

X19334708

IAEA/UNDP-THA/85/004-22
Technical Report 22

IMPROVING FOOD AND AGRICULTURAL PRODUCTION

THAILAND

**IMPROVING FOOD AND AGRICULTURAL PRODUCTION
WITH NUCLEAR AND RELATED TECHNOLOGY**



UNITED NATIONS DEVELOPMENT PROGRAMME



INTERNATIONAL ATOMIC ENERGY AGENCY

VIENNA 1991

IAEA/UNDP-INS/85/004-22
Technical Report 22

IMPROVING FOOD AND AGRICULTURAL PRODUCTION

THAILAND

**IMPROVING FOOD AND AGRICULTURAL PRODUCTION
WITH NUCLEAR AND RELATED TECHNOLOGY**

Report prepared for
the Government of the Republic of Thailand

by

the International Atomic Energy Agency
acting as Executing Agency for
the United Nations Development Programme

UNITED NATIONS DEVELOPMENT PROGRAMME
INTERNATIONAL ATOMIC ENERGY AGENCY

VIENNA 1991

TABLE OF CONTENTS

1. Terms of reference	2
2. Time schedule	3
3. Premises	6
4. Locations monitored and activities	6
5. Laboratory facilities	8
6. Personnel	9
7. Evaluation of the current research activities	9
8. Proposal of an integrated research on rock phosphate	10
8.1. Laboratory level	11
8.2. Combination rock phosphate - soil	12
8.2.1. Laboratory level	12
8.2.2. Semi-field	12
8.3. Combination rock phosphate - soil - crop	13
8.3.1. Laboratory level	13
8.3.2. Field trials	13
9. Assignment of labelled P	13
10. Means of achievement of the program	14
11. Recommendations for the Counterpart Institution	15
12. Recommendations for the Government	16
13. Recommendations for the Agency	18
14. References	20
15. Acknowledgment	20

1. TERMS OF REFERENCE

JOB DESCRIPTION No : THA/85/004-11.04 (THA/5/031/045)

PROJECT TITLE : Improving Food and Agricultural Production
with Nuclear and Related Technology.

SPECIAL TASK : Optimal use of naturally occurring rock phosphate deposits or phosphate fertiliser using P-32.

2. TIME SCHEDULE

- Sunday, April 15 : 15.25 h departure from Brussels to Bangkok with SN 287
- Monday, April 16 : 10.10 h arrival at Bangkok. pick up by UNDP project car and transfer to Rama Garden hotel. Installation.
13.30 h transfer to the Department of Agriculture, Bangkok. Meeting with Mrs Patoom Snitwongse, Mrs Pornpimol Chaiwanakupt and Mrs Jittiwan to set the time schedule and discussion on project matters.
- Tuesday, April 17 : 8.30 h Discussion with Mr Prasat Kesawapitak, Mr Ring Meesawat, Mr Werapol Chatchawalwong and Mr Noi Tiazanan from Soil Science Division of the Ministry of Agriculture on the experimental results of a field trial with rock phosphate and triple super phosphate.
13.30 h Discussion with Mrs Patoom and Mrs Pornpimol on the assessment of analytical results.
- Wednesday, April 18 : 7.30 h leaving Bangkok with Mrs Pornpimol to Khon Kaen with TG 210.
8.30 h arrival at Khon Kaen, welcome by Dr Wittaya Masena. Transfer to Department of Soil Science of Khon Kaen University. Meeting with Dr Banyong Toomsan, Dr Amnuaysilpa Suksri and Dr Patcharee Saenjan on current activities. Visit to field trials on mungbean.
14.00 h Visit to experimental field station on saline soils. Discussion with Dr Bubpha Topark Ngarm.
17.30 Installation at Kosa hotel.
19.00 h Dinner with Dr Wittaya, Dr Amnuaysilpa and Mrs Pornpimol.
- Thursday, April 19 : 8.30 h Meeting with Dr Paitoom Ponsana, director of Agricultural Development Research Centre on problem soils in northeast Thailand. Visit of laboratories.
14.00 h Meeting with Dr Wittaya Masena. Visit of laboratories and discussion with staff members on analyti-

cal methodologies.

17.00 h Transfer to airport by project car.

20.30 h leaving Khon Kaen to Bangkok with TG 215
(delayed)

21.45 h arrival at Bangkok and transfer to Rama Garden hotel by project car.

Friday, April 20 : Discussion with Mrs Chantana Siripaibool on the results of a pot experiment on rock phosphate with P-32.

Saturday, April 21 : free (at the hotel) ; elaborating of an integrated study on rock phosphate.

Sunday, April 22 : free (rest)

Monday, April 23 : 8.30 h Discussion with Mrs Jittiwan on the results of a field trial on rock phosphate with P-32.

Tuesday, April 24 : 8.30 h Visit with Mrs Jittiwan to the field trial on rock phosphate with P-32 at Praputhabath Field and Crop Station, Saraburi (150 km north of Bangkok).

Wednesday, April 25 : 8.30 h Detailing with Mrs Chantana and Mrs Jittiwan on an integrated study on rock phosphate.
13.30 h Performing an analytical P determination in the laboratory with Mrs Chantana. Discussion.

Thursday, April 26 : 8.30 h Discussion with Mrs Chantana and Mrs Jittiwan on the integrated study on rock phosphate.
13.30 h Integrating of literature references into the research proposal on rock phosphate.

Friday, April 27 : 8.30 h Meeting with Dr Amnat Suwanarit from Kasetsart University on the possibilities of radioisotopes in agricultural research.

Saturday, April 28 : Free (sightseeing)

Sunday, April 29 : Free (rest)

Monday, April 30 : 7.30 h leaving Bangkok with Mrs Pornpimol to Chiangmai with TG 100.
8.30 h arrival at Chiangmai and transfer with project car to Phucome hotel. Installation.
9.30 h Meeting with Dr Wiroy Wajananawat from Field Crop Research Institute on the use of rock phosphate in northern Thai soils. Discussion of results.
12.00 h Visit to a rock phosphate deposit at Lampung.
14.00 h Visit to the laboratories of the Department of Agriculture and discussion on analytical methodologies.

Tuesday, May 1 : Before noon : reporting
13.00 h Meeting with Dr Suchart Jiraporncharoen and staff members of Department of Soil Science of Chiangmai University on theoretical and experimental aspects of using radioisotopes in agricultural research.
18.35 h leaving Chiangmai for Bangkok with TG 113.
19.45 h arrival at Bangkok and transfer to Rama Garden hotel with UNDP project car.

Wednesday, May 2 : Before noon : preparing notes and final discussion with staff members.
13.00 h Meeting with Dr Chairerk Suwannarat from Soil Science Department of Kasetsart University on current research activities.

Thursday, May 3 : 8.30 h Briefing to Mrs Patoom and Mrs Pornpimol.
14.00 h Final discussion with Mrs Chantana and Mrs Jittiwan on rock phosphate research including P-32.

Friday, May 4 : 8.30 h Meeting with Dr Sumalee Suthipradit (on visit) from Prince of Songkhla University, Songkhla, Thailand
12.00 h Farewell lunch with all staff members of Division of Agriculture at Bangkok.
14.00 h Reporting
21.20 h Departure from Bangkok to Brussels with SN 288.

Saturday, May 5 : 6.30 h Arrival in Brussels airport.

3. PREMISES

The low native phosphorus content and the absence of any fertilization history in tropical soils in addition to stringent economical reasons have put the study of direct application of rock phosphate (R.P.) on top of the applied agricultural research in these countries. Due to the presence of many deposits of R.P. in northern and north-eastern regions of Thailand, a field trial was initiated within the framework of the UNDP project at the Field Crop Research Institute at Chiangmai in 1986. The aim was to assess their direct plant availability and residual effect.

In opposition to this, a steady increase of the P_2O_5 fertilizer consumption in Thailand has been recorded, amounting to 200,000 tons in 1988 (1). It is emphasized, that most (if not all) is applied as a combined fertilizer. Anyhow a matter of contradiction becomes obvious.

Apart from foregoing isolated objective, very similar but more extended studies have been carried out for longer times in several developing countries.

From the hundreds of references which have been generated during the last twenty years with special emphasis towards direct application of R.P. to soils, diverse conclusions and controversies have become apparent. This should be attributed to both inappropriate methodologies but mainly to the fact that the overall study is conditioned by the three-dimensional matrix rock phosphate - soil - crop. A thorough knowledge of each individual vector is a *conditio sine qua non* in order to fully understand their interrelationship.

4. LOCATIONS MONITORED AND ACTIVITIES

During this mission three locations, involved with research activities on R.P., including labelled P-32 or not, were monitored. A report by location and affiliation as well as by type of activity and matter of discussion on the person(s) contacted can be found in tables 1 to 3.

Table 1. LOCATION : BANGKOK

Contacted person(s)	Affiliation	Activity
-Patoom -Pornpimol	Division Agricultural Chemistry	-Discussion on internal laboratory organisation -Assessment of analytical results and P-32 analyses -Suggestions on analytical procedures
-Chantana Siripaibool	"	-Discussion on methodology of pot ex- periments including P-32 -Evaluation of analytical data and statistical analysis of P-32 results
-Jittiwan	"	-Elaboration of a proper P analysis -Visit field trial at Praputhabath, Saraburi -Discussion on field trial methodology -Evaluation of analytical data and statistical analysis with P-32
-Prasat Kesawapitak -Ring Meesawat -Werapol Chatchawal- wong -Noi Tiazanan -Amnat Suwanarit	Soil Science Division	-Suggestions on analytical procedures -Evaluation of analytical data of field trial on R.P. and triple super phos- phate fertilizers
-Chairerk Suwannarat	Kasetsart Univ	Detailing on the possibilities of radioisotopes in agricultural research
	"	Discussion on current research activities

Table 2. LOCATION : KHON KAEN

Contacted person(s)	Affiliation	Activity
-Wittaya Masena and staff members	University	Visit to laboratories and discussion on analytical methodologies including radioisotopes
-Paitoom Ponsana	Agricultural Development Research Centre	Discussion on problem soils (sandy and lateritic) in Northeast Thailand
-Bubpha Topark Ngarm	University	Discussion on the use of R.P. in saline soils
-Amnuaysilpa Suksri	"	Visit of field plots on mungbean

Table 3. LOCATION : CHIANG MAI

Contacted person(s)	Affiliation	Activity
-Wiroy Wajananawat	Field Crop Research Centre, Dept Agriculture University	-Discussion on the use of phosphate in field trials : yield production and residual effect -Visit to R.P. deposits at Lampung
-Suchart Jiraporncha- roen and staff members		-Discussion on the use of radio- isotopes in agricultural research : methodology, limitations and expected results

5. LABORATORY FACILITIES

At the three sites monitored spacious laboratories are available for both analytical and radiochemical preparations. Concerning the latter, radioactive equipment is installed very near, in a separate room. At Bangkok and Khon Kaen sites proper functioning liquid scintillation counters in addition to gamma scintillation counters allow to record all radioisotopes which are of interest in agro-chemical research. As recommended perfect internal organisation is established in both laboratories with regard to waste disposal, safety protection and minor laboratory items.

At the three locations basic laboratory equipment (balance, pH meter, spectrophotometer, oven, furnace and centrifuge) is in good working conditions in order to perform smoothly all P determinations in plants and soils. In addition an up-to-date atomic absorption spectrophotometer is available; it includes the peripherals allowing to monitor Na, K, Ca, Mg and all trace elements.

The mobility within the project is perfectly assured by a project car.

Thanks to an adequate technical infrastructure of each lab, no excuse can be invoked if inaccurate and (or) unprecise analytical and radiochemical data are delivered.

6. PERSONNEL

The three sites are staffed with academic trained researchers, most eager to be initiated in a fully elaborated research program. This overall objective on rock phosphate can be shared by the three research centres or universities involved in the project. Within each of them, tasks can be assigned to the participants according to their motivation and background. Routine analyses of soils and plants can be assigned to laboratory assistants.

A skilled project coordinator who can strengthen research activities and provide, at least initially, technical assistance with assessment of analytical phosphate determinations and manipulations with radio-isotopes is however imperative to succeed.

The academic personnel's knowledge of scientific English in relation to their own business is on average levelled at the stage of communicating and consulting literature. Rationalisation of the congested administrative units could enhance performance.

7. EVALUATION OF THE CURRENT RESEARCH ACTIVITIES

Considering the activities of the three locations involved in the project, little evidence is displayed towards the elaboration of a coherent program, in the use of R.P. as direct fertiliser. It is our strong feeling that the initiatives undertaken are mainly confined to a particular location and that within a specific research institution, isolated and individual proceedings of the researchers evolve. If such a shaky take-off is moreover superimposed by a limited experience of the participants in combination with an imperfect insight into the phenomena and (or) a casual guidance no significant outcome is to be expected at the very beginning.

What are actually the most occurring imperfections ?

Referring to the inexperience to conduct a pot or a field experiment properly in combination with a limited theoretical knowledge, the occurrence of the following shortcomings is easily understood :

- improper analytical P determination;
- too low P-32 doses added to a pot;
- statistical errors on P-32 counting;
- simultaneous variation of two independent variables in one trial;
- incomplete characterisation of the R.P. fertilisers;
- heterogeneous administration of the P fertiliser to the soil;

Starting from the premise that any objective scientific conclusion should be supported by very reliable analytical data, corrections on the methodology and assessment of the data are urgently required.

With emphasis on the field experiments on R.P. conducted at the Field Crop Research Centre at Chiangmai by Dr Wiroy Wajanawat relevant results were displayed. In order to strengthen this study additional laboratory characterisations on the material under elaboration should be very beneficial in order to fully understand the phenomena observed and evaluate the analytical data recorded.

Finally we have to emphasize that the experiments including labelled phosphate are limited to the Division of Agriculture at Bangkok, where they are conducted by Mrs Chantana and Mrs Jittivan.

8. PROPOSAL OF AN INTEGRATED RESEARCH ON ROCK PHOSPHATE

Taking account of the remarks displayed in the previous section, a research proposal on R.P. at different levels will be elaborated. The framework of this proposal was detailed with Mrs Patoom and Mrs Pornpimol and the technical aspects with the

researchers of the Division of Agriculture at Bangkok.

Basically we start from the fact that in order to acquire a maximum insight in the phenomena involved in a complex medium such as tropical soil, additional experiments in very restricted conditions (laboratory or semi-field level) should be highly recommended. This integrated study with the final aim of direct application of rock phosphate to Thai soils is situated at three distinct levels. Although to each of them a specific finality can be assigned, they will provide a useful support to the final objective.

8.1. Laboratory level

Initially a general survey on the economical value of all potential R.P. deposits in Thailand looks very essential (if this is not available, so far).

In order to fully characterise the materials of interest the following data are of primary interest:

- total content of P, Ca, K, Na, Mg, Fe, F, Al and CO₃.
- Laboratory reactivity values should complete previous total contents. They can either be obtained using a single extraction (Leon et al., 1986) or by monitoring the rate of solubilisation as function of time using a particular chemical extractant. Other common reagents of interest on this subject are formic and citric acid.
- A basic feature is the particle size of the material. It is a well-known chemical fact that this will highly influence the rate of solubilisation so that this parameter is a basic characteristic if R.P. is used for direct application.
- From a chemical point of view it is known that the degree of cristallinity of the material will also affect the solubility of the primary material. X-ray analysis seems to be indicated in this regard.
- A thorough soil characterisation from both physical and chemical points of view is an essential primary feature.

8.2. Combination rock phosphate - soil

8.2.1. Laboratory level

From the literature it is obvious that quite simple solubilisation experiments, performed at laboratory scale, will contain valuable information with regard to the final application in the field. On this subject we refer to Mackay et al. (1986): using 0.5 M NaOH as a chemical extractant they were able to recover the rock phosphate solubilised during incubation of the fertilizer in the presence of a soil in laboratory conditions. The limitations of this extractant and further investigations have recently been discussed by Bolan and Hedley (1989). On this point we assume that exchangeability using P-32 will provide additional information in this matter.

Anyhow this methodology, which is limited to upland soils, seems to be a very useful tool for monitoring the behaviour of R.P. in soils.

For the solubilisation of this material in flooded soils, we refer to Chien (1977).

8.2.2. Semi-field level

The climatic conditions being optimized in laboratory experiments, the interaction between soils and R.P. should be extended to natural conditions, where drought and flood alternate. To that purpose we suggest to mix larger amounts of soil (15 to 20 kg) homogeneously with appropriate rates of R.P. in cylinders of 20 cm diameter and incubate at natural climatic conditions. Periodic sampling down to a 10 or 15 cm depth by augering and monitoring of soil P characteristics using chemical extractants similar to those used in laboratory conditions will enable the evaluation of the solubilisation rate. It follows that the rate ratios at natural and optimized conditions will be recorded.

8.3. Combination rock phosphate - soil - crop

8.3.1. Laboratory level

Using pot experiments (1 up to 5 kg soil) external parameters will be optimized allowing to monitor only the variable under consideration. Basically similar procedures as in section 8.2.1. may be adopted here. Of course the specificity of the crop will be assessed in this case : monitoring of yield in combination with P crop content and P characterisation of the soil is imperative (Chien and Hammond, 1978, Anderson et al, 1985, Leon et al. 1986).

8.3.2. Field trials

With the final aim of advising farmers for direct application of R.P., field trials should be ultimately conducted in flooded and upland soils. Due to the inevitable heterogeneity in field trials, yields and analytical data should be processed according to an appropriate statistical analysis.

In the present case monitoring of the climatic conditions such as rainfall in combination with periodical assessment of P characterisations in crops and soils will enable a thorough description of the three-dimensional matrix rock phosphate - soil - crop.

The field trials which are under elaboration at the Field Crop Research Centre by Wiroy Wajananawat on upland soils could be indicative .

9. ASSIGNMENT OF LABELLED PHOSPHORUS

It is evident that the use of labelled P-32 or P-33 may positively interfere at the different levels with foregoing overall research program for assessing the agronomic value of the fertilizer. As already suggested, we assume that additional but useful information could be obtained using labelled phosphate with regard to the evaluation of the rock phosphate solubility in the presence of a soil (Bolan and Hedley , 1989). Moreover the use

of tracer techniques in optimized conditions will provide more reliable indices of fertilizer availability than the nontracer method did. Correlation with chemical extraction measurements will be obtained (Kucey and Bole, 1984).

Using the longer lasting P-33 radio-isotope versus P-32, correct evaluation of the effectiveness of synthetic labelled fertilizers was monitored (Ressler and Werner, 1989). Here however, the question will always subsist on the chemical similarity between the synthetic and commercial fertilizers. The distribution of labelled fertilizers in the roots and upper plant parts could easily be monitored using radio-autographic techniques.

10. MEANS OF ACHIEVEMENT OF THE PROGRAM

In order to elaborate the proposed study, no additional input of equipment and personnel is required. The complete apparatus of an agro-chemical laboratory is in good functioning condition and the infrastructure of the labs at the three sites visited will allow proper chemical manipulations.

These observations apply to radiochemical manipulations and radioactive counting as well.

In order to succeed with such a complex and heterogeneous challenge however, a close coordination through regular meetings or workshops between all participants is of primary importance. Moreover an external supervisor enabling the provision of a perfect technical and theoretical guidance is imperative.

11. RECOMMENDATIONS FOR THE COUNTERPART INSTITUTION

-An additional effort should be made by the local staff members in order to become perfectly acquainted with the scientific equipment (pH meter and spectrophotometer). A thorough theoretical background in combination with a perfect practical knowledge is highly recommended in order to deliver accurate and reproducible results. With regard to the current analytical methods, dilution effects, recoveries and reproducibilities should be fully elaborated in several soil and plant media.

-Additional basic education in combination with experiments on radio-agrology (half-live, desintegration law, counting efficiency and statistical analysis) is highly desirable.

-Basically the policy of a central analytical laboratory, performing very common analytical characterisations in soils (total and available P) has to be rejected unless close control is maintained : every researcher is responsible for his (her) analytical data.

-The research officers should make an effort to become familiarised with P.C. facilities for editing (word perfect, volkswriter,....) and processing and (or) displaying of data (statgraphics).

-A regular and periodic literature search is indispensable in order to be fully informed on the current state of the topics of interest.

-Due to the presence of colloidal Fe_2O_3 in most Thai soil solutions, which may affect the proper determination of P and Ca, a filtration unit with calibrated pore size filters could be very suitable (Millipore, Nucleopore type).

-Every researcher should have a ready reference book of chemical and physical data at his (her) disposal.

-In order to characterise the soils and fertilizers on particle size, a set of sieves is highly desirable in any agro-chemical laboratory.

12. RECOMMENDATIONS FOR THE GOVERNMENT

In the northern and north-eastern regions of Thailand, with an obvious discrepancy between population and gross domestic product, low agricultural production is mainly due to poor soil conditions and variability in the seasonal rainfall distribution. Concerning the former, P fertilisation is one of the major constraints. It is the duty of the agricultural authorities in Thailand to help improving agricultural production in both quantity and quality so as to raise the living standard of the farmers involved. Faced with this actual but stringent problem, local natural P deposits may be of particular value: without processing the rock phosphate to a readily soluble P fertilizer which will at least double the cost per unit weight, the objective of direct application of rock phosphate to soils has to be effectively considered.

Within some departments of the Ministry of Agriculture, which is supposed to provide close guidance and support towards the actual needs of the farmers, a study of rock phosphate is actually under elaboration. We have noticed that at the current stage this study is mainly limited to valuable but isolated trials scattered over the three locations monitored (Bangkok, Khon Kaen and Chiangmai). Although great efforts have been made by several participants, no relevant results are to be expected very soon from this study : the trials are too fragmentary and isolated in order to guarantee valuable and persistent results.

In order to improve the chances to succeed with the final aim of advising farmers on direct application of rock phosphate to soils, two primary prerequisites have been omitted so far: a fully elaborated and integrated program performing at different levels (laboratory, semi-field and field) should be conducted by a skilled supervisor. With regard to the former a general framework of an overall research program is displayed in section 8. Because of the extension and specificity, the program should be spread over the three locations. Subsequently, within each of them, special tasks can be shared by several staff members according to their interest and background. Intimately linked to this, the fact subsists that in order to succeed, the program to be ela-

borated should be conducted by a clever coordinator who can motivate, guide and provide technical assistance to each of the participants. As items of primary importance to which very special attention should be paid, we mention : experimental design of pot and field experiments, manipulating of labelled P products, assessment of analytical results and statistical processing of the data.

Starting from the fact that within the current UNDP project the laboratories at Bangkok and Khon Kaen are perfectly equipped with a radioactive apparatus and accessory infrastructure for handling of radio-isotopes, special tasks within the program with emphasis on the study of rock phosphate can be assigned to these units. For this purpose we refer to section 9.

With regard to the means to achieve this overall project, let us quote that basic technical infrastructure, equipment and facilities are available for the scientific teams.

As one is primarily concerned with the aiming and strengthening of the research activities on the assessment of natural phosphates, the question arises if an additional outcome has to be expected from these activities.

It is expected that this country, which is actually mainly oriented towards improving the agricultural production, will have to overcome other problems in agriculture and related areas in the future. In these circumstances it should be very appropriate and also highly advisable to rely on a few " laboratories of reference" whose technical infrastructure and skilled research staff are able to consider any particular problem in agriculture or related areas, including the use of radio-isotopes. It is our feeling that the laboratories monitored are staffed with motivated people who, provided they receive an additional training, can be prepared for this challenge. To that purpose local authorities should provide them with the adequate facilities.

13. RECOMMENDATIONS FOR THE AGENCY

Thanks to the financial input of the Agency, mainly in infrastructure and laboratory facilities, an advanced technical basis for conducting high levelled research activities in agrochemistry has been developed.

It has been reported that, apart from very few occasions, no relevant results have been delivered so far. This evidence is further strengthened if labelled P is included in the experiments. The reasons are evident: a limited theoretical background and experience on radio-agrology of the researchers in combination with a weak guidance and assistance. The following conclusion can be drawn : the people involved in the UNDP project, in particular concerning the use of labelled P, are not prepared to take over independently the study of the rock phosphate at the current stage. Due to the lack of information, we should not extrapolate this evidence to other radio-isotopes (such as S-35), but we remain suspicious. Referring to this matter, it is our feeling that a program including experiments with radio-isotopes can only be assigned in a developing country to a PhD researcher unless very strict guidance and supervision are provided.

Yet we advise against abandoning the project in the actual conditions. It is rather the task of the Agency to extend their presence and to make corrections at two distinct levels in order to fully elaborate this project:

-detailing of an overall program (a framework of a proposal is displayed in section 8) on rock phosphate and assigning of the tasks to each of the three locations involved and, within each of them, to each participant. The coordinator, able to provide thorough technical assistance, should closely look after the proper elaboration of each topic within the general program.

-A theoretical and practical refreshment of analytical and radiochemical methodology including the assessment of the analytical data should be highly valued by the research officers. How this should be optimally realised, will depend on the means or facilities provided: either the research officer will be sent to a laboratory of reference for an intensive training of several months or (and to us this appears to be the effective way) the coordinator should take care of this on site. This latter alternative has the additional advantage that several people can


participate in this refreshment and that the actual local conditions are encountered, which are different from those in western countries.

14. REFERENCES

1. Agricultural Statistics of Thailand, Crop year 1988/89
Agricultural Statistics No 414.
2. Anderson D.L., Kussow W.R. and Corey R.B.
Soil Science Society of America Journal, 1985, 49, 918-925
3. Bolan N.S. and Hedley M.J.
Fertiliser Research, 1989, 19, 65-75
4. Chien S.H.
Soil Science Society of America Journal, 1977, 41, 1106-1109
5. Chien S.H. and Hammond L.L.
Soil Science Society of America Journal, 1978, 42, 935-939
6. Kucey R.M.N. and Bole J.B.
Soil Science, 1984, 138, 180-188
7. Leon L.A., Fenster W.E. and Hammond L.L.
Soil Science Society of America Journal, 1986, 50, 798-802
8. Mackay A.D., Syers J.K., Tillman R.W. and Gregg P.E.H.
Soil Science Society of America Journal, 1986, 50, 291-296
9. Ressler H. and Werner W.
Zeitschrift fur Pflanzenernahrung, Dungung und Bodenkunde
1989, 152, 325-332.

15. ACKNOWLEDGMENT

I want to convey sincere thanks to all people who contributed to the project and especially to those who were closely involved in my mission for their kind cooperation and the facilities provided.



May 21, 1990

J. Vanderdeelen