THIRD RESEARCH CO-ORDINATION MEETING

OF THE

FAO/IAEA CO-ORDINATED RESEARCH PROGRAMME

"THE USE OF NUCLEAR AND RELATED TECHNIQUES FOR EVALUATING THE AGRONOMIC EFFECTIVENESS OF PHOSPHATE FERTILIZERS, IN PARTICULAR, ROCK PHOSPHATES"

17 - 21 MARCH 1997
VIENNA INTERNATIONAL CENTRE
VIENNA, AUSTRIA

REPORT
D 1 - RC - 542.3

BY

F. ZAPATA
SCIENTIFIC SECRETARY OF THE MEETING
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1. Introduction

Soils in developing countries are often deficient in available P, and therefore require inputs of P fertilizer for optimum plant growth and production of food and fibre. Due to economic considerations, the cost of applying imported or locally produced watersoluble P fertilizers is often more expensive than utilizing indigenous phosphate rock.

Phosphate rocks show large differences in their suitability for direct application and several factors influence their capability to supply phosphorus to crops. Therefore, quantifying the P availability of soils amended with phosphate rocks in a variety of crop management and environmental conditions in developing countries is imperative for making recommendations on best type and rate of P fertilizer sources to be used to obtain maximum agronomic and economic benefits. P-32 isotope techniques are very useful for such studies.

The background situation of phosphate research and the topics to be investigated using isotope techniques were critically examined in a Consultants Meeting, held at the IAEA Headquarters, Vienna, Austria, from 10 to 12 May 1993. For detailed information please refer to IAEA Report CT-1112.

Based on the recommendations of this Consultants Meeting, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture with the generous support of the French Government decided to establish an international networked research project. The Soil Fertility, Irrigation and Crop Production Section started the implementation of this Co-ordinated Research Programme (CRP) on "The Use of Nuclear and Related Techniques for Evaluating the Agronomic Effectiveness of Phosphate Fertilizers, in particular Rock Phosphates" (D1.50.03).

The First Research Co-ordination Meeting (RCM) of the CRP was held at the IAEA Headquarters in Vienna, from 1 to 5 November 1993. (Refer to IAEA Report D1-RC-542.1).

The Second Research Co-ordination Meeting (RCM) was convened in the installations of the "Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement" (CIRAD), Montpellier, France, from 24 to 29 April 1995. Dr. Truong Binh was the local organizer of the meeting. (Refer to IAEA Report D1-RC-542.3).

Thanks to the generous support of the French Government, 5 new contracts have been awarded in 1996 to scientists from Eastern Europe, i.e., Belarus, Hungary, Lithuania, Poland and Russian Federation.

This report describes the Third RCM of the CRP which was held in Vienna, 17-21 March 1997. In addition, following the workplan of the CRP (described in detail in the report of the Second RCM), an Action Plan to be implemented during Phase 3, as well as guidelines for the standard characterization of sorts and phosphate works and the preparation of reports and the final publication are included.
2. **The Meeting**

The Third Research Co-ordination Meeting of the FAO/IAEA Co-ordinated Research Programme on “The Use of Nuclear and Related Techniques for Evaluating the Agronomic Effectiveness of Phosphate Fertilizers, in particular Rock Phosphates” was held at the IAEA Headquarters in Vienna, Austria, from 17 to 21 March 1997.

The objectives of the meeting were:

a) To present research results obtained so far during the reporting period and to assess the progress made in the implementation of the CRP.

b) To discuss and agree on the final action plan until completion of the CRP in 1998.

The meeting was attended by 35 participants: 15 contractors, 4 agreement holders, 8 observers (including 6 IAEA fellows) and 8 staff members from Headquarters and Laboratory. The list of participants is shown in Annex I.

The official opening was made by Dr. C. Hera, Head of Soil and Water Management and Crop Nutrition Section of the Joint FAO/IAEA Division, and followed by remarks of Dr. F. Zapata, Scientific Secretary of the CRP.

The programme of the meeting (Annex II) included presentations of the contractors and agreement holders, a session to review the overall workplan of the CRP and the support of the World Phosphate Institute (IMPHOS), individual meetings with contractors, and discussion sessions to define final experimental and publication plans.

A visit to the FAO/IAEA Agriculture and Biotechnology Laboratory, at Seibersdorf was organized for the new contractors on Thursday, 20 March. The final wrap-up session took place on Friday morning, 21 March and the meeting was officially closed by Dr. C. Hera. In the afternoon, individual discussions continued with some of the new contractors.

The quality of the presentations was very good. Some methodological issues were discussed for harmonization purposes. Abstracts of the presentations are given in Annex III. Some participants have already published their results in national and international journals. The final action plan of the CRP includes both experimental and publication plans (Section 4 of this report).

3. **Action Plan of the CRP (D1.50.03)**

The overall goal of the project is to develop an efficient and economic phosphate management programme for acid soils with low P fertility status.

Specific objectives are the following:

1) To assess the initial available P and its changes in soils amended with phosphate rocks and water-soluble P fertilizers, using the P-32 isotopic exchange method, and other chemical extraction techniques for comparisons,
2) To quantitatively evaluate P uptake and utilization from P fertilizers, in particular phosphate rocks by crops in diverse soil and climatic conditions. Also where necessary, to enhance their agronomic effectiveness. This information will be utilized and to obtain agronomic and economic recommendations on the efficient use of P fertilizers, in particular phosphate rocks.

The following activities are foreseen during the Phase 3 to achieve the outputs expected from the CRP. For detailed information, please refer to, IAEA Report DIRC-542.2.

3.1. OBJECTIVE 1

Outputs I and 2:

All contractors have gathered basic information on soil P dynamics through the assistance provided by CEN, Cadarache and the Soil Science Unit, FAO/IAEA Agriculture and Biotechnology Laboratory, Seibersdorf. Over 100 soil samples from the network have been analysed by Dr. J.C. Fardeau, CEN-Cadarache utilizing the P-32 isotope exchange technique.

The majority of contractors have also gathered information on soil available P utilizing routine and other chemical extraction methods. Some contractors still need to collect such information.

ACTION:

- Contractors to complete the information on available soil P through the use of routine chemical methods utilized in their countries. Additional information for the benchmark soils utilized in the network will be generated as follows:
  "Resin method" With assistance of Dr. 1Q.RAJ111 1~UIQ.VQ, t^_.L~ Ill, UA biO
  "P; soil P test" with assistance of Dr. D. Montange, CIRAD (support of Dr. Sen Chien, IFDC).

- NEW CONTRACTORS will send as soon as possible soil and P fertilizers (including PRs) to Dr. D. Montange, CIRAD, Montpellier, France for both the standard soil characterization (physico-chemical analysis) at CIRAD and soil P dynamics (P-32 isotopic exchange method) at CEN, Cadarache.

Output 3:

About half the contractors have incorporated the P-32 isotopic exchange method into their laboratories. They have included adjustments/modifications to the technique according to the physico-chemistry of their soils.

ACTION:

- Contractors to apply the P-32 isotopic exchange method to generate their own data
Output 4:

Few contractors have evaluated the performance of the routine chemical method for assessing available P. During the meeting, Drs. J.C. Fardeau and Sen Chien elaborated on the methodological issues of soil P testing.

ACTION:

- Contractors to compile all information from outputs 1, 2 and 3 and establish correlations between the data obtained from chemical methods and the isotopic parameters of P availability. Analyze the results and draw-up recommendations.

3.2. OBJECTIVE 2

Outputs 5 and 6:

Most contractors have conducted research to gather information on the Relative Agronomic Effectiveness (RAE) of local and imported PRs as well on the identification of ways/means to enhance the RAE of PRs under controlled conditions.

ACTION:

Few contractors need to complete information on these topics.

- In order to harmonize the evaluation of RAE of P fertilizers the various parameters utilized in conventional and isotopic studies were explained by Dr. F. Zapata. (Annex IV).

Output 7:

Few contractors have conducted a field evaluation of the AE of local rock phosphates using P-32 isotopic techniques.

ACTION:

- Contractors must conduct field trials using P-32 isotopic techniques to gather this basic information to achieve objective 2. This activity may be combined with next one related to output 8. It is essential that the contractors record the minimum data set required for the P SUBMODEL. Dr. S. H. Chien, IFDC will provide a data-sheet to be filled out by the contractors. This information will be used for both the validation of the model and the extrapolation of the results to other locations. (Annex V).

Output 8:

In order to draw-up practical P fertilizer recommendations experimental field trials will be set-up for testing/validation of selected P fertilizer treatments. A basic set of treatments will include: best (natural/imported) natural PR, best recommended PR product or mixture, reactive PR from IMPHOS, water-soluble P fertilizer (TSP) and a check (no P application).
Utilize large yield plots and measure conventional yield parameters (total biomass/agronomic yield) and total P uptake. As aforementioned, some contractors will have P-32 labelled microplots within the field trials to collect information related to output 7.

**ACTION:**

- All contractors must conduct the field trials to evaluate the agronomic effectiveness of rock phosphates under a variety of soil and climatic conditions. Record the minimum data set for the P SUBMODEL.

Output 9:

Developing an efficient and economic phosphate management programme.

**ACTION:**

- All contractors will analyze the results obtained from outputs 4 and 8 and they will elaborate a set of recommendations for P fertilization under their own conditions. It is expected that the results of the CRP will have impact on the end-users.

**4. Standard Characterization of Soils and PRs - IMPHOS Support.**

**IMPHOS Support To FAO/IAEA Phosphate Network**

In 1995 after the Second Research Co-ordination Meeting of the FAO/IAEA CRP on "The Use of Nuclear and Related Techniques for Evaluating the Agronomic Effectiveness of Phosphate Fertilizers, in particular Rock Phosphates" held in Montpellier, France, the World Phosphate Institute (IMPHOS) decided to establish a co-operation agreement with the International Atomic Energy Agency (IAEA) and to provide a financial contribution of 60,000 US $ in support of the CRP. The corresponding Memorandum of Understanding between the IAEA and IMPHOS was signed in the beginning of 1996.

The main objectives of this mutual collaboration are:

a) To contribute to improving the consistency and comparability of the data obtained from the CRP by conducting a "standard characterization" of soils and rock phosphates utilized in the network;

b) To facilitate the access to a wider range of rock phosphates to test within the network; and

c) To contribute to the dissemination of the information generated from the programme and thus increasing the potential of the CRP.

Accordingly, the following activities will be conducted during the period 1996-1998:

1. Analysis of the soils from the benchmark sites in the countries participating in the CRP. This has been completed in 1996 at the laboratories of CIRAD, Montpellier. France.
2. Characterization of the rock phosphates used in the CRP. This activity will be done this year in two selected laboratories: The "Centre de Recherches Petrographiques et Géochimiques" (CNRS), Nancy, France for the mineralogical composition and the "Centre d'Étude et de Recherche sur les Phosphates (CERPHOS), Casablanca, Morocco for the physical and chemical characterization including solubility indices. The contractors participating in the network have been requested to send their rock phosphate samples.

3. Selection of countries willing to include rock phosphates from IMPHOS in their field experiments, and follow-up of field activities in these countries. The first task has been done and the second one is underway.

4. Organization of the final research co-ordination meeting in 1998 and preparation of the final report of the CRP. Detailed plans for these activities will be made during the Third Research Co-ordination Meeting to be held in March 1997 in Vienna, Austria.

**Detailed Action Plan for 1997-98**

a) Soil Characterization

- Contractors have been asked to check the soil samples sent for analysis and to provide the correct names of the soil series and the International Classification (Soil Taxonomy or FAO system). In doubt, please consult with a pedologist to provide correct information.

- Dr. D. Montange, CIRAD, will provide the protocols or references of the analytical methods utilized for the characterization.

- New contractors will proceed as above described for outputs 1 and 2.
- Dr. D. Montange, CIRAD, in close collaboration with the Scientific Secretary, will produce a full report of the benchmark soils of the network.

b) Phosphate rock characterization

As per circular letter of 1997-02-06, the characterization of phosphate rocks utilized in field work will be done in two laboratories during 1997.

- Contractors (except the newcomers) are asked to dispatch as soon as possible their phosphate rock materials, as per instructions given in the circular letter. In addition, please notify the Scientific Secretary about the number/name of the PRs and date of shipment.

- The laboratories will send the analytical results to the Scientific Secretary for co-ordination with IMPHOS and onforwarding to the contractors.

- Mr. Benjelloun, IMPHOS will gather information from the laboratories on the analytical methods utilized in the characterization of PRs.

c) Reactive PRs from IMPHOS for the field trials.
The Scientific Secretary provided IMPHOS with a list of contractors willing to utilize reactive PRs in their field trials.

During the meeting, Mr. Benjelloun, IMPHOS, had the opportunity to check on the request of these PR materials with the contractors, i.e. countries, addresses, number of PRs and deadlines for their supply.

5. Reports and Final Publications

- During the meeting contractors were requested to follow guidelines provided by the Contracts Administration Section to prepare their progress reports (for renewal) and the final report including summary.

- The final publication of the CRP will be made in the format of an unpriced IAEA publication. Instructions for the preparation of the publication were distributed to all the participants. The contributions of the contractors and agreement holders will be provided in a diskette and a hard copy. Deadlines for the submission was set on 31 July 1998.

- The Scientific Secretary will prepare a schedule for the preparation of the final publication with the assistance of an external consultant. A first version of the final publication should be available by the final meeting.

Conclusions and Recommendations

- The objectives of the meeting were successfully accomplished.

- As indicated in the Action Plan of the CRP, implementation during phase 3 should focus on the activities to be completed so as to achieve the outputs set for the CRP during the time frame of the project. Most contractors will conduct field testing/validation trials to draw-up practical P fertilizer recommendations.

- The collection of the minimum data set for validation of the P submodel will be essential during this phase. All contractors will record the basic information in the data sheets provided by Dr. S.H. Chien, IFDC.

- The financial support of IMPHOS will continue during 1997 and 1998. The standard characterization of PRs utilized in the network will be carried out in 1997. In addition, IMPHOS will supply reactive PRs to the contractors for inclusion in the field trials. Final reports on the standard characterization of soils and PRs utilized for the network will be prepared during 1997 and 1998, respectively.

- Contractors are strongly encouraged to publish their own research results in national and international scientific journals. Due acknowledgement to the IAEA support should be given.
• The final publication with the outcome of the CRP will be published as unpriced IAEA publication. All participants will prepare their contributions following IAEA instructions and submit them by 31 July 1998 (hard copy and diskette). The Scientific Secretary will prepare a schedule for the preparation of the final publication with the assistance of an external consultant.

• The environmental issue of heavy metals, in particular cadmium as a result of P fertilizer applications is becoming a high priority issue. There is a lack of information on the Cadmium uptake by plants when phosphate rock materials are applied. Drs. Sen Chien, IFDC, and M. MacLaughlin, CSIRO, are currently working on these topics. In addition, several contractors where rock phosphates are commonly applied have become involved in this type of research.

• The final meeting of the CRP will be held during the last quarter of 1998. Contractors are expected to bring along their final reports with the summary.

7. Acknowledgements

On behalf of the Joint FAO/IAEA Division, the Scientific Secretary of the CRP would like thank all the participants, contractors and agreement holders, for their active participation in implementing the several activities of the project.

Special thanks are given to the French Government and IMPHOS for their financial support of the project.

8. Key References


ANNEX I

Research Co-ordination Meeting
on "The Use of Nuclear and Related Techniques for Evaluating the
Agronomic Effectiveness of Phosphate Fertilizers, in particular, Rock Phosphates
(D1-RC-542.3) 17 - 21 March 1997, (Room IV, C-07)

Project Officer: Felipe Zapata

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THIRD RESEARCH CO-ORDINATION MEETING OF THE
FAO/IAEA CO-ORDINATED RESEARCH PROGRAMME (CRP)
ON
THE USE OF NUCLEAR AND RELATED TECHNIQUES FOR EVALUATING
THE AGRONOMIC EFFECTIVENESS OF PHOSPHATE FERTILIZERS IN
PARTICULAR, ROCK PHOSPHATES
17 - 21 MARCH 1997
Vienna, Austria

Scientific Secretary: F. ZAPATA

PROGRAMME

Monday, 17 March

09:30 OFFICIAL OPENING

Christian Hera
Head, Soil and Water Management and Crop Nutrition Section

09:45 Remarks by Scientific Secretary

10:15 - 10:45 Coffee Break

Session I Chairperson: Christian Hera

11:00 - 11:30 Eduardo Casanova
"Use of nuclear and related techniques for evaluating
the agronomic effectiveness of P fertilizers in particular
phosphate rocks, in Venezuela"
Venezuela

11:30 - 12:00 Jittiwan Mahisarakul
"Phosphate rock materials in a soybean-maize crop
rotation using isotope techniques"
Thailand
12:00 - 14:00  Lunch Break

**Session II**  
Chairperson: J.C. Fardeau

14:00 - 14:30  
*Zenoviu Borlan*  
Romania  
"Phosphate rock studies in Romania within the IAEA CRP"

14:30 - 15:00  
*Zaharah A. Rahman*  
Malaysia  
"Evaluation of P availability in an Ultisol amended with phosphate rocks"

15:00 - 15:30  Coffee Break

15:30 - 16:00  
*Nancy Karanja*  
Kenya  
"Evaluation of P uptake from MINJIGU phosphate rock and growth of tree species on an acid soil from Western Kenya using P-32 isotope dilution technique"

16:00 - 16:30  
*Elsje Sisworo*  
Indonesia  
"The use of P-32 for the agronomic evaluation of phosphate rock"

17:00  Welcome Reception at the V.I.C. Restaurant.

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**Tuesday, 18 March**

**Session III**  
Chairperson: J.M. Barea

09:00 - 09:30  
*GuangLin Feng*  
China, PR -  
"Phosphorus dynamics and its availability of alternative fertilizers applied to sustainable ecosystems in Southern China"

09:30 - 10:00  
*Ines Pino*  
Chile  
"Dynamics of phosphorus and phosphate fertilizer efficiency in soils derived from volcanic ash, Chile"

10:00 - 10:30  Coffee Break

**Session IV**  
Chairperson: M. Fotyma

10:30 - 11:00  
*Jose A. Herrera Altuve*  
Cuba  
"Studies on alternative phosphorus fertilizer sources for cropping systems grown in Red Ferralitic soils using nuclear technique"
11:00 - 11:30  **Takashi Muraoka**
Brazil
"Effect of methods of applying phosphate rock mixed or not with superphosphate"

11:30 - 12:00  Summary of results

12:00 - 14:00  Lunch Break

**Session V**  
**Chairman:**  **T. Muraoka**

14:00 - 14:30 **Iossif Bogdevitch**
Belarus
"Comparative evaluation of the effect of P fertilizers (rock phosphate and mono ammonium phosphate) on plant P nutrition in mineral and peat soils"

14:30 - 15:00 **Tamas Nemeth**
Hungary
"The use of nuclear and related techniques for evaluating the agronomic effectiveness of phosphate fertilizers, in particular rock phosphates"

15:00 - 15:30  Coffee Break

**Session VI**  
**Chairperson:**  **T. Nemeth**

15:30 - 16:00 **Gvidas Sidlauskas**
Lithuania
"Studies on the effect of liming on the agronomic effectiveness of Maardu rock phosphate"

16:00 - 16:30 **Mariusz Fotyma**
Poland
"Evaluation of fertilizers, particularly rock phosphate, derived soil phosphorus by biological and chemical methods"

16:30 - 17:00 **Rudolf Alexakhin**
Russian Federation
"Studies on the effectiveness of rock phosphates as agricultural counter measure in soils contaminated by radionuclides"

**Wednesday, 19 March**

**Session VII**  
**Chairperson:**  **I. Pino**

09:00 - 09:30 **J.C. Fardeau**
France
"P-32 Isotope exchange technique"
<table>
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<tr>
<th>Time</th>
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<td>09:30 - 10:00</td>
<td>Sen H. Chien</td>
<td>&quot;Effect of acidulation of phosphate rocks having high cadmium content on cadmium uptake by upland rice&quot;</td>
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<td>10:00 - 10:30</td>
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<td>Coffee Break</td>
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<td><strong>Session VIII</strong></td>
<td><strong>Chairperson:</strong> Z. Borlan</td>
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<td>10:30 - 11:00</td>
<td>J.M. Barea</td>
<td>&quot;The use of mycorrhizas and phosphate solubilizing micro-organisms to improve the agronomic effectiveness of natural rock phosphates&quot;</td>
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<td>11:00 - 11:30</td>
<td>D. Montange</td>
<td>&quot;Characterization of soils used in the CRP and compared effectiveness of partially acidulated PR's and SSP on various soils&quot;</td>
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<td>11:30 - 12:00</td>
<td>J.C. Fardeau</td>
<td>&quot;Soil P fertility replenishment and liming using phosphate rocks in low pH tropical soils&quot;</td>
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<td>12:00 - 14:00</td>
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<td>Lunch Break</td>
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<td><strong>Session IX</strong></td>
<td><strong>Chairperson:</strong> Zaharah Abdul Rahman</td>
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<td>14:00 - 15:30</td>
<td>F. Zapata</td>
<td>&quot;Review: Workplan CRP&quot;</td>
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<td>15:00 - 15:30</td>
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<td>Coffee Break</td>
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<td>15:30 - 16:30</td>
<td>A. Benjelloun</td>
<td>&quot;IMPHOS support to CRP&quot;</td>
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<td>16:30 - 17:30</td>
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<td>Interviews with contractors</td>
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<td><strong>Thursday, 20 March</strong></td>
<td><strong>Chairman:</strong> S.A. Chien</td>
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<tr>
<td>09 - 10:00</td>
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<td>General discussion</td>
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<td>Future activities of the network research programme</td>
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10:00 - 10:30  Coffee Break
10:30 - 12:00  Presentation of future experimental plans by participants.
12:00 - 14:00  Lunch Break

**Session XI**  
**Chairperson:**  
**E. Casanova**
14:00 - 15:00  General discussion  
Publications and Final Report of the CRP
15:00 - 15:30  Coffee Break
15:30 - 16:30  (Continuation)
16:30 - 17:30  Interviews with contractors

**Friday, 21 March**

**Session XII**  
**Chairperson:**  
**F. Zapata**
09:00 - 10:00  Conclusions and recommendations
10:00 - 10:30  Coffee Break
10:30 - 11:30  Conclusions and recommendations (cont'd.)
11:45  
**CLOSING SESSION**

**C. Hera**
12:00 - 14:00  Lunch Break
14:00 - 16:00  Individual discussions
ANNEX III

ABSTRACTS OF THE PRESENTATIONS
A pot experiment was conducted to evaluate the optimum P level supplied as triple superphosphate and phosphate rocks from Algeria, China, Christmas Island, Jordan, Tunisia, and the USA, on oil palm seedlings planted on a Rengam series soil (Typic Paleudult) under nursery conditions. Five P rates, 0, 2, 4, 6 and 8 mg P kg⁻¹ soil were tested. Uniform three-months old oil palms seedlings were grown in 15 kg soil amended with the above treatments for 9 months. Based on the relative dry matter weights produced, 4 mg P kg⁻¹ soil was found to be optimum P rate to produce >90% relative dry matter weight.

Another experiment was set up on the same soil series using 4 mg P kg⁻¹ soil using 32P isotope dilution method to quantify P derived from fertilizer treatments on plants grown from 0-3 months, 3-6 months, 6-9 months and 9-12 months after P application. Plants harvested at each time were analysed for 32P activity and E-value was calculated. Phosphorus content in the tissue was also determined to calculate total P taken up during the growth period. The soils obtained at the end of each harvest time was extracted with Pi strip in 0.01M CaCl₂ shaking medium and E-value method of Fardeau. P availability obtained by E-value, Pi strip and E-value were correlated with plant P uptake.

It was found that E-value over-estimated the available P in the soil. The correlation coefficient (R) obtained between E-value and plant P uptake was 0.87 while E-value at 1 minute gave a correlation coefficient of 0.954, and P extracted by Pi strip gave a correlation coefficient of 0.953. This shows that E-value at 1 minute and Pi strip were the best method to give the highest correlation. While E-value is not easily carried out as routine method in all laboratories, Pi strip extractable P can be easily carried out by routine laboratories. Thus this method can be recommended to be used as indicator of soil P availability by plants in the Ultisols when amended with phosphate rock.
The Use Of Rock Phosphates For Decreasing "Sr And "Cs Uptake By Crops

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Obninsk
Russia

One of the major factors responsible for poor yields of farm crops in the Russian Federation is the low level of mobile forms of P in soil. For 65% of arable lands in the Russian Federation the phosphate content in soil is low and does not exceed 100 mg/kg. It should be noted that about 70% of arable lands in the Non-Chernozem area of the Russian Federation have acidic reaction in the soil suspension (pH<5.5). The application of phosphorous fertilizers is currently greatly reduced due to difficult economic situation and the available soil phosphorus content constantly tends to decrease. In 1995, average doses of applied mineral fertilizers amounted to 10 kg P2O5/ha. At the moment, amounts of applied mineral fertilizers on agricultural lands of the Russian Federation continue to decrease.

Following the accident at the Chernobyl NPP, the total area a with density of contamination by Cs above 1 kBq/m2 amounts to 56,900 km". One of the most effective ways to reduce radionuclides uptake to plant products is the application of higher doses of PK fertilizers. The data obtained by RIARAE have shown that application of increased doses of PK-fertilizers reduces 9°Sr and '3' Cs uptake by crops by a factor of 1.5-2.0. However, the difficult economic situation in the Russian Federation prevents the application of PK fertilizers on arable lands at recommended doses, thus resulting in elevated levels of radioactive contamination of products and extra irradiation of local population due to the consumption of these products. The application of local rock phosphates (RP) containing phosphorus as mineral fertilizers is one of the most promising ways to solve the problem.

Some 250 deposits of RP have been explored on the Russian Federation territory. Of these, 35 are suitable for immediate development and the overall ore reserves reaching 483 million tons P2O5. The largest deposits of RP in Russia where acid podzollic soils are common are located in the Moscow, Kaluga, Smolensk and Bryansk regions, subjected to contamination as a result of accident at the Chernobyl NPP. Preliminary investigations have demonstrated that RP are highly effective for improving fertility of soils and nutrition of plants and decreasing "Sr and 137CS uptake by plants. Rock phosphates however vary significantly in the content of P2O5, chemical impurities and reactivity. This calls for correct assessment of RP applications in each particular case.
The Use Of Mycorrhiza And Phosphate Solubilizing Microorganisms To Improve The Agronomic Effectiveness of Natural Sources Of Rock Phosphate

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A number of experiments were carried out with the overall aim of studying the interactive effect of mycorrhizal fungi and phosphate-solubilizing microorganisms on nutrient uptake from rock phosphates by plants, and their interactions in soil/plant system using several methods. A full list of these studies will be presented in the meeting being available upon request. This presentation will focus on those where isotopic techniques were used:

1. A soil microcosm system was designed to evaluate, by using 'SN and 32P isotopic dilution approaches, the interactive effects of multi-functional microbial inoculation treatments and rock phosphate (RP) application on N and P acquisition by alfalfa plants. The microbial inocula consisted of a wild type (WT) Rhizobium meliloti strain, its genetically modified (GM) derivative, which had an enhanced competitiveness, the arbuscular mycorrhizal (AM) fungus Glomus mosseae, and a phosphate solubilizing rhizobacterium. Improvements in N and P accumulation in alfalfa corroborate beneficial effects of the improved on AM performance, in RP-amended plants. Measurements of the 'SN/4N ratio in plant shoots indicate an enhancement of the N2 fixation rates in Rhizobium-inoculated AM-plants, over that achieved by the same Rhizobium strain in non-mycorrhizal plants. Regardless of the Rhizobium strain and of whether or not RP was added, AM-inoculated plants showed a lower specific activity ('ZP/3'P) than did their comparable non-mycorrhizal controls, suggesting that the plant is using otherwise unavailable P sources. The proportion of plant P derived either from L (labelled soil P) or from RP was about the same for AM inoculated and non-mycorrhizal controls (without rhizobacteria inoculation), for each Rhizobium strain, but the total P uptake, regardless of the P source, was far higher in AM-plants. Rhizobacteria inoculation seems to improve the use of RP in the rhizosphere of non-mycorrhizal plants, but only in those inoculated with the WT Rhizobium.

2. The interactive effect of phosphate-solubilizing, bacteria and arbuscular mycorrhizal (AM) fungi on plant use of "low bio-available" soil P sources (endogenous or added as rock phosphate (RP) material) was evaluated by using a soil microcosm system which integrated P isotopic dilution approaches. The microbial inocula consisted of the AM fungal species Glomus intraradices and two phosphate-solubilizing rhizobacterial isolates: an Enterobacter sp. and a Bacillus subtilis. These rhizobacteria behaved as "mycorrhiza helper bacteria" promoting AM establishment by either the indigenous AM endophytes or the inoculated G. intraradices, The dual inoculation treatment G. intraradices and B. subtilis significantly increased biomass and N and P accumulation in plant tissues. Regardless of the rhizobacteria strain and of whether or not RP had been added, AM-inoculated plants displayed lower specific activity ("P/3'P) than their comparable controls, suggesting that the plants were using otherwise unavailable P sources. At least 75% of the P in dually inoculated plants was derived from the added RP. It appears that these mycorrhizosphere interactions contributed to the
biogeochemical P (and N) cycling thus promoting a sustainable nutrient supply to plants.

3. A microcosm bioassay was proposed to evaluate the effect of mycorrhizal fungi and phosphate-solubilizing bacteria in improving the agronomic effectiveness of rock phosphate (RP) sources in a neutral soil, using $^{32}$P isotopic dilution approaches. The method appears suitable for quick screening of microbial inoculants with regard to improved plant use of RP materials. The relative availability the three RP sources tested, determined by isotopic dilution (% RAID index), was: North Carolina > Riecito > PN-BRUT.

4. The $^{32}$P isotopic dilution approach was used to evaluate the effect of mycorrhizal inoculation on plant uptake of P released from the resulting fermentation-resulting mixtures of agrowastes, Aspergillus and rock phosphate (RP). Mycorrhizal inoculation lowered the specific activity in plant regardless the fermentation-resulting product tested. The most effective product was the mixture of sugar beet wastes, RP and Aspergillus inoculation. The results support a potential agronomic benefit of using such products by AM-plants (Vassilev, Vassileva, Azcon, Barea).
Comparative Evaluation Of The Effect Of P Fertilizers On Plant P Nutrition In Sod-podzolic And Peat Soils"

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Research Institute for Soil Science and Agrochemistry
Minsk
Belarus

Direct application of phosphate rock (PR) has been practised in Belarus in 1960-70. It was especially effective in the cultivation of legumes and other crops on acid soils. After the intensive liming of acid soils in Belarus, the consumption of PR for direct application rapidly has decreased. The water-soluble P-fertilizers are very expensive and their application have continuously declined. Nowadays we have evidence of a poor P balance in agriculture and possible depletion of soil fertility, which is especially dangerous for land contaminated with radionuclides after the Chernobyl accident.

Therefore, it is important to study the possibility of utilizing the finely powdered PR imported from Russia (Bryansk deposit), which is sufficiently cheaper, than water soluble P fertilizers. The direct application of suitable kinds of PR may be potentially effective on acid (moderately limed) sod-podzolic and peat soils, in total about 30% of agricultural land of Belarus.

The objectives of our experiments are: (1) to determine of the fraction of Pin plants derived from P fertilizers (mono-ammonium phosphate and rock phosphate) by means of isotopic techniques; (2) to make a comparative evaluation of the availability of phosphorus from rock phosphate and mono-ammonium phosphate for agricultural plants and 3) assess the effect of P-fertilizers on the reduction of the root uptake of radionuclides '3'Cs and 9°Sr in contaminated soils.

The pot experiment will be set up using two main soil types: in 1997 sodpodzolic loamy clay with pH (KCl) 5.0-5.5 and in 1998 peat soil with pH 4.5-15.0. The extractable P content, 'Cs and 'Sr deposition levels of the selected soils will be. typical for the contaminated zone of Belarus. Other chemical characteristics of the studied soils will be analysed by conventional methods (organic matter %, exchangeable K, Ca, Mg, etc.).

Evaluation of PR (8.3% total P) as direct fertilizer against MAP (21.8% total P) will be make using the 32P isotope dilution technique. Lupine plants will be grown for two months in 1997. Similar pot experiment on peat soil is planned to set up in 1998 with annual rye grass using the same P fertilizers. Then quantitative comparison of rock phosphate and mono-ammonium phosphate efficiency on plant nutrition and radionuclide uptake will be determined.
Phosphate Rock Studies Using Isotope Techniques In Romania During 1995-1997

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Romania

Phosphate rock studies in Romania were carried out on Haplic Luvisols and Phaeozems (FAO classification) while in last American approximation they are included in Hapludoll and Hapludalf great soil groups. Phosphate rock samples from Kola-Russia; Gafsa-Tunisia; North Carolina, USA; Morocco and Arad, Israel, were studied as sources of phosphorus for plants, being compared with TSP.

Chemical properties of the soils were combined in a phosphate rock use opportunity index of the soil.

\[ \text{PRUOIS} = \frac{(A_h . H^2 . T . 100)}{(\text{SEB} . 10^{0.0245} \text{PAL})} \]

while those of PR have been combined in a phosphate rock suitability index for direct use.

\[ \text{PRSIDU} = \frac{[(P_{120} - P_{60})/60](1 - 0.03 \cdot \text{CaCO}_3)}{\text{ppm P} \cdot \text{min}^{-1}} \]

in which: A_h, SEB and T are adsorbed acidity, sum of exchangeable bases and cation exchange capacity respectively, all as mill equivalents per 100 g of dry soil; H - humus content (%) ; PAL - mobile P in the soil extended with Ammonium Lactate as ppm P; P_{120} and P_{60} - P dissolved from PR during 60 and 120 min. equilibrium extraction with CaCl_2 0.01 M-hepta molybdate of ammonia 1:200; CaCO_3 - free carbonate content in PR (%).

A synthetic index of soil and phosphate rock chemical properties, obtained by multiplicative combination of PRUOIS with PRSIDU was found to correlate highly significantly \((r^2 > 0.80)\) with both PfPR and with RAE of PR. A comparison of \(^{32}\text{P}\) isotope dilution technique with non-isotope difference method was categorically in the favour of the former. At the same rate of P application (100 ppm P in soil), using half rate (50 ppm P) of P as PR and half rate as TSP have significantly enhanced plant uptake of P from PR. Such an effect has been obtained also by leaf application of diluted (0.4%) aminoacid-ureide complex (AAUC). From five comparatively studied equilibrium extraction methods for mobile P (PAL; P_{NaHCO}_3; P_{MoCa0.3}; P_{MoCa0.6}; P_{Br2}), ammonium molybdate-calcium chloride methods gave significantly higher correlation coefficients with P uptake in plants from PR-amended soils.
The Use Of Nuclear And Related Techniques For Evaluating The Agronomic Effectiveness Of Phosphate Fertilizers In Venezuela

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Venezuela and nine other countries are "contractors" since 1994 of the FAO/IAEA Coordinated Research Programme on the "Use of Nuclear and Related Techniques in the Evaluation of the Agronomic Effectiveness of Phosphate Fertilizers, in Particular Rock Phosphate", with the objectives to assess the initial "available" P status of the soils, and its evolution with time and to quantify the uptake and use of P fertilizers by the crops under a variety of soil and climatic conditions. Particular emphasis on enhancing rock phosphate efficiency through technological and biological processes has been given in Venezuela to have reliable data on "available" soil P status and P utilization from phosphate fertilizers under the tropical conditions of the country, standardization of methods for the agronomic evaluation of P fertilizers and to obtain information on the potential harmful effects of P-fertilization on the environment.

In order to study the agronomic effectiveness of Venezuelan rock phosphates and their suitability for direct application, $^{32}P$ was used as a powerful approach for assessing the bio-availability of P and the use of P efficiency in rock phosphate materials applied in tropical soils. Incubation, greenhouse and field studies were carried out to measure: 1) the soil P parameters Intensity (I), Quantity (Q), and Capacity (C); and 2) the crop responses through the quantification of the amount of P derived from the fertilizer (Pdff).

Phosphate fertilizers of different solubility either natural or acidulated from Riecito Rock Phosphate were evaluated in an acid soil (Typic Paleustult) from El Pao, Cojedes State, Venezuela to evaluate their application effect on P bio-availability parameters and the capacity to supply P to annual crops of high P requirements. The treatments were applications of Natural Rock Phosphate Riecito (RR), Riecito Rock Phosphate Acidulated at 40 % (RR40), 60 % (RR60), and Triple Superphosphate.

In the soil incubation experiment, the variables measured after 60 days were: available P (Bray 1), inorganic P fractions (P-Al, P-Fe, P-Ca, P-Ocluded), isotope exchangeable P and retention coefficient. In the greenhouse, several biology experiments were conducted to isolate phosphate solubilizers micro-organisms and to quantify the infective potential of arbuscular mycorrhiza in an agroecosystem in order .to have a "bank" of autochtonous organisms. They will be inoculated to the soil in greenhouse and field experiments to evaluate the effectiveness in solubilizing natural and modified rock phosphate where isotopic techniques will be used. In a field experiment the efficiency of the phosphate fertilizers used was determined by conventional and isotopic techniques at. different times during the corn growing stages. Total dry matter accumulation and P absorbed by the plant at 20, 31, 45 and 60 days were measured.
In the incubation experiment the soil without P applied showed a significant increment on available soil P (Bray 1) after 60 days which was also observed in the soluble P and Al-P. It is concluded that this P comes from the organic phosphorus in the soil. There was also a significant treatment effect on available P (Cp) and the P extracted by Bray I and isotopically exchangeable P (E value). RR showed an intermediate response and the acidulated fertilizers had the higher values of soluble P (0.45 mg/l), E value (6.33-6.47 mg P/kg) and P-Bray (54.7-52.8 mg P/kg). The isotopic evaluation showed that 70 to 80% of the soluble P was derived from the RR, RR40 or RR60. There was a similar value of % Pdff between RR40 and RR60. Increments in the concentration of P in soil solution produced a decrease in the P fixing capacity of the soil (rl/Ro). The value change from 0.55 in the check plot to 0.70-0.72 in the soil with the acidulated fertilizers.

In the greenhouse experiment, several isolates of phosphate solubilizing microorganism and of arbuscular mycorrhiza were made. They will be used in greenhouse and field experiments to evaluate their effectiveness. Isotopic techniques will be used in these experiments.

In the field experiment the dry matter production and P-plant accumulation at 60 days after emergency confirmed the data showed in the unmarked plots. The corn yields increased with the solubility of the fertilizers applied. It was also concluded that the conventional methods overestimate the coefficient of utilization "UP".
Effect Of Acidulation Of Phosphate Rocks Having High Cadmium Content On Cadmium Uptake By Upland Rice

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Potential for Cd uptake by food crops from applied P fertilizers containing significant amount of Cd, has become an important environmental issue. Little information is available in literature on Cd uptake by crops from either phosphate rock (PR) or partially acidulated PR (PAPR). The purpose of this greenhouse experiment was to study the effect of acidulation of two PRs having high Cd content (highly reactive North Carolina PR and low reactive Togo PR) on Cd uptake by upland rice. The degree of acidulation with HZSO4 were 100% for NC-PR (i.e., NC-SSP) and 50%/a or 100% for Togo-PR (i.e., Togo PAPR or Togo-SSP). Separation of confounding effect between P uptake and Cd uptake from various P sources was made by adding 400 mg P/kg as KH2PO4 to all the treatments so that P was not limiting plant growth. Rates of Cd added from various P sources were 0, 50, 100, 200 and 400 gg Cd/kg. Upland rice was grown on two acid soils (Hartsells, pH 5.0 and Waverly soil, pH 5.6) to maturity.

The results showed that Cd uptake by rice grains followed the order of NC-SSP > NC-PR and Togo S SP > Togo PAPR > Togo PR. Total uptake of Cd, Ca, and P by rice plant (roots, straw and grains) was higher from NC-PR than from Togo-PR. This suggests that Cd is associated with Ca and P in the same apatite structure. There was a significant relationship between total Cd uptake by rice plant and DTPA-extractable Cd from soils treated with various P sources. It is concluded that if unacidulated PRs (e.g., NC-PR) and partially acidulated PRs (e.g., Togo-PAPR) are as effective as fully acidulated P source (e.g., SSP) under certain soil and crop conditions, these water-insoluble and partially water-soluble P sources are not only more cost effective but they may also contribute less Cd uptake by crops than the use of water-soluble P sources.
Quantitative estimation of the enhancement effect of water-soluble P on P availability from phosphate rock (PR) has not been reported. The objective of this study was to use radioactive $^{32}$P as a tracer to distinguish P availability from soil, PR, and TSP so that P uptake by crops from PR in the presence of TSP could be estimated. Three sets of 4-kg soil samples of an acid Hartsells silt loam (fine-loamy, siliceous, thermic Typic Hapludult, pH 4.8) were mixed with the following treatments: (i) $^{32}$P solution and central Florida PR (CFPR), (ii) $^{32}$P-tagged TSP, and (iii) $^{32}$P-tagged TSP and CFPR at a P ratio of 50:50. The rates of P applied were 0, 12.5, 25, 50, 100, and 200 mg P kg$^{-1}$. For treatment (iii), an additional rate of 400 mg P kg$^{-1}$ was also prepared. Maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* [L.] Walp. *ssp. unguiculata*) were planted and harvested at 42 d after planting for maize and 45 d for cowpea. The effectiveness of P sources in terms of increasing dry matter yield and P uptake followed the order of TSP > (CFPR + TSP) > CFPR for maize and TSP = (CFPR + TSP) > CFPR for cowpea. Phosphorus uptake from CFPR in the presence of TSP as higher than P uptake from CFPR applied alone, indicating an enhancement effect of TSP on the effectiveness of CFPR. The increase in P uptake from CFPR due to TSP influence, across all the PR rates applied, was 3.48 mg P pot$^{-1}$ for maize and 1.38 mg P pot$^{-1}$ for cowpea. With respect to P uptake from CFPR applied alone, the corresponding relative increase in P uptake from CFPR due to TSP influence was 165% for maize and 72% for cowpea.
Soil P Fertility Replenishment And "<Liming>" Using Phosphate Rocks In Soils With A Low pH And Developed Under Tropical Climates

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The soil P fertility replenishment with a phosphate rock (PR) from Tunisia (Gafsa PR) and its "liming effect" were studied in five tropical soils whose initial pH was lower than 6.0. This PR was applied in its powdered form at five rates (0, 50, 500, 1000 and 2000 mg P kg\(^{-1}\)). The soil-fertilizer mixtures were incubated in wet conditions during 1 month. A complementary experiment has been carried out, by adding 50 mg P kg\(^{-1}\) as TSP on soil previously incubated without and with a PR application at 1000 mg P kg\(^{-1}\). The effects of such applications on bioavailable soil P but also on soil pH and on Ca++, Mg++, K+ and Na+ ion concentrations in the soil solution were determined. To avoid difficulties in interpreting the data obtained using extraction methods, bioavailable soil P was analyzed using the P-32 isotopic exchange kinetic method, which can not only quantify the intensity, the quantity and the capacity factors but also provide information on the ability of soil phosphate to leave the soil particles in order to enter with time into the soil solution. The main results can be summarized as follows: (i) the replenishment of soil P fertility using phosphate rocks can be partly obtained in soils whose pH is really lower than 5.8 and with medium P sorption capacity (ii) the "<liming effect>" of PR must be considered as limited or near zero, but PR can provide calcium ions to soils and/or crops (iii) heavy applications of PR cannot saturate all sorption sites of soil colloidal particles able to fix phosphate ions. Thus a policy of replenishment using high rates of PR applications must be carefully examined before its implementation to predict the soils where such recommendations can be efficient.
Evaluation of Fertilizers, Particularly Rock Phosphate, Derived Soil Phosphorus by Biological and Chemical Methods

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Poland joined the research team executing the project 9352/RO/France in 1997 thanks to the recommendation of FAO/IAEA and extra funding by French Government. Utilization of phosphorus by crops from soils and fertilizers is at present one of the key points for Polish agriculture. Due to economical reasons the consumption of phosphorus fertilizers decreased from about 50 kg, P₂O₅/ha in late 80's to less than 15 kg P₂O₅/ha in mid-90's. The consumption is definitely too low for equilibrating the crop uptake, and gradually increasing the content of available phosphorus in soils poor in this nutrient. The production capacity of phosphorus plants in Poland exceeds by far the present demand and to satisfy farmers requirements most of the phosphorus is supplied in the form of highly processed compound NP and NPK fertilizers. The driving force for sales of these fertilizers is their nitrogen content. The sources of rock phosphate come from Russia, Mediterranean countries and Togo and until 1990 about 6% of total P production was unprocessed phosphate rock (mainly from Tunisia). The idea of the project is to compare, in short-term phytotron test, the relative efficiency of phosphate rock sources with that of highly processed superphosphate in respect to plant biomass and indices of phosphorus availability in acid soil.
Assessment of Phosphorus Availability of Phosphate Fertilizers Using Nuclear Techniques

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Soil samples coming from pot experiments and a long-term field experiment in a red ferrallitic soil of Ciego de Avila, were analysed using the isotopic dilution method with $^{32}$P as a tracer and different chemical methods. Static and kinetic parameters were determined by the method of Fardeau. $E_1$ value and P concentration in soil solution were more affected by the method of fertilizer application than by P rate. It was clear that fresh P application is the best method in this high P fixing soil, in relation to $C_p$, $E_1$ value and capacity factor, respectively. Oniam method, commonly used in Cuba, and Mehlich II both acid extractant methods were not efficient in soils amended with rock phosphate.

Local rock phosphates (Sancti Spiritus, La Pimienta and Trinidad de Guedes) and Riecito rock phosphate from Venezuela were not effective when used directly in the neutral soil under study. Partial acidulation of the PR was not a successful modification for increasing $E$ value although it did increment P concentration in soil solution when the level of acidulation was of 60 % for Riecito PR. Natural rock phosphates were as effective as superphosphate to increase sugar cane yield and production (sugar production) when used at low to medium rates, but the TSP was superior at the highest rate of 200 kg $P_2O_5/ha$. The reactivity of two Trinidad de Guedes PAPR products, as indicated by their solubility in formic acid, citric acid and neutral ammonium citrate showed a potential for their direct application in the near future.
Evaluation Of P Uptake From Minjingu Phosphate Rock And Growth Of Tree Species Growing On An Acid Soil From Western Kenya Using $^{32}$P-Isotope Dilution Technique

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²Kenya Forestry Research Institute, P.O. Box 20412, Nairobi
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A greenhouse experiment was conducted to evaluate availability and uptake of P from Minjingu phosphate rock (MPR) using the $^{32}$P-isotope dilution technique. An acid soil collected from Malava in Kakamega, Kenya and six agroforestry tree species namely Leucaena leucocephala, Ghricitia sepium, Sesbania sesban (legumes); Grevillea robusta, Cassia siamea and Eucalyptus grandis (non-legumes) were used. The isotopic exchange kinetic parameters of the soil solution showed that the soil was high in P fixing ability with the ratio of radioactivity remaining in the soil solution over the total initial radioactivity ($r_1/R$) averaging 0.030 before incubation and decreasing to 0.015 after incubation.

The legumes and E. Grandis showed high P uptake where P was added at 3 months after transplanting (MAT) and an increase of up to 150-250% in growth and P uptake at 6 MAT. Percent P derived from fertilizer (Pdff) at 3 MAT by L. leucocephala, G. sepium and C. siamea from MPR was higher than from TSP. The relative availability of PR (RAID) values showed that these trees derived 2.93, 1.06 and 1.04 times more P from MPR than from TSP, respectively. Grevillea robusta showed preference to soil P rather than the external inorganic P sources throughout the 9 months of the experiment. A Species X fertilizer P interactions were also observed.
Research work for residual effect of P in the second year continued in the greenhouse on the same acid soils (Rangsit soil, Pakchong soil, Warin soil and Mae Tang soil) and in the field trial (Pakchong soil). The materials and methods are the same as in the first year experiment. The results of the greenhouse experiment showed that there was no responsive of P from TSP of soybean in terms of dry matter yield in every representative acid soil. The biomass in the second year of the experiment increased more than in the first year in Rangsit soil and Pakchong soil. Dry matter yield of soybean in Warin soil was somehow lower than yield in the first year. Soybean grown in Mac Tang soil had lower biomass in every treatment than in the first year of the experiment. The ranking of % Pdff and % FPU from TSP and PRs in different in different acid soils would be Rangsit soil > Pakchong soil > Mae Tang soil > Warin soil. The percentage of relative agronomic effectiveness of PRs compared with TSP in the same rate had the rank as Rangsit soil > Mae Tang soil > Warin soil > Pakchong soil. The dominant of % RE of each soil would be Ratchaburi phosphate rock (Rangsit soil) and Algerian phosphate rock (Mae Tang and Warin soil).

Maize had biomass yield in the second year in every soil higher than in the first year. The second year was the third crop residual effect of P. Anyway, Pakchong soil showed the highest increasing yield. Maize had capability to uptake more P from TSP than PRs (% Pdff and % FPU). The Mae Tang soil series gave highest percentage of the relative agronomic effectiveness of PRs Mae Tang soil series.

In the field experiment, grain yield of soybean variety Nakornswan 1 was higher than in the first year (1995). There was no response of P from TSP in terms of yield. The % Pdff, % FPU and % RE at flowering and harvesting stages were in the same trend. North Carolina phosphate rock gave very good agronomic effectiveness to soybean.

Yield of maize variety Sawan 3504 (hybrid) in the second year was lower than in the first year (1995). The % Pdff did not have any change from the first year in both flowering and maturity stages. The percentage of fertilizer phosphorus utilization (% FPU) in both stages were higher than in the first year. Algerian phosphate rock showed the highest % RE among all representative of phosphate rocks.
Characterization Of Soils Used For Experiments By Contractors Of The RCM.
Compared Effectiveness Of Partially Solubilized Phosphates, PR And SSP On Various Soils

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CIRAD has received 45 samples of soils from 12 countries: Austria (2), Brazil (2), Chile (3), China (20), Cuba (2), Ghana (6), Hungary (1), Indonesia (3), Kenya (1), Malaysia (1), Romania (2) and Thailand (2).

The soil conditions to be considered for a direct application of PR are: low available P, low pH (<6.0) for a better dissolution of PR, low saturation rate of the CEC (to have enough space on the complex for the P solubilized).

The granulometric analyses (0-2µ, 2-20µ, 20-50µ, 50-200µ and 200-2000µ) show a huge heterogeneity within the samples; the sands (coarse and fine ones) are representing from 4.5% to 87.3% and the clay from 6.5% to 70.5%. A high percentage of clay can correspond to a high fixation potential of the soil for soluble P. Organic matter ranges from 0.46% to 13.3%. This is resulting in a large heterogeneity when considering the CEC (1.7 to 35.8 meq/100g) and the percentage of CEC saturation (8.7 to 100%).

For the 45 samples analysed, the pH Hz0 is ranging from 4.20 to 8.50. 30 have a pH <6.0 (16 pH are <5.0). As a first approximation, we expect that these soils will be showing an adequate PR dissolution.

17 soils show a percentage of CEC saturation lower than 70% and 16 of them have a pH <5.0, which are both good indications but these soils have also a very low CEC (<10 meq/100g).

Considering the soils with a pH higher than 6 and a high CEC saturation, PR should not be very efficient in supplying P to the crops. Improvement of the effectiveness of the P supply by PR should be investigated.

The preparation of water soluble phosphates (SSP or TSP) from the PR is made using strong acids. Only a fraction of them is used for dissolution of apatite and thus increase of available phosphorus, the remaining acid is used to dissolve some carbonates and release Fe and Al. So the partial dissolution saves acid (when compared to soluble P) and improves the agronomic effectiveness of PR. As they are containing more soluble P, Partially Solubilized Phosphate Rocks can be used in soils with a pH higher than 6.0.
Phosphate rocks from Brazil (Araxa) and Viet Nam (Lao Cal), respectively, from igneous and old sedimentary origins, are not sufficiently reactive for direct application. They were partially solubilized at 60 and 54%, in order to create a starting effect and to keep the production cost as low as possible. These Partially Solubilized Phosphate Rocks (PSP) were compared to reactive PR from Algeria (Djebel Onk) and soluble phosphate (SSP), in a range of soil types and crops representative of each country, in pot experiments and field conditions.

Results showed that Araxa PSP needs to be improved while Lao Cal PSP and Djebel Onk PR are equivalent to SSP in most of the soils tested. Furthermore, they improve the soil fertility by increasing available P content, exchangeable Ca, and decreasing exchangeable Al, contributing to the depression of aluminium toxicity.
Effect Of Methods Of Applying Phosphate Rock Mixed Or Not With Superphosphate

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With the objective of evaluating the effect of Patos phosphate rock (PPR) mixed or not with triple (TSP) or ordinary superphosphate (OSP) on the P availability to rice plant, a pot experiment, using 32P dilution method was carried out. The PPR (0, 500 and 1000 Kg P₂O₅/ha) was applied mixed with the soil, banded near the soil surface or as briquet combined with TSP or OSP (0, 50 and 100 Kg P₂O₅/ha). The TSP and OSP were applied banded as for PPR or in briquet form.

The plants were harvested 63 days after seeding. The pots were then left for a period long enough to allow the applied P-32 for decay and rice was sown again for the residual effect evaluation, through L value technique, applying 3.7 MBq ³²P/pot and 10 Kg P₂O₅/ha (KH₂P0₄) as the carrier.

Mixing PPR with the soil was the worst method for P application as the soil P fixation exceeded the P solubilization, both processes being enhanced by better contact of PR with soil particles. This was probably the reason why the banded application of PPR was better than when it was mixed with the soil. Mixing PPR with TSP or OSP and briquetted increased slightly its efficiency, but the effect of water soluble phosphates did not appear when applied separately.

The residual effects followed the trends observed in the former experiment. The solubilization of PPR, or the balance of solubilization/fixation of P was less than what was expected. A prior incubation study had already shown that the Bray 1 available P decreased with incubation period.
The Role Of Rock Phosphates In Sustainable Agriculture: The Hungarian Experience With Algerian Rock Phosphate

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From the early 60's till the late 80's, in many countries - among them also in Hungary - agricultural production went through a tremendous development. In Hungary there was a 2-3-fold increase in the average yields of winter wheat and maize - the two main crops - in comparison to those of the 50's. One of the main factors determining these developments was the increasing use of mineral fertilizers. From the turn of the century till the late 50's, nutrient balances in Hungary were strongly negative: 20-30 kg/ha/year less N and K2O and 10 kg/ha/year less P2O5 was given to the fields in the different forms (farmyard manure, mineral fertilizer and by-products, etc.), than was removed by the harvested yields. Nutrient balances of P became positive in the early 60's, while balances of N and K in the early 70's respectively. Then, for 20 years, N balances were positive by 10-20 kg/ha/year, while both P2O5 and K2O balances by 30-50 kg/ha/year, respectively. These long-term positive nutrient balances resulted in the NPK enrichment of our soils, which was also proven by the national soil test series. During the 80's, for example, the amount of yearly applied mineral fertilizer was 230-280 kg N + P2O5 + K2O /arable land. In certain regions N leaching could cause environmental damage, while, as a result of the P-Zn antagonism on the fields poorly supplied with Zn, over-fertilization with P resulted in 1-2 t/ha/year maize yield losses.

From the early 90's, however, when political and ecological changes took place in the country, the free market was introduced, and state subsidies on mineral fertilizer were withdrawn, there was a sharp decrease in mineral fertilizer use: applied N dropped to 1/5th, P and K to 1/20th of the amount used in the 80's. This dramatic decrease resulted in the change of nutrient balances: in 1991 the balance for N was -60, for P2O5-30, and for K2O -40 kg/ha for the whole country, respectively. In 1992 and 1993 the situation was similar, while in 1994 a slight increase in mineral fertilizer use was observed.

According to our estimation, mineral fertilization of 150 kg/ha/year N + P2O5 + K2O is sufficient for long-term sustainable plant nutrition in Hungary, if farmyard manure application and the incorporation of by-products remains on the recent level.

During intensive fertilization practice, emphasis was on the quantity, while crop and soil demands for specific or more economic fertilizers were not taken into consideration. For N, lime ammonium nitrate, for P superphosphate, and for K, potash chloride was used on almost the whole area. As a new attempt to find more economic P sources, Algerian rock phosphate was checked in the greenhouse and field trials set up on characteristic acidic soils in different regions of Hungary, as well as other Central European countries. The first two-year results are discussed in the presentation.
Dynamic Of Phosphorus And Phosphate Fertilizer Efficiency In Soils Derived From Volcanic Ash (Chile)

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Only the surface horizon (0-20 cm depth of ten representative volcanic ash-derived soils were sampled in the X Region. It was concluded that these soils are characterized by an acid pH and a high P retention capacity that reaches, in some of them, 99% (Blakemore method). The available P (Olsen) is low to medium. The organic carbon is high to very high and the C/N ratio is high. The Cp values are very low and related to the retention index.

Four soil profiles were sampled in the IX Region. As in the X Region, the C/N ratio was very high. It means that the high summer temperatures and the recently summer showers, during the sampling time, would promote a very high microbial activity and consequently a high oxygen consumption. P retention is over 85% in all soils, except in one classified as Palehumult (Metrenco Soil Series). Nevertheless, P retention, from 72.1% to 78.6%, are considered very high figures for non-volcanic ash soils. In the same way, the A1+1/2 Fe (ox) in all profiles shows high values for non volcanic ash soils. These data confirm the extensive and deep covering of volcanic ashes that has been gradually added in the soils of the Region. The available P (Olsen) gave very low values but normal ones for Andisols. According to the results, it is considered that the forest covered Pinus radiata does not produce an important alteration in the soils, at least for the following parameters: pH, P (Olsen), P retention (Blackmore), total N, CO and C/N. The retention index is less than 0.2. For this reason, these soils classified as a high fixing capacity through the whole profile. The inverse relation (R/ri) of the retention index is very high. That means it is very difficult in some of the soils to increase the available P even when we applied with high rates of phosphate fertilizers. The main limiting factor in both regions is the intensity factor.

In both field and greenhouse trials, it was found that a low utilization efficiency in the case of water-soluble phosphate fertilizers, such as TSP. The phosphoric rock from Bahia Inglesa, show a low efficiency in annual intensive crops, whereas in permanent crops, it showed a residual effect. Although, it is important to mention that in these soils Ca++ is considered the most relevant cation that modifies the physico-chemical components involved in the sorption processes. The phosphoric rock would release Ca++ to the soil solution, producing an increase in the pH, and so an increment of P in the plant derived from the soil (% Pdfs), but not in the P derived from the rock. A combination of TSP and PR as a mixture may be a potential alternative for some of the studied soils.
The Agronomic Effectiveness Of Phosphate Rock On Acid And Limed Soils In Lithuania

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Due to economic, political and social changes the use of mineral fertilizers, especially phosphorus and potassium in Lithuanian agriculture decreased from 653 000 tons in 1985 to 55,000 tons in 1994 resulting in a severe decrease of agricultural crop yields. To improve this extremely negative situation currently prevailing in Lithuanian agriculture cheaper fertilizer sources should be looked for. As 20% of soils are acid, phosphate rock could be one of the alternatives.

With a view to evaluate the agronomic effectiveness of phosphate rock on acid and limed soils a field trial with the following crop rotation (barley sown in mixture with grasses, grasses, winter wheat and fodder beet) will be established in the spring of 1997. The field experiment will be carried out on soddy-podzolic acid soil with a pH level below 5.5.

The objectives of this study are: (i) to assess the agronomic effectiveness of phosphate rock from Maardu (Estonia) deposit, (ii) to compare the effectiveness of phosphate rock with single superphosphate, (iii) to investigate the impact of liming on the effectiveness of phosphate rock, (iv) to evaluate the effect of phosphate rock on yield quality and its components.

The experiment findings will be relevant for the whole Baltic region as the soil, climatic and economic conditions are very similar there.
The Use Of \(^{32}\text{P}\) For The Agronomic Evaluation Of Phosphate Rock

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One pot experiment and three field experiments have been conducted to evaluate the agronomic effectiveness of phosphate rock (PR) and chemical P-fertilizers (TSP, SP-36). In the pot experiment (Experiment I) and the last field experiment (Experiment IV) a crop rotation of upland rice-soybean-mungbean was been done. The two other field experiments, Experiment II and III, have been carried out using lowland rice and corn, respectively. In Experiments I, II and III where \(^{32}\text{P}\) was used to evaluate the agronomic effectiveness of PR and chemical P-fertilizer, it was shown that PR has a lower fertilizer use efficiency (FUE) compared to the chemical P-fertilizers, ranging from 0.26%-29.65% (PR) vs 5.92% to 31.75% (TSP or SP-36) depending on the amount of P(P-rate) applied and the crop used. The same data pattern was shown in Experiment IV where relative FUE was determined. In spite of this, all the field experiments (Experiment II, III and IV) showed that PR were able to increase the grain yield of lowland rice, corn, upland rice, soybean and mungbean. The increase in grain of several crops were quite promising. The lowest yield obtained from PR was as follows, for lowland rice (PR-5117 kg/ha vs 0 P-4617 kg/ha), corn (PR-8.575 t/ha vs 0 P-5.650 t/ha), upland rice (PR-2525.3 kg/ha vs 0 P-17657.8 kg/ha), soybean (PR-622 kg/ha vs 0 P-365 kg/ha), and mungbean (PR-765 kg/ha vs 0 p-438 kg/ha). For mungbean only the residue of P-PR or P-TSP of the two previous crops was used.
Enhanced Plant Growth by Uniform Placement of Superphosphate with Rock Phosphate in Acidic Soils

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Partially acidulated rock phosphate or compacted soluble phosphate-rock phosphate mixture has been suggested as an alternative phosphorus (P) source for plants in acidic soils. Interaction between the soluble and the insoluble fractions would be conducive to plant utilization of both P sources in the fertilizer material. Direct evidence supports the beneficial reactions between the two P sources, however, was still insufficient. A pot experiment was hence conducted to evaluate the possible interaction of 32P-labelled single superphosphate (SSP) and a less reactive rock phosphate (RP) from Jinxiang mine, China. In the experiment, SSP and RP were applied to two acidic red soils (type Hapludults) in a manner that would favour or diminish their interaction either by distributing both P sources homogeneously within the whole volume of the pot soil (uniform placement) or by separating them vertically with each being applied to half of the soil volume (fraction placement). The reference treatments of SSP and RP were arranged in similar manners. Two successive harvests of ryegrass were made during a 2-month period. Results indicated that uniform placement of SSP and RP significantly enhanced plant growth and P uptake, and that P recovery of SSP-P significantly enhanced plant growth and P uptake, and that P recovery of SSP-P in the higher P-fixing soil was almost twice that of the fraction placement. The data of plant PdfL % (percentage of P derived from labelled P), which indicated that>80% of plant P was derived from SSP, however, failed to support the idea that soluble P had increased plant utilization of RP. Alternatively, it is considered that the low grade RP had increased plant utilization of both SSP-P and soil-P. Uniform placement of RP and SSP also strikingly improve plant calcium (Ca) and magnesium (Mg) nutrition. The phenomenon suggested that SSP-RP mixture might be a good P source on similar acidic soils in subtropical China.
IMPHOs Support To The Co-ordinated Research Programme (CRP)

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This presentation is about the work already done by IMPHOS in support of the FAO/IAEA project on the "Use of Nuclear and Related Techniques for Evaluating the Agronomic Effectiveness of Phosphate Fertilizer, in particular Phosphate Rock"

It is useful to stress the fact that IMPHOS does not have groups of scientists, laboratories or experimental stations. Thus, to achieve its objectives, IMPHOS carries out its activities with the assistance of research structures existing in the world within the context of Agreements, similar to the IAEA/IMPHOS Agreement.

This agreement was established in 1996 with the following objectives: (i) to contribute to improving consistency and comparability of the data obtained from the CRP by conducting a "Standard Characterization" of soils and rock phosphates utilized in the network; (ii) to facilitate access to a wider range of rock phosphates to be tested within the network, and; (iii) to contribute to the dissemination of the information generated from the programme and thus increasing the impact of the CRP.

The work already done to achieve these objectives can be summarized in 3 points:

I. Soils Characterization
II. Rock phosphate Characterization
III. Access to wider range of R.P. to test within the network
ANNEX IV

INDICES OF AGRONOMIC EFFECTIVENESS

OF PHOSPHATE FERTILIZERS

F. Zapata

1. CONVENTIONAL INDICES

1. 1. Relative Agronomic Effectiveness = (R.A.E.) (%)

$$\frac{X_1 - X_0}{X_2 - X_0} \times 100$$

$X_1 = \text{D.M. Yield or P uptake at a given P level with PR-based product.}$

$X_2 = \text{D.M. yield or P uptake at the same P level with TSP.}$

$X_0 = \text{D.M. yield or P uptake obtained with check (no P added).}$

1.2 Apparent P Fertilizer Utilization Coefficient (Recovery) = (A.U.C.) (%)

$$\frac{TP_F - TP_0}{AppliedPRate} \times 100$$

$TP_F = \text{Total P uptake in the P fertilizer treatment}$

$TP_0 = \text{Total P uptake in the check (no P added) treatment}$

P rate of application as P fertilizer
2. **ISOTOPIC INDICES**

2.1 **Pdf (%)** - Phosphorus in the plant derived from the fertilizer.

\[
\frac{S.A. \text{- plant}}{S.A. \text{- fertilizer}} \times 100
\]

S.A. = Specific activity in dps or dpm 32P/mg or g.P.

PdfR (%) - P in the plant derived from the phosphate rock.

\[
= 100 \times \left[ 1 - \frac{S.S. \text{plant} - \text{withPR}}{S.S. \text{plant} - \text{noPR}} \right] \times 100
\]

2.2. **Real P Fertilizer Utilization Coefficient (Recovery) = (R.U.C.) (%)**

\[
\frac{PFert.\text{uptake}}{AppliedPRate} \times 100
\]

\[
PFert.\text{uptake} = TP_r \times \frac{P_{dff}}{100}
\]

P rate of application as P fertilizer.

2.3. **RAID (%)** - Relative Availability (agronomic effectiveness) by Isotopic Dilution

\[
= \frac{%P_{dff} - PR}{%P_{dff} - TSP} \times 100
\]

To be utilized only when PR and TSP have been applied at the same P rate.

2.4. **Quantitative Comparison of PR and TSP; Agronomic Evaluation. (Example)**

As = 100

\[A_{S+R} = 150\]

\[A_R = 50 \text{ mg P/kg. as TSP equivalent units by difference}\]

P Rate of Application as PR = 200 mg P/kg

200 mg P as PR = 50 mg P as TSP

4 kg PasPR = 1 kg PasTSP
ANNEX V

P SUB-MODEL

Field & Laboratory Methods for the

IBSNAT Minimum Data Set