	801	578	1,054
Hyperphosphate	200	-	100	-	501	2,150	1,710	3,000	-	-
Rock phosphate	10	-	-	50	-	31	203	-	26	179
Other phosphates	32	20	-	30	61	151	153	-	11	39
Total	555	250	335	480	882	3,022	2,849	3,801	615	1,272
Potash group										
Muriate of potash	10	100	-	-	82	264	375	480	168	522
Sulphate of potash	50	122	120	300	32	160	405	100	250	702
Potash of magnesium	-	5	20	-	50	90	200	350	-	50
Bicarbonate of potash	-	-	-	-	-	-	-	-	-	5
Total	60	227	140	300	164	514	980	930	418	1,279
NP group										
16-12	-	-	-	-	-	-	-	-	-	-
16-20 Ammophos	5	5	-	-	-	-	850	5,555	6,629	12,210
18-22	-	-	-	-	-	-	-	-	-	-
20-20	-	-	-	-	-	11	270	360	590	370
Others	9	9	10	-	-	205	200	400	-	539
Total	14	14	10	-	-	216	1,320	6,315	7,219	13,119
NPK group										
All formulas	10	39	80	250	630	840	1,480	4,272	2,687	8,458
Unspecified	14	33	56	62	48	94	160	51	31	106
Total	24	72	136	312	678	934	1,640	4,323	2,718	8,564
TOTAL FERTILIZER IMPORTS	9,353	6,443	15,881	9,250	15,385	24,280	23,570	40,020	31,361	47,899

TABLE 12 (continued)

Kind of fertilizer	1960	1961	1962	1963	1964	1965	1966	1967	1968
Nitrogen group									
Ammonium sulphate	29,022	30,081	28,956	43,614	32,980	25,991	39,729	44,135	27,177
Ammonium sulphate nitrate	338	565	550	505	467	490	1,010	1,490	6,055
Urea	746	718	1,428	1,475	1,210	2,235	2,480	2,244	1,979
Calcium ammonium	475	1,185	2,175	1,745	2,911	4,000	5,990	6,680	7,400
Calcium cyanamide	3	-	-	3	-	3	-	-	8
Nitrate of soda and others	2,122	1,956	2,808	1,876	1,774	2,197	1,980	1,039	3,931
Total	32,706	34,505	35,847	49,225	39,342	34,916	51,189	55,588	46,550
Phosphate group									
Superphosphate	1,164	1,020	2,865	3,884	2,355	2,170	3,233	2,241	1,637
Hyperphosphate	-	300	650	500	400	400	400	-	-
Rock phosphate	92	265	549	416	494	324	313	100	208
Other phosphates	257	37	14	150	-	-	-	-	4,947
Total	1,513	1,622	4,078	4,950	3,249	2,794	3,946	2,341	6,792
Potash group									
Muriate of potash	421	265	599	650	480	939	890	506	807
Sulphate of potash	420	300	1,048	1,151	760	1,500	1,204	1,000	850
Potash of magnesium	100	110	-	-	-	-	-	-	300
Bicarbonate of potash	-	-	-	-	-	-	-	1,753	1,900
Total	941	675	1,647	1,801	1,240	2,439	2,094	3,253	3,857
NP group									
16-12	-	-	-	-	-	-	-	1,100	250
16-20 Ammophos	7,741	10,384	16,233	27,343	37,728	24,377	45,690	89,168	127,499
18-22	-	-	30	1,630	2,730	2,085	2,985	1,000	1,923
20-20	650	380	150	154	1,432	450	872	3,850	12,548
Others	425	103	266	165	122	141	70	-	526
Total	8,816	10,867	16,679	29,292	41,412	27,053	49,617	95,118	142,397
NPK group									
All formulas	10,112	7,950	10,417	14,090	22,594	16,606	24,470	37,686	55,000
Unspecified	467	493	689	525	446	1,132	758	300	861
Total	10,579	8,443	11,106	14,615	23,040	17,738	25,228	37,986	55,861
TOTAL FERTILIZER IMPORTS	54,555	56,112	69,407	9,883	108,283	84,937	132,074	194,292	255,457

Sources: Department of Customs; Chemical Fertilizers Co.,Ltd. (personal communication).

TABLE 13
CONSUMPTION OF CHEMICAL FERTILIZERS
IN TERMS OF N NUTRIENT CONTENT
(in tonnes)

Year	Single fertilizers: Ammon. sulph.	Urea	Ammon. sulph. nit.	Calc. ammon. nit.	Calcium cyanamide	Others[1/]	Total[1/]	NP fertilizer	NPK fertilizer	Total N consumption
1950	1,814	-	-	-	-	15	1,829	3	1	1,833
1951	1,226	-	-	-	-	10	1,236	3	4	1,243
1952	3,184	-	-	6	1	15	3,206	2	9	3,217
1953	1,704	-	-	-	-	10	1,714	0	27	1,741
1954	2,844	-	-	11	-	15	2,870	0	69	2,939
1955	4,094	-	5	12	1	5	4,117	43	92	4,252
1956	3,455	2	31	12	-	19	3,549	94	163	3,806
1957	5,032	-	221	37	-	4	5,294	152	470	5,916
1958	3,733	23	139	6	-	548	4,485	1,178	295	5,958
1959	4,732	47	211	45	5	66	5,106	2,135	930	8,171
1960	6,094	113	335	97	1	530	7,170	1,453	1,112	9,835
1961	6,317	189	329	245	-	489	7,561	1,684	874	10,119
1962	6,076	148	642	446	-	702	8,014	2,686	1,146	11,846
1963	9,158	169	663	358	1	469	10,818	4,797	1,550	17,165
1964	6,926	156	544	597	-	443	8,666	6,815	2,485	17,966
1965	5,458	169	1,005	820	1	549	8,002	4,477	1,826	14,305
1966	8,343	338	1,116	1,228	-	495	11,520	8,155	2,692	22,367
1967	10,786	499	1,396	1,369	-	260	14,310	15,433	4,154	33,897
1968	9,743	2,028	4,149	1,517	1	771	18,209	23,422	4,756	46,378

1/ Approximate.

Sources: Table 12; Sauchelli (1963); Chemical Fertilizer Co.,Ltd. (personal communication).

TABLE 14
CONSUMPTION OF CHEMICAL FERTILIZERS
IN TERMS OF P_2O_5 NUTRIENT CONTENT

(in tonnes)

Year	Single fertilizers					NP fertilizers	NPK fertilizers	Total P_2O_5 consumption
	Superphosphate							
	18-20	36/38	40	47	Others[1]			
1950	42	-	35	-	72	2	1	152
1951	6	-	80	-	6	2	5	99
1952	-	-	94	-	30	2	10	136
1953	-	-	160	-	20	-	30	210
1954	4	-	120	-	160	-	75	359
1955	102	-	60	-	699	40	101	1,002
1956	53	-	200	-	620	260	177	1,310
1957	123	-	60	-	900	1,200	512	2,795
1958	21	37	147	-	11	1,400	322	1,938
1959	92	127	90	-	60	2,600	1,014	3,983
1960	106	48	189	-	90	1,600	1,213	3,246
1961	89	120	50	47	180	2,000	954	3,440
1962	227	407	28	235	360	3,200	1,250	5,707
1963	390	279	-	504	170	5,800	1,690	8,833
1964	181	403	-	145	220	8,500	2,711	12,210
1965	62	312	-	422	210	5,400	1,992	8,998
1966	114	475	-	632	210	9,800	1,515	12,746
1967	-	829	-	-	270	19,000	4,522	24,621
1968	-	689	-	-	900	28,400	5,133	35,122

[1] Approximate.

Sources: Table 12; Sauchelli (1963); Chemical Fertilizer Co.,Ltd. (personal communication).

TABLE 15
CONSUMPTION OF CHEMICAL FERTILIZERS
IN TERMS OF K_2O NUTRIENT CONTENT
(in tonnes)

Year	Single fertilizers			NPK fertilizers	Total K_2O consumption
	Muriate of potash	Sulphate of potash	Others[1/]		
1950	6	25	-	2	33
1951	60	61	2	6	129
1952	-	60	10	13	83
1953	-	150	-	42	192
1954	48	16	25	107	196
1955	158	80	50	143	431
1956	225	202	100	251	778
1957	288	50	175	726	1,239
1958	101	125	-	456	682
1959	313	350	25	1,438	2,126
1960	252	210	50	1,719	2,231
1961	159	150	55	1,351	1,515
1962	359	524	-	1,770	2,653
1963	390	575	-	2,533	3,498
1964	288	380	-	3,841	4,509
1965	563	750	-	2,823	4,136
1966	534	600	-	4,160	5,294
1967	303	500	876	6,406	8,085
1968	245	425	1,100	7,272	9,092

1/ Approximate.

Sources: Table 12; Sauchelli (1963); Chemical Fertilizer Co.,Ltd. (personal communication).

ANNEX II

OPTIMUM POTENTIAL FERTILIZER NEED FOR THAILAND

INTRODUCTION

Fertilization research was initiated by the Department of Agriculture nearly twenty years ago. At first the operations were not fully effective due to the limited facilities and insufficient number of researchers. The results obtained during these years were not quite conclusive. However, in the second decade more precise and reliable results were obtained. The experiments which had been hitherto restricted to a handful of research centres were progressively widened in scope and farmers' land was also used for experiments. The work was concentrated on various economic crops grown in important cultivated areas throughout Thailand using soil tests as a guide to fertilizing evaluation.

The more important crops (e.g. rice) were studied in the early years and relatively more definite answers relating to their yield increases have been obtained. But for most crops the experiments were started too recently and since this kind of research takes a long time, the first definitive results on these projects will probably be obtained no sooner than the middle seventies.

The UNDP/SF soil fertility research project includes economic evaluation of fertilizer application to various crops. However, since this study is still in progress, it will be some time before the results become available.

The figures employed here are often based on the first tentative results obtained from these various research activities and must be regarded as highly approximate.

This annex is concerned with estimating the total optimum fertilizer need of Thailand. The optimum fertilizer need of a crop is defined as the amount of fertilizer which, when applied to that crop, produces the highest return in monetary terms. This amount does not necessarily corresponds to the amount of fertilizer which produces the maximum yield on the same crop. The above definition is employed as the basic rule for the estimation of the total optimum fertilizer need of Thailand.

The optimum fertilizer need of a crop is affected by many variables. Soil, climate, and farming practices exert strong influences. Experimental conditions usually differ significantly from practical farming conditions. Clearly, projections based on preliminary recommendations should not be relied upon too heavily.

Changes in the prices of fertilizers and, even more important, fluctuations in the market prices of crops, greatly affect optimum fertilizer needs. Residual effects of fertilizers and introduction of new crop varieties can also produce significant shifts. At best, calculated optimum fertilizer needs can only be strictly valid for short periods.

However, despite limitations, calculation of optimum fertilizer needs is the rational way to estimate the upper limit of potential fertilizer demand for countries like Thailand which do not aim to produce "more crops at any price". Although the available data is approximate it serves the purpose of this report, which is to foresee in broad outline the future market for fertilizers, so that Thailand may make appropriate plans for the rational development of an indigenous fertilizer industry.

POTENTIAL FERTILIZER NEEDS FOR THE MAIN CROPS GROWN IN THAILAND

(a) Rice

Rice not only constitutes the staple diet of Thais but also exports of rice contribute a significant amount to the foreign currency earnings of Thailand. Currently about 100,000 tonnes of fertilizers are being used on rice which is almost half of the total fertilizer use in Thailand.

Due to the importance of the crop, the experiments on rice fertilizing started as early as 1950. Since then extensive research on rice fertilizing has been conducted throughout the country. The cumulative results of the experiments indicate that the yield of the existing varieties responds largely to nitrogen and phosphorus fertilizers throughout the country, and responses to potassium are usually obtained only in certain areas where soils are rather sandy and low in clay. These areas occur mostly in north-eastern Thailand. Maximum yields of rice were obtained in the central plain and in the north by applying about 8 kg N and 8 kg P_2O_5 per rai (50 kg per hectare) and in the north-east addition of 8 kg of K_2O to the same formula provided the highest yields.

However, maximum returns in money terms were obtained at a much lower level of fertilization. The Department of Rice is currently recommending the use of 15 kg of ammophos fertilizer (16-20-0) per rai as a basal dressing in all regions except the north-east. In the north-east where the soil is sandy addition of 4 kg of K_2O (equivalent to 8 kg of muriate of potash) to ammophos is recommended. The Department also recommends application of an additional 10 kg of ammonium sulphate (contains about 2 kg of N) as top dressing for maximum returns. According to the experiments, application of a dressing which doubles the nitrogen rate has increased the yield in all cases, but increases also in profits have occurred only in the majority of cases (15 times out of 21). Therefore, top dressing is recommended optionally where the soil and water situation is favourable. Consequently to calculate the total fertilizer need for rice, application of 15 kg of ammophos per rai for all the rice growing lands, 10 kg of ammonium sulphate only for 30 per cent of all the rice planted areas, and 8 kg per rai of potash for only half of the rice growing lands in the north-east is assumed.

The size of the rice planted area has been stable throughout the country for the past several years. Almost all the available land for rice is currently under cultivation and there will not be any substantial enlargement in the size of this area, thus the average of the last four years is taken as the rice area.

TABLE 16
RICE PLANTED AREA
(in thousands of rai)

Region	1964	1965	1966	1967	Average
Central plain	19,539	19,391	20,273	19,833	19,750
North-east	15,470	15,183	19,277	14,095	16,000
North	2,712	2,674	2,726	2,742	2,700
South	3,149	3,239	3,386	3,446	3,300
Total	40,871	40,491	45,663	40,067	41,750

Sources: Division of Agricultural Economics (1968); Department of Rice (1968).

TABLE 17
ANNUAL OPTIMUM FERTILIZER NEED FOR RICE
(in tonnes)

Region	Nutrients			Corresponding fertilizers		
	N	P_2O_5	K_2O	Ammophos	Ammonium sulphate	Potash
Central plain	79,000	59,200	-	296,250	59,250	-
North-east	64,000	48,000	28,800	240,000	48,000	64,000
North	10,800	6,100	-	30,500	8,100	-
South	13,200	9,900	-	49,500	9,900	-
Total	167,000	123,200	28,800	616,250	125,250	64,000

On the other hand, some new hybrid rice varieties have already been developed in Thailand. These new varieties are more virus disease resistant and produce higher yields. They are not yet released to the public, and also their optimum need for fertilization is not determined. According to the officials of the Department of Rice, the probable optimum amount for the new varieties is 6-6-0 kg per rai or 6-4-2 kg per rai. The first formula means doubling the amount of top dressing, and the second formula replaces 2 kg per rai P_2O_5 with equal amount of K_2O. However, the new varieties have short straws and as a result their production requires better water control. This will probably limit their usage in certain areas of the country where the water level rises too high for their height.

(b) Other food, fibre, and oil seed crops

Maize

Experiments on maize fertilization actually started in 1951 and have been continuously conducted up to the present. The research was carried out mainly for the Guatemala variety.

The experiments have proved that the fertilizer grade 12-12-6 (100 kg/rai) has a tendency to produce high yields of maize.* However, it was found that the increased yield hardly justified the cost of

* Samart Meekangwan. Paper submitted to Seminar on fertilizers sponsored by the Agricultural Science Society of Thailand, October 1969.

fertilizer investment due to low price of maize and relatively high cost of fertilizer investment. The Division of Agricultural Chemistry is currently recommending the application of fertilizers at 6-6-3 ratio (100 kg/rai). For the experiments urea, double superphosphate, and potassium chloride were used. Therefore, application of 13.3 kg per rai of the mixture is regarded the best available formula.

The size of the maize planted area has shown a steady increase over the past years, especially in the central plain where the bulk of the maize is produced. Thus the planted area figures for the latest available year is considered more representative than the average of a few years.

TABLE 18
ANNUAL OPTIMUM FERTILIZER NEED FOR MAIZE
(in tonnes)

Region	Planted area (1000 rai)	Nutrients			Corresponding fertilizers		
		N	P_2O_5	K_2O	Urea	Double super-phosphate	Potash
Central plain	3,377	20,200	20,200	10,300	43,901	50,655	16,885
North-east	436	2,600	2,600	1,200	5,668	6,540	2,180
North	191	1,100	1,100	600	2,483	2,865	955
South	79	500	500	200	1,027	1,185	395
Total	4,083	24,400	24,400	12,300	53,079	61,245	20,415

Sources: Division of Agricultural Economics (1968); Division of Agricultural Chemistry (personal communication).

On the other hand, fertilization of maize even at this lower level still appears unprofitable in a majority of cases due to depressed price for maize. Only in certain areas where the maize response to fertilizers is above average, fertilization may be profitable. Therefore, under present conditions potential optimum need for maize fertilization is estimated to amount to not more than 15 per cent of the calculated total.

Sorghum

Fertilizer experiments for sorghum have started quite recently. Conclusive results have not yet been obtained. The available data*

* Ring Meesawat. Paper submitted to Seminar on fertilizers cited previously.

indicated that sorghum responds to the application of N but no responses were obtained to P_2O_5 when the soils contain more than 10 p.p.m. of available phosphorus and of potassium.

A long term experiment on this subject is currently being conducted (Division of Agricultural Chemistry 1967). The optimum rates for fertilization will be determined only after the completion of this project.

Sugar cane

Experiments since 1956 indicate significant responses to N at application rate of 12 kg per rai in certain types of soils where the organic matter content of the soil is below 1.1 per cent.* Correlation between soil test values and field responses indicates that above 15 p.p.m. the crop does not response to phosphorus (Division of Agricultural Chemistry 1967). Also sugar cane response to added K is found not to be statistically significant below 90 kg per rai. However, application of that much potassium is not economical.

It was also found that application of NPK fertilizers did not affect the commercial sugar cane value.

These results indicate a limited potential need of fertilizers for sugar cane. The Division of Agricultural Chemistry is generally recommending the use of NPK fertilizers at 12-8-15 grade and 100 kg per rai. However, in the light of the above results it is difficult to adopt this recommendation as the basis for calculation. Therefore, application of only N fertilizers (12 kg/rai) for 50 per cent of the sugar planted area is assumed to constitute the total potential need for sugar cane fertilization.

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* Preecha Prachuabmoh. Paper submitted to Seminar on fertilizers cited previously.

TABLE 19
ANNUAL OPTIMUM FERTILIZER NEED FOR SUGAR CANE
(in tonnes)

Region	Area planted[1/] (1000 rai)	N value	Ammonium sulphate
Central plain	552	6,624	31,540
North-east	225	2,700	13,000
North	50	600	2,850
South	20	240	1,150
Total	847	10,164	48,540

[1/] Average of 1967 - 66.

Sources: Division of Agricultural Economics (1968); Division of Agricultural Chemistry (personal communication).

Cassava

Research on the fertilization of cassava started in 1954. The results obtained up to 1964 indicate that 8-8-4 kg per rai produces the maximum yield of 4,845 kg per rai and also provides highest economic return.*

Experiments conducted later in Sattahip showed stronger responses to higher levels, and also produced better profits. The combination of NPK fertilizers which produced best results was 14-8-7 kg per rai (FAO 1969). In this study this latter result is taken as the base for the calculations.

TABLE 20
ANNUAL OPTIMUM FERTILIZER NEED FOR CASSAVA
(in tonnes)

Region	Area planted[1/] (1000 rai)	Nutrients			Corresponding fertilizers		
		N	P_2O_5	K_2O	Ammonium sulphate	Double super-phosphate	Potash
Central plain	607	8,498	4,856	4,249	40,400	12,100	9,440
North-east	59	826	472	413	3,900	1,180	920
North	12	168	96	84	800	240	180
South	70	980	560	490	4,700	1,400	1,080
Total	748	10,472	5,984	5,236	49,800	14,920	11,620

[1/] Average of 1962-66.

Sources: Division of Agricultural Economics (1968); FAO (1968).

* Vicha Nopamorabodi. Paper submitted to Seminar on fertilizers cited previously.

Cotton

Soil fertility research on cotton has been conducted since 1960. Up to the present no firm conclusion could be reached. Application of fertilizers intensified the insect (weevil) attacks on the cotton. There are some indications that addition of N nutrients would be profitable (FAO 1969). Division of Agricultural Chemistry is recommending the use of NPK fertilizer 5-10-5 kg per rai (personal communication). However, fertilization may produce better results only if it is used together with extreme application of insecticides. Use of insecticides up to 300 baht/rai was ineffective. Higher amounts of insecticides (at the present price levels) made the additional yield due to fertilizers and insecticides uneconomical. Thus it appears that there is no point of using fertilizers for cotton production unless the problem of insects is solved.

Kenaf

The fertilizer experimentation programme for kenaf started in 1955. No response of kenaf can be obtained if soils contain more than 1.9 per cent of organic matter or available phosphorus exceeding 5 p.p.m. In the sandy soils of the north-east application of 4 kg per rai of N and 4 kg per rai of P_2O_5 have produced notable results for increasing the fibre yield.

Kenaf is mainly cultivated in the north-east region where the soils are quite low in fertility. But the plant is tolerant of poor soil conditions and produces adequate yields on a wide range of soils. Even the poorer sandy soils in the north-east region provide a reasonable crop where no other crop yields satisfactory returns without irrigation or fertilizers (Sholton 1968). Therefore, expansion of kenaf in the north-east has not occurred at the expense of other upland crops or paddy. It is mainly planted on marginal land. When the previous years prices were good more marginal land was planted with kenaf on the succeeding year, and when the fibre prices were low the next year less land was planted to kenaf. Consequently, to increase the fibre yield of kenaf (per rai) will not result in any economic gains since the available land in the north-east for kenaf growing which are left idle otherwise can produce without using fertilizers more fibre than the potential effective demand for kenaf fibre (internal or external).

Moreover, kenaf fibre prices may vary more than 100 per cent from one season to another while the income which the producers obtain from fibre is quite low even during the periods when the fibre prices are high. Thus under these market conditions increasing the cash spendings of the farmers by using fertilizers in order to increase the yield, where additional land is usually available, should not be considered.

Peanut

Fertilization experiments on peanut have started only in 1966. The results of the experiments thus far obtained may be summarized as follows: highest yield was obtained from the application of N nutrients at the rate of 3 kg per rai. Experiments showed that peanut did not require much application of N for it could utilize this element through the N-fixation process. Peanut yield has not responded to P_2O_5 nutrients where the available P of the soil is higher than 2 p.p.m. The crop needed small amounts of K_2O when it was grown on soils where potassium is deficient. Besides NPK the crop showed some response to calcium.*

For loamy or sandy soils, use of approximately 8-9 kg per rai each of P_2O_5 and K_2O seems to be optimum. Therefore in this study application of 3 kg per rai of N to all peanut growing areas and application of 8 kg per rai each P_2O_5 and K_2O only to 50 per cent of the peanut plantings in the north-east region is assumed to give the potential use of fertilizers on peanut production.

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* Sathien Pimsan. Paper submitted to Seminar on fertilizers cited previously.

TABLE 21
ANNUAL OPTIMUM FERTILIZER NEED FOR PEANUT
(in tonnes)

Region	Area planted[1/] (1000 rai)	Nutrients			Corresponding fertilizers		
		N	P_2O_5	K_2O	Ammonium sulphate	Double super-phosphate	Potash
Central plain	292	876	-	-	1,390	-	-
North-east	170	510	680	680	810	1,700	1,700
North	491	1,473	-	-	7,000	-	-
South	29	87	-	-	140	-	-
Total	982	2,946	680	680	9,340	1,700	1,700

1/ Peanut planted area in 1966. Peanut production especially in the north is showing a steady increase.

Sources: Division of Agricultural Economics (1968); Sathien Pimsan, cited previously.

Castor bean

Fertilizer research on castor beans was started in 1968. The preliminary experiments indicate that for the Thai variety the best results are obtained with NPK at 8-10-8 kg per rai. The response of introduced varieties of castor bean (such as Baken 296 or Cimoran) was best at 10-10-10 kg per rai (Division of Agricultural Chemistry 1966, 1967).

The foreign varieties have smaller seeds resulting in increased labour need at harvest. However, foreign varieties have a shorter growing period and therefore could be grown as cash crops in dry season. As a result new varieties are progressively accepted by Thai farmers since they were introduced by the Ministry of Agriculture. Accordingly, to calculate the optimum potential fertilizer use, application of NPK (10 kg/rai each) is accepted.

TABLE 22
ANNUAL OPTIMUM FERTILIZER NEED FOR CASTOR BEANS
(in tonnes)

Region	Area planted[1/] (1000 rai)	Nutrients			Corresponding fertilizers		
		N	P_2O_5	K_2O	Ammonium sulphate	Double super-phosphate	Potash
Central plain	168	1,680	1,680	1,680	8,000	4,200	3,700
North-east	88	880	880	880	410	220	190
North	15	150	150	150	710	370	330
South	-	-	-	-	-	-	-
Total	271	2,710	2,710	2,710	9,120	4,790	4,220

1/ Average of 1962-66.

Sources: Division of Agricultural Economics (1968); Division of Agricultural Chemistry (1966, 1967).

Soya bean

No experiments at a reasonable scale have as yet been carried out for the fertilization of soya beans. The Division of Agricultural Chemistry recommends the general use of NPK fertilizers at 3-8-8 kg per rai (personal communication). This recommendation is similar to the recommendation for peanuts by the same Division. In the AID report (Bond, et al. 1966), application of NPK fertilizers at the rate of 1-6-6 kg per rai was accepted as optimum. This later recommendation seems more plausible since soya bean obtains its N through N-fixation and therefore it is adopted in this study.

TABLE 23
ANNUAL FERTILIZATION NEED FOR SOYA BEAN
(in tonnes)

Region	Area planted[1/] (1000 rai)	Nutrients			Corresponding fertilizers		
		N	P_2O_5	K_2O	Ammonium sulphate	Double super-phosphate	Potash
Central plain	130	130	780	780	610	1,950	1,730
North-east	4	4	24	24	19	60	53
North	62	62	372	372	290	930	820
South	-	-	-	-	-	-	-
Total	196	196	1,176	1,176	919	2,940	2,603

1/ Average 1962-66.

Sources: Division of Agricultural Economics (1968); Bond, et al. (1966).

(c) Tobacco

The Tobacco Monopoly in Thailand ensures the fertilization of almost the entire crop by providing credit to the growers. Various formulas are being used, but the most widespread one is 4-24-12 kg per rai which is recommended by the Monopoly. It is a high grade compound fertilizer. Division of Agricultural Chemistry recommends 16-16-20 kg per rai but the actual use of this formula seems to be rather limited.

TABLE 24
ANNUAL FERTILIZATION NEED FOR TOBACCO

Region	Area planted 1/ (1000 rai)	N	P_2O_5	K_2O
Central plain	77	1,232	1,232	1,540
North-east	106	1,696	1,696	2,120
North	344	5,504	5,504	6,880
South	11	176	176	200
Total	538	8,608	8,608	10,760

1/ 1966.

Sources: Ministry of Agriculture (1968); Thai Tobacco Monopoly (personal communication).

(d) Rubber*

Fertilizers are used primarily in areas of immature replanted rubber, most of which receive assistance in the form of a grant from the Replanting Aid Fund office. This grant totalling 2,000 baht per rai and paid part in cash and part in kind includes the issue of 264.8 kg of compound fertilizer per rai.

Replanting under this scheme to date amounted to some 250,000 rai of immature trees. Replanting is proceeding and expected to continue at a rate of some 70,000 rai per year. This can be taken as the effective rubber area on which fertilizers are regularly used.

Fertilizers applied on rubber are mixtures recommended by the Rubber Research Institute of Malaya for use in Malaysia. Those most generally used are compounds produced specially for the manuring of rubber, except that an application of Christmas Island rock phosphate is made in each planting hole at the time of, or shortly before, planting.

The following compound fertilizers are currently used for replanted rubber.

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* The data used here are mainly obtained from Mr. J.M.F. Greenwood from the Rubber Research Centre in Hat Yai.

(1) Christmas Island rock phosphate (CIRP) 36 per cent P_2O_5.

	N%	P_2O_5%	K_2O%	MgO%
(2) For sandy soils				
CCM 15 formula	10	16	9	2.5
CCM 25 formula	14	13	9	2.5
(3) For inland loams and clays				
CCM 11 formula	11	18	4	3
CCM 22 formula	18	11	5	25

CIRP applied 9.6 kg per rai for 70,000 rai annually amounts to 672 tonnes. For the compound fertilizers different formulas are applied but total of 264.8 kg per rai for 70,000 rai annual replantings amounts to 18,536 tonnes.

General use of fertilizers is currently limited to immature rubber. Applications to young mature rubber, however, is also recommended and it is to be hoped this practice will increase although its adoption will inevitably be slow. Manuring of young mature rubber will depend upon the results of extension efforts only now commencing. Ninety-eight per cent of the rubber in Thailand is grown on small holdings and technical innovation among such growers is always a slow process. This is particularly true of long term tree crop such as rubber where economic benefits from fertilizer applications are not immediately noticeable nor even clearly discernible unless careful records are kept.

Using current Thai fertilizer costs and price for rubber, the extra yield obtained by fertilizing the younger mature rubber trees increases the profits of the farmers at least 4,707 baht per rai over the 17 years of maturity period or 277 baht per rai per annum.

The recommendation is that a 15-17-13-4 (MgO) compound should be applied annually at the rate of 1 kg per tree.

At 64 trees per rai, this means application of 64 kg of fertilizer per rai per year. The cheapest nutrient sources are preferred, no advantages having been shown for soluble phosphate nor for granulated fertilizers.

Tappable area in 1966 amounted to 3,330,000 rai. Complete fertilization of this area needs 21,312 tonnes of fertilizers. Annual NPK nutrient values of the fertilizer will be 3,196 tonnes of N, 3,623 tonnes of P_2O_5, and 2,705 tonnes of K_2O and 852 tonnes of MgO., or 7,100 tonnes of urea, 9,000 tonnes of double superphosphate, and 6,000 tonnes of potash.

(e) Vegetables

Fertilizer experiments on vegetable crops have been conducted in two directions: on fresh vegetable production and on vegetable seed production. Results can be summarized as follows: all vegetable crops, especially those produced as fresh vegetables, show remarkable response to N applications. NPK is important also for vegetable seed production. The amounts and rates of fertilizers appropriate for particular vegetables are still under investigation. But Division of Agricultural Chemistry recommends the use of compound fertilizer 13-13-13 100 kg per rai, and top dressing of ammonium sulphate 50 kg per rai.

Fertilizing vegetables has already become quite popular in Thailand due to high prices for vegetables. Most users prefer the application of 13-13-13.

TABLE 25
VEGETABLE PLANTED AREA IN 1966
(in thousands of rai)

Kind	Central	North-east	North	South	Total
Chilli peppers	185	115	113	40	453
Cauliflower	11	10	24	1	46
Kale	29	13	10	3	56
Cabbage	21	19	38	3	80
Chinese cabbage	91	63	158	17	329
Onion	1	3	4	-	8
Garlic	13	25	153	-	191
String bean	55	39	30	24	148
Tomato	15	12	10	2	39
Egg plant	74	42	30	26	172
Cucumber	46	14	12	12	84
Shallot	32	34	62	1	129
Chinese radish	35	8	8	3	55
Sugar pea	3	3	10	1	17
Total	611	400	662	133	1,806

Source: Division of Agricultural Economics (1968).

TABLE 26
ANNUAL FERTILIZER NEED FOR VEGETABLES
(in tonnes)

Region	Planted area (1000 rai)	Nutrients			Corresponding fertilizers[1]	
		N	P_2O_5	K_2O	13-13-13	Ammonium sulphate
Central plain	611	14,300	7,900	7,900	61,100	30,550
North-east	400	9,400	5,200	5,200	40,000	20,000
North	602	14,100	7,800	7,800	60,200	80,100
South	133	3,100	1,700	1,700	13,300	6,650
Total	1,806	40,900	22,600	22,600	180,600	87,300

1/ Assuming that fertilization recommended by the Division of Agricultural Chemistry represents the average general need for all the vegetables.

Sources: Division of Agricultural Economics (1968); Division of Agricultural Chemistry (personal communication).

(f) Fruits

Banana

Banana is one of the more important economic fruit crops in Thailand, particularly golden aromatic banana (kluai hom-thong), is very popular in the local market. Fertilization experiments were started in 1964 at Ratchaburi and in 1965 at Khlong Luang district. The highest yield was obtainable from grade 15-5-5 fertilizer applied at the rate of 1 kg per tree* (Division of Agricultural Chemistry 1967). Assuming 400 trees application per rai amounts to 60 kg of N, 20 kg of P_2O_5, and 20 kg of K_2O, or 280 kg of ammonium sulphate, 50 kg of double superphosphate, and 44 kg of potash. Total cost of these fertilizers amounts to 432 baht at current local prices.

The maximum banana yield over control is 4.06 kg per tree or 1,624 kg per rai. Current wholesale price of banana in Bangkok market (including transportation cost and wholesalers' profit) is 42 baht/picul or 0.70 baht/kg. According to these figures the increased yield due to fertilization provides an additional income of 1,137 baht minus wholesale

* Aree Keo-hgarm. Paper submitted to Seminar on fertilizers cited previously.

profits, transportation costs and labour cost for fertilization. After these deductions and allowances for less succesful results, it seems that there still remains on adequate profit margin to provide incentive for fertilizer application.

TABLE 27
ANNUAL FERTILIZER NEED FOR BANANA
(in tonnes)

Region	Area planted[1/] (1000 rai)	Nutrients			Corresponding fertilizers		
		N	P_2O_5	K_2O	Ammonium sulphate	Double super-phosphate	Potash
Central plain	598	35,000	11,960	11,960	167,000	29,900	26,300
North-east	216	12,960	4,320	4,320	60,480	10,800	9,500
North	126	7,260	2,420	2,420	33,880	6,050	5,324
South	121	11,520	3,840	3,840	53,760	9,600	8,450
Total	1,127	66,740	22,540	22,540	315,120	56,350	49,574

[1/] Average 1962-66.

Sources: Division of Agricultural Economics (1968); Division of Agricultural Chemistry (1967).

Coconut

A fertilizer trial on young coconut plants was started in 1964 at Sawi Agricultural Experiment Station. It is yet too early to know the yield increases due to fertilization, however, Division of Agricultural Chemistry recommends the use of 12-12-19 grade at the rate of 1.5-3 kg per tree. Assuming that there are 20 coconut trees per rai the recommended rate amounts to 30-60 kg per rai.*

Assuming 45 kg per rai, the use of nutrients amounts to 5.4-5.4-8.5 kg per rai. Coconut plantations amount to approximately 1,400,000 rai (Bond *et al.* 1966) which require annual use 63,000 tonnes of compound fertilizer (12-12-19) or 7,560 tonnes of N, 7,560 tonnes of P_2O_5 and 11,970 tonnes of K_2O.

* Variation in application is due to different soil conditions.

Other fruits

Fertilizer research on other fruits has not yet yielded conclusive results. However, preliminary experiments indicated good responses to NPK fertilizers. In the AID report (Bond et al. 1966) some different formulations were used for different fruits. These formulas, however, were not the results of local experiments but probably formulas obtained from experiments carried out in other countries for similar crops. Application of fertilizers to fruit crops is spreading in Thailand due to high fruit prices. Fertilizer rates which are currently applied by the Thai growers may not represent the optimum rates but their use has already been proven profitable. In the absence of better data these formulations are also used in this study.

TABLE 28
ANNUAL OPTIMUM FERTILIZER NEED FOR OTHER FRUITS

	Used formula	Planted area (1000 rai)	Application per rai (kg)	Nutrients N (kg)	P_2O_5 (kg)	K_2O (kg)
Citrus	10-8-10	9,545	20	11,990	8,872	11,190
Water-melon	13-13-13	157	50	920	920	920
Mango	10-5-5-5	219	30	657	329	329

Source: Bond et al. 1966.

(g) Total optimum fertilizer need of Thailand

In Tables 29 and 30 optimum need for NPK nutrients and optimum need for identifiable fertilizers are shown. For identifying the kind of fertilizer to be applied to a certain crop the fertilizers used in the experiments are taken. In the cases where the kind of fertilizer was not reported, the calculated nutrient values are not included in Table 30. Therefore, Table 30 does not suggest the use of any kind of single or compound fertilizer. The actual users may apply different kind of fertilizers with identical nutrient value due to availability of fertilizers, commercial practices, and to other factors.

TABLE 29

OPTIMUM NEED FOR NPK NUTRIENT IN THAILAND

	N					P_2O_5					K_2O				
	Central plain	North-east	North	South	Total	Central plain	North-east	North	South	Total	Central plain	North-east	North	South	Total
Rice	79.0	64.0	10.8	13.2	167.0	59.2	48.0	6.1	9.9	123.2	-	28.8	-	-	28.8
Maize	3.0	0.3	0.1	0.0	3.4	3.0	0.3	0.1	0.0	3.4	1.5	0.1	0.0	0.0	12.3
Sugar cane	6.6	2.7	0.6	0.2	10.1	-	-	-	-	-	-	-	-	-	-
Cassava	8.5	0.8	0.1	1.0	10.4	4.8	0.5	0.1	0.6	5.9	4.2	0.4	0.1	0.5	5.2
Peanut	0.8	0.5	1.5	0.1	2.9	-	0.7	-	-	0.7	-	0.7	-	-	0.7
Caster bean	1.7	0.9	0.1	-	2.7	1.7	0.9	0.1	-	2.7	1.7	0.9	0.1	-	2.7
Soya bean	0.1	-	0.1	-	0.2	0.8	-	0.4	-	1.2	0.8	-	0.4	-	1.2
Tobacco	1.2	1.7	5.5	0.2	8.6	1.2	1.7	5.5	0.2	8.6	1.5	2.1	6.9	0.2	10.7
Rubber	-	-	-	3.2	3.2	-	-	-	3.6	3.6	-	-	-	2.7	2.7
Banana	35.0	12.9	7.3	11.5	66.7	12.0	4.3	2.4	3.8	22.5	12.0	4.3	2.4	3.8	22.5
Coconut	...	...	...	...	7.5	...	...	...	...	7.5	...	...	...	...	12.0
Water-melon	...	...	...	...	0.9	...	...	...	...	0.9	...	...	...	...	0.9
Citrus	...	...	...	...	11.2	...	...	...	...	8.8	...	...	...	...	11.2
Mango	...	...	...	...	0.6	...	...	...	...	0.6	...	...	...	...	0.6
Vegetables	14.3	9.4	14.1	3.1	40.9	7.9	5.2	7.8	1.7	22.6	7.9	5.2	7.8	1.7	22.6
Total	150.2	93.2	40.2	34.7	336.3	90.6	61.6	22.5	19.8	212.2	29.6	42.5	17.7	8.9	123.4

TABLE 30
OPTIMUM NEED FOR IDENTIFIABLE FERTILIZERS

Fertilizer	Central	North-east	North	South	Total
Single fertilizers					
Ammonium sulphate	344,350	146,619	78,120	76,250	645,339
Urea	6,585	850	372	1,219	9,126
Double superphosphate	42,967	14,930	8,020	20,180	87,097
Potash	43,702	76,493	6,794	15,590	142,579
Compound fertilizers					
Ammophos (10-20-0)	296,250	240,000	30,500	49,500	616,250
4-24-12	7,700	10,600	34,400	1,100	53,800
13-13-13 (vegetables)	61,100	40,000	60,200	13,200	180,600
13-13-13 (fruits)	...	...	...	...	7,850
10-8-10	...	...	...	...	110,900
10-5-5-5 (Mg)	...	...	...	...	6,570
Formulas for rubber	-	-	-	18,536	18,536