REPORT

CONSULTANTS’ MEETING
(311-99CT00069)

on

THE USE OF NUCLEAR TECHNIQUES TO DEVELOP MANAGEMENT PRACTICES FOR INCREASING CROP PRODUCTION AND SOIL FERTILITY IN ACID SOILS

March 1-3, 1999

VIENNA INTERNATIONAL CENTRE
Vienna, Austria

By

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Consultant

and

Felipe Zapata
Scientific Secretary of the Meeting

Soil and Water Management & Crop Nutrition Section
Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
International Atomic Energy Agency
Report of a Consultants’ Meeting on
"The use of nuclear techniques to develop management practices for increasing crop production and soil fertility in acid soils"
Vienna, March 1-3, 1999

1. INTRODUCTION

A Consultants' Meeting on "The use of nuclear techniques to develop management practices for increasing crop production and soil fertility in acid soils" was held in Vienna at the IAEA headquarters from March 1-3, 1999. The meeting was attended by six consultants with expertise in tropical acid soils drawn from International Agricultural Research Organisations and universities together with staff members of the Joint FAO/IAEA Division. The list of participants is given in Annex 1.

The meeting was formally opened by Mr. P. M. Chalk, Head of the Soil and Water Management & Crop Nutrition Section, who explained the purpose of the meeting and gave an outline of the philosophy behind the co-ordinated research projects of the Section. He also explained the desire to link these activities with other similar networks and specifically those involving tropical acid soils.

Mr. Felipe Zapata, the Scientific Secretary of the meeting, outlined the background to the proposed project and gave the general guidelines for the meeting. The programme of the meeting is included in Annex 2.

The consultants’ presentations reviewed advances in approaches for the sustainable intensification of agricultural productivity in tropical acid soils in Latin America, Africa and South East Asia. The summaries of the presentations are given in Annex 3. The consultants also provided recommendations on the formulation and implementation of the future CRP.

2. PROJECT PROPOSAL

Co-ordinated Research Project on the use of nuclear techniques to develop management practices for increasing production and soil fertility in acid soils (IAEA PWB 1999-2000, Project D1.02, Task 4).

The original project proposal written by the Scientific Secretary was thoroughly examined and modified during the second part of the Consultants’ Meeting. Please refer to Annex 4.
3. GENERAL RECOMMENDATIONS

At the end of the meeting, the Consultants formulated the following recommendations:

1. Recommend initiation of a CRP to improve agricultural production of tropical acid soils through the use of adapted plants, the amelioration of soil acidity and infertility and better soil, water, nutrient and crop management.

2. Recommend implementation of the CRP according to the project document included in Annex 4.

3. The target research topics should include:
   • The identification of useful P-efficient and Al-tolerant genotypes through comparison of adapted and susceptible lines
   • The use of plant residues, green manures, rock-P and amendments such as lime to improve nutrient availability and to alleviate Al-toxicity
   • Analysis of C, nutrient and water dynamics in different soil and crop management systems

4. The Research Contract Holders should include NARS partners with:
   • expertise in tropical acid soils particularly acid savannahs
   • some experience in nuclear-based techniques
   Preferably, they should:
   • have experience in inter-disciplinary research in soils, agronomy, germplasm enhancement, etc.
   • be collaborators in research networks or participants in multi-institutional projects

5. The sites to be used should be representative of major problems, have potential for intensification and follow existing farmer practices, and should include on-station and on-farm studies. They should be well characterised, using the same methodologies, with respect to soils, climate, etc., and include existing cropping system experiments (on productivity enhancement or natural resource conservation) such as research on crop rotations with ground covers and/or minimum or no-tillage, improved fallows, with/without legumes and related work on acid soil tolerant germplasm enhancement.

6. Isotope techniques for use in the target topics may include some of the following:
   • $^{15}$N for root studies, nitrogen dynamics (N-fixation, N-transfer, N-fertilizer balance, N losses).
• $^{13}$C for soil organic matter dynamics, root studies, drought stress, water use efficiency.
• $^{32}$P for root studies, P dynamics (P-fixation, P-transformations, P-fertilizer).
• Neutron probe, $^{18}$O for water dynamics.

7. Considering the complexity of C, nutrient and water dynamics in these systems, and the time required to assess genotypic variations in P-efficiency and acid tolerance, it may be necessary to consider an extension of the proposed CRP beyond five years.
ANNEX 1

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CONSULTANTS’ MEETING ON THE USE OF NUCLEAR TECHNIQUES TO DEVELOP MANAGEMENT PRACTICES FOR INCREASING CROP PRODUCTION AND SOIL FERTILITY IN ACID SOILS

PROGRAMME
V.I.C., Meeting Room 10, A-2210

Monday, 1 March 1999

09:00 - 09:30 Opening Session
P.M. Chalk, Head
Soil and Water Management & Crop Nutrition Section

09:30 - 10:00 Remarks by the Scientific Secretary
F. Zapata

10:00 - 10:30 Coffee break

Session I
Chairperson: P.M. Chalk

10:30 - 11:30 R. Thomas
Presentation of the contribution of CIAT (Cali, Colombia)
"Management and conservation of acid soils in the savannahs of Latin America: Lessons from the agricultural development of the Brazilian cerrados"

11:30 - 12:30 R. Lefroy
Presentation of the contribution of IBSRAM (Bangkok, Thailand) “Towards improved management of marginal soils of Southeast Asia”

12:30 - 12:45 General discussion

12:45 - 14:00 LUNCH BREAK
Session II  
Chairperson: R. Thomas

14:00 - 15:00  S.H. Chien  
Presentation of the contribution of IFDC (Muscle Shoals, Alabama, USA) "Fertilizer management for sustainable crop production in acid savannah soils of Latin America and Africa"

15:00 - 15:30  Coffee break

15:30 - 16:30  K. Sahrawat  
Presentation of the contribution of WARDA (Bouake, Côte d'Ivoire) “The role of tolerant genotypes and plant nutrients in the management of acid soil infertility in upland rice”

16:30 - 16:45  General discussion

Tuesday, 2 March 1999

Session III  
Chairperson: R. Lefroy

08:30 - 09:30  W. Horst  
Presentation of EU-funded INCO project (Hannover, Germany) “Fitting maize into sustainable cropping systems on acid soils of the tropics”

09:30 - 10:00  G. Keerthisinghe (IAEA)  
“Role of root-derived organic acids in the acquisition of P from acid soils”

10:00 - 10:15  General discussion

10:15 - 10:45  Coffee break

Session IV  
Chairperson: W. Horst

10:45 - 11:45  T. Bachmann  
Presentation of the contribution of FAO (Rome, Italy) “Restoration of soil fertility in the humid savannas of Côte d'Ivoire"

11:45 - 12:00  General discussion
12:00 - 14:00   LUNCH BREAK

Session V   Chairperson: S. H. Chien
14:00 - 15:30   Formulation of the CRP (Title, Objectives, Approaches)
15:30 - 16:00   Coffee break
16:00 - 17:30   Formulation of the CRP

Wednesday, 3 March 1999

Session VI   Chairperson: T. Bachmann
09:00 - 10:30   Establishment of Guidelines
10:30 - 11:00   Coffee Break
11:00 - 12:30   Guidelines
12:30 - 14:00   LUNCH BREAK

Session VII   Chairperson: F. Zapata
14:00 - 15:30   Conclusions and Recommendations
15:30 - 16:00   Coffee break
16:00   Closing Session

REMARKS
Invited Participants are kindly requested to make written recommendations in the topics discussed according to their field of expertise.
ANNEX 3

SUMMARIES OF PAPERS PRESENTED

MANAGEMENT AND CONSERVATION OF ACID SOILS IN THE SAVANNAHS OF LATIN AMERICA: LESSONS FROM THE AGRICULTURAL DEVELOPMENT OF THE BRAZILIAN CERRADOS

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Acid-soil savannahs represent most of the remaining land suitable for agricultural development in the world. They are considered to be marginal lands as they have low inherent productivity for agriculture and are susceptible to rapid degradation. In Latin America the majority of these lands are found in the Brazilian "cerrados" or savannahs. They were opened up for agriculture some 30 years ago and today they supply a considerable portion of the country's agricultural produce. The development pathway in the cerrados has shifted from extensive grazing on native grasslands to improved pastures and annual monocrops. More recently no-tillage systems have been introduced along with perennial crops and integrated crop-pasture systems. Monocultures of either grain crops or pastures have proved to be unsustainable under today's conditions and alternative production systems are being developed and implemented that incorporate improved production technologies and conservation of the natural resources. No-till, minimum till and integrated crop-livestock systems are proving to be successful in terms of farmer adoption. A number of variations in no-till systems have been developed mainly by farmers in response to climate and/or soil conditions. No-till systems are more productive and economical and are perceived to be more sustainable. However there is a need to elucidate the principles and functioning of these systems in order to assess their suitability for long-term sustainability of the marginal savannah lands. The challenges that remain to ensure that these lands are developed in a more sustainable manner include social, cultural and economic aspects, a favourable policy environment and a clearer understanding of sustainability, its measurement and how farmers perceive this concept. In this article we review the lessons learned from the "cerrados" experience including the scientific breakthroughs made. The relevance of these lessons to other tropical acid soil
savannahs is also discussed. Future research topics are highlighted that include the development of further crop options with tolerance to acid soils, a better understanding of water and nutrient cycles, the development of principles of soil organic matter and crop residue management and the biological management of soil fertility.

THE ROLE OF TOLERANT GENOTYPES AND PLANT NUTRIENTS IN THE MANAGEMENT OF ACID SOIL INFERTILITY IN UPLAND RICE

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Upland rice is the staple food for 100 million people including some of the poorest people in the world. The upland ecosystem in West Africa is very important to rice production. About 70% of upland rice is in the humid zone of the subregion. Like in other parts of the humid tropics, acid-related soil infertility is the major constraint to crop production on low-activity clay soils in the humid and sub-humid zones of West Africa. For increasing and stabilising rice productivity of the acid uplands at reasonable levels, a strategy is needed that integrates the use of tolerant rice cultivars with soil and plant nutrient management.

Research conducted on Alfisols and Ultisols of the humid forest and savannah zones in West Africa showed that upland rice is a very robust crop and possesses a wide range in tolerance to acid soil conditions. Recent research at WARDA also showed that the tolerance to acid soil conditions can be further enhanced through the use of interspecific *Oryza sativa* and *O. glaberrima* Steud. progenies. The development of interspecific progenies has not only increased the rice plant's tolerance to acid soil conditions, but they also possess superior overall adaptability to the diverse upland rice growing environments in the subregion.

Our research in the diagnosis of acid soil infertility problems on the Ultisols and Alfisols of the humid savannah and forest zones indicated that P deficiency is the most important nutrient disorder for upland rice. In the forest zone, response to N depended on the application of P. In the savannah and forest-savannah transition zones, N deficiency is more important than P deficiency. Among other plant nutrients, the application of Ca and Mg (as plant nutrients) did not appear initially as important on the performance of acid-tolerant upland rice cultivars. The results from a long-term study on an Ultisol with four acid-tolerant rice cultivars, revealed that they differed in agronomic and physiological P efficiencies, and the efficiencies were higher at the lower rates of P. The amounts of total P removed in three successive crops were similar for all the four rice cultivars although P harvest index was 10-12% higher in the P efficient than inefficient cultivars. It was suggested that the differences observed in the P efficiency of the rice cultivars are due to
differences in the internal efficiency of P.

It is indicated that the use of new genotypes adapted to the acid soil environments along with proper crop and nutrient management, especially N and P, could provide the basis for a sustainable rice production system.

FITTING MAIZE INTO SUSTAINABLE CROPPING SYSTEMS ON ACID SOILS OF THE TROPICS

W.J. HORST
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Agricultural systems may be called sustainable if the management of the resources for agriculture successfully meets the human needs while maintaining or enhancing the quality of the environment and conserving natural resources. Among the major threats to sustainable soil productivity related to soil acidity are: (i) H⁺, Al and Mn toxicities (ii) low availability (P, Mo) and supply of nutrients (N, Ca, Mg), (iii) high nutrient (base) losses. One of the key elements of sustainable cropping systems is the integration of crops and/or crop cultivars with high tolerance of soil acidity and which make most efficient use of the nutrients supplied by soil and fertilizer. Improved acid soil-tolerant germplasm may contribute to minimise the maintenance fertilizer-applications through different pathways: (i) deeper root growth --> more efficient uptake of nutrients from subsoil --> less leaching, (ii) more biomass production --> less seepage, less leaching, --> more intensive nutrient cycling, --> maintenance of a higher soil organic-matter content, --> less erosion owing to better soil protection by vegetation and mulch.

The main objectives of the EU-INCO Programme ERBIC 18CT 960063 on which this presentation is mainly based, are

- To advance breeding strategies and breed maize cultivars with improved adaptation to acid soils high in Al and low in P.
- To develop screening procedures for aluminium (Al) resistance and phosphorus (P) efficiency in maize based on an improved in-depth knowledge of the underlying physiological and molecular mechanisms.
- To improve the quantitative understanding of the comparative contributions of genetic and agronomic approaches to sustainable maize production on acid soils.

The results suggest that large genetic variability in adaptation of plants to acid soils exist. There is a range of different morphological and physiological plant characteristics that contribute to acid soil tolerance. Their understanding has contributed to develop quick screening techniques for acid soil tolerance. There is a need to better characterise these properties on a molecular basis and to systematically select for them. Incorporation of soil
acidity tolerant plant species and cultivars into cropping systems contribute to improved nutrient efficiency of the overall system and thus reduce fertilizer needs.

The application of nuclear techniques could contribute to facilitate and enhance scientific progress especially in the following areas:

- Quantification of morphological root characteristics and rooting patterns.
- Studying water-use efficiency as affected by soil acidity and plant adaptation.
- Establishment of carbon and nitrogen budgets of cropping systems as affected by soil pH and crop management.
- Quantification of the soil/fertilizer P mobilisation capacity of crops and cropping systems.
- Molecular characterisation of plant adaptation-mechanisms.

RESTORATION OF SOIL FERTILITY AND IMPROVEMENT OF CROPPING SYSTEMS FOR SUSTAINABLE DEVELOPMENT IN THE HUMID SAVANNAHS OF CÔTE d’IVOIRE

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Traditionally production systems in the Savannah were based on shifting cultivation with short cropping periods (sometimes only one year) and long fallow periods (> 15 years). Bush clearing and burning of the fallow vegetation provided the farmers with a relatively fertile soil free of noxious weeds. Often only short cultivation periods of less than three years were possible because of strong weed development. Increasing population pressure (> 20 persons/Km²) has forced farmers to reduce fallow periods (often < 5 years) with the subsequent consequences:

- increasing spread of noxious weeds (e.g. Cyperaceae, Poaceae, Euphorbiacea, Chromolena odorata) which are difficult to control by manual weeding;
- soil fertility declines (i.e. low N, P and soil organic matter content);
- increased susceptibility of soils to water erosion.

Other factors, which contribute to soil fertility decline are:

- higher exportation of organic and inorganic soil nutrients, including the removal of farmyard manure due to a more intensive grazing by the increased livestock population;
- Significant nutrient losses due to the annual bush fires that destroy the biomass of both fallow and crop residues and considerably limit the potential benefits of the fallow on the soil fertility;
the lack of financial resources and scarcity of family labor in the farm have exacerbated the negative impacts on soil fertility under the short fallow production system.

The central issue for improving agricultural productivity in the humid savannah is how to build up and maintain soil fertility despite the low incomes of the small holders and the increasing land and labor constraints they face. The success of the green revolution in Asia, led by the introduction of high-yielding varieties for the more fertile soils has biased research and development in Africa towards plant breeding. However, crop varietal improvement will have only limited impact on small holder farming unless the widespread decline in soil fertility is reversed.

The present FAO-project addresses the soil fertility problems by combining organic with inorganic nutrient sources and actively involving farmers and other beneficiaries in an integrated, long-term development process. A major objective of the project is the participatory on-farm testing and validation of available technological innovations for soil fertility improvement. The results should fulfill two main requirements: (i) provide the farmer with a short-term production increase and (ii) improve/maintain soil fertility in the medium and long-term.

The strategic framework of the project is based on the following three main elements:
- the need to take into account all aspects of soil fertility restoration including areas concerned, cost of fertility restoration, and economic profitability and sustainability;
- the need to test all fertility improving measures at farm level in representative agro-ecozones of the humid and sub-humid savannas before their extension at large;
- the need to identify major macro-economic constraints (e.g. marketing) which impede sustainable agricultural development in the savannah region.

The primary goal of the project is to replace traditional shifting cultivation in the humid savannas of the country by economically, ecologically and socially more sustainable production systems. In order to achieve this development objective the project focuses on the following main issues:
- restoration of soil fertility through improved land and crop management and more efficient use of mineral and organic fertilizers;
- crop diversification through more efficient use of water resources (irrigation);
- introduction of new cropping systems which have been successfully tested in countries with similar agro-ecological conditions;
- adapting traditional land tenure to the market economy;
- involving the private sector in all aspects of regional development assisted by Government through the creation of a favorable environment.

The project will be implemented in three phases:
- Phase 1: constraint analysis and formulation of a pilot project to be financed by donors;
- Phase 2: implementation of the pilot project (1999 - 2003) including a mid-term evaluation;
- Phase 3: long-term extension phase (15 years) starting in 2004, based on successful results of the pilot phase.

The on-going first (diagnostic) phase is expected to produce the following results:
- methodological guidelines for the identification of constraints and test zones (agro-ecological zones and their fertility criteria) and the formulation of technological options for the improvement of soil and crop productivity;
- a document for negotiating the pilot project;
- a regional development program proposal with a particular focus on institutional support and crops with agro-industrial development potential (e.g. maize, soybean and groundnuts).

Technical proposals to be tested at field level.

Weed control: animal traction, herbicides and cover crops.
Inorganic and organic fertilisers for food and perennial crops.
Cropping systems with cover crops: improved short fallow system with legumes, e.g., *Pueraria, Cassia* and integrated food/cover crop system, e.g., maize/*Pueraria*/*Chromolena*

Technologies considered for inland valley swamps
- against iron toxicity: (i) introduction of iron toxicity tolerant rice varieties; (ii) improved inorganic fertilisation
- for better weed control: (i) direct planting of rice with use of herbicides; (ii) transplanting of rice and manual weed control
- against yellow mottle virus: farmer group formation for multiplication of available yellow mottle virus resistant varieties

Technologies considered for peri-urban horticulture:
- against nematodes/bacteria: improved crop rotation
- improved fertilisation: crop-specific balanced inorganic and organic fertiliser application

Technical proposals to be tested at farm level.

Livestock/agriculture integration and improved production and use of farm yard manure
Legumes: inclusion of food legumes and improved fallow with tree/herbaceous/forage legumes.
Water erosion control: soil and crop management on contour lines, and direct planting of crops into mulch of cover crops.
Perennial crops for humid savannahs (anacardium, mango, teak) and the forest transition zone (coffee with wind breaks and shade trees).

Technical proposals to be tested at community level.

Watershed management: improved water control in small scale irrigation perimeters and community erosion control.
Bush fire control: planting of live fences.
Protection of fields against livestock: planting of live fences.
Traditional tree cropping (karité, néré).

TOWARDS IMPROVED MANAGEMENT OF MARGINAL SOILS OF SOUTHEAST ASIA

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Increased agricultural production is required to improve the diets of those currently under-nourished, to increase the standard of living of the poor, and to satisfy the needs of an increasing world population. The marginal lands have been underused while better land has been available, or they have been converted into more marginal land due to degradation resulting from inappropriate management. The driving forces behind the need for increased agricultural production and the nature of the marginal lands differ between regions, but the need for improved management of marginal lands exists in most regions of the world, particularly the developing world, and certainly in Southeast Asia.

The low fertility of marginal soils can be due to inherent infertility or that the fertility has declined through degradation resulting from mismanagement. As such, the need to improve the fertility of inherently infertile soils or restore the fertility of degraded soils can be considered as the capitalisation or, in the case of the degraded soils, recapitalisation of the natural resources. In most cases, phosphorus and nitrogen are the most important nutrients limiting agricultural production, and therefore requiring the greatest capitalisation. Sustainable N replenishment strategies should rely mainly on biological N₂ fixation processes, with limited reliance on supplementation with chemical fertilizers. Conversely, it is likely that P replenishment strategies will remain predominantly fertilizer-based, although with as much use of biological supplementation as feasible. As such, fertility management requires adaptation of the farming systems and of the strategies for amendment with inorganic and organic sources.
Once management strategies have been established to improve the N and P fertility of soils, the status of other nutrients may or, in time, limit production. Consequently, the initial focus on P and N management must be expanded to an integrated plant nutrient management approach.

The process of soil fertility capitalisation, or recapitalisation, involves three important steps. Firstly, appropriate strategies need to be identified. These can come from identification of the best local practices, from introduction of best practices from other areas, or from adaptation of current local or introduced practices. Secondly, an accurate assessment must be made of where particular strategies will work. This involves sufficiently detailed understanding of the underlying processes so as to match the strategies with particular agroecosystems, through consideration of biophysical factors, as well as social, economic, political, and cultural factors. The third stage is how to implement the designated strategies. Again, this involves consideration of both the biophysical and socioeconomic, and can have important implications on policy development if policy intervention is required for implementation.

The objective of the IBSRAM ASIALAND Management of Acid Soils network is to contribute to the process of improving management of infertile marginal soils, with a particular focus on improved management of phosphorus in the acid upland soils of Southeast Asia. This is undertaken through collaboration with partners in the national agricultural research and extension systems (NARES) of Viet Nam, Philippines, Indonesia, Myanmar and Thailand, with advanced research institutes (ARI) in Australia and New Zealand, and with other research and development agencies working in the region.

Although there is a large body of research work on phosphorus, a number of knowledge gaps exist. There is reasonably good understanding of management of phosphorus with inorganic fertilizers, less detailed information on management with organic forms, and limited information on the interaction of organic and inorganic forms. In addition, methods for efficiently matching management strategies to particular farming systems are limited. Practical recommendations are required that improve the synchrony of phosphorus supply and plant demand through management of organic and inorganic phosphatic sources. A major aim of this network is to contribute to reducing these knowledge gaps through undertaking quality research. Critical to developing and assessing these issues of improved management is the use of multidisciplinary and interdisciplinary approaches within the biophysical and the socio-economic context. An expected outcome of this approach is a significant improvement in the capacity of all the collaborators, as individuals, as institutions, and as groups of institutions, to undertake quality collaborative research, development and implementation towards improved sustainable land management.
As development of more agricultural lands is limited in highly populated Asia, the greatest potential for expanding crop production to feed an increasing world population lies in the tropical savannah regions dominated by acid, infertile soils (Oxisols and Ultisols) of Latin America and Africa. The major soil-related chemical constraints of acid savannah soils are deficiency of most of the plant nutrients plus aluminium (Al) toxicity and high phosphorus (P) fixation.

Phosphorus is probably the single most widespread limiting nutrient on plant growth in Oxisols and Ultisols. Use of conventional water-soluble P fertilizers such as TSP or SSP at high P rates can be agronomically effective but may be economically prohibitive to resource-poor farmers. Under certain conditions, use of indigenous phosphate rocks (PR) and modified PR products such as partially acidulated PR (PAPR) or compaction of PR with TSP/SSP are potentially attractive alternatives to the use of water-soluble P fertilizers, both agronomically and economically, in increasing crop production on acid Oxisols and Ultisols. Additionally, reactive PR sources may provide Ca nutrient and reduce Al saturation that in turn may reduce Al toxicity to plants. Some PR sources may also contain micronutrients such as Zn, Mo. A combination of the effects of proper P and nitrogen (N) management including biological N fixation, judicious use of lime, and the development of acid soil tolerant and/or P-efficient cultivars in a sustainable cropping system can provide an effective technology to increase crop yield in these acid savannah soils.

Nuclear techniques including $^{15}$N and $^{32}$P isotopes as tracers are powerful tools to study: (1) efficiency of N and P from mineral and organic sources, (2) transformations of N and P in soil, (3) biological N fixation, and (4) recycling of N and P in the soil-plant system. It was shown that Sechura PR (Peru) was 78% as effective as TSP in biological N fixation by soybean in an Ultisol. The enhancement effect of water-soluble P on the agronomic effectiveness of PR in an Ultisol was also quantified. Thus, the use of nuclear techniques is essential to implement the proposed CRP on acid soils.
ANNEX 4

PROJECT DOCUMENT

1. Title of the CRP:

   Development of management practices for sustainable crop production systems on tropical acid soils through the use of nuclear and related techniques

2. Justification

   As a result of the increasing world population, there is a need to increase food production. This can be achieved through intensification, diversification and specialisation of agricultural production systems in existing cultivated land or by expansion of the land under cultivation. Currently, about 40% of the potentially arable land resources are cultivated world-wide. The greatest potential for expanding agricultural land lies in the tropical rainforest and savannah regions dominated by acid, infertile soils. It should be noted however, that the cultivation of marginal lands and the lack of appropriate soil management and conservation practices on the better lands, have resulted in an accelerated rate of degradation of the natural resource base. Therefore, the required increased food production must be achieved without further degrading the resource base. Much of the required production will have to come from agro-ecologies that are capable of supporting more intensified production systems.

   Acid soils, mostly Oxisols and Ultisols, cover 1.7 billion ha, approximately, 43% of the world’s tropical land area; with 64% of tropical South America, 38% of tropical Asia and 27% of tropical Africa. The problems of acidic soils are likely to increase, with increasing CO₂ levels in the atmosphere. In addition, more land in developing countries is becoming acidic due to the use of ammonium-based nitrogenous fertilisers, removal of farm products and nitrate leaching.

   The most favoured lands are concentrated in the savannah agroecosystem. The savannah area is located in the sub-humid tropical zone, and comprises a sizeable amount of the agricultural land in many countries of Africa and Latin America. In terms of agro-climatic conditions, the savannahs represent the most suited conditions for rainfed conditions. In Africa the savannahs have historically produced all of the sorghum, millet, cowpea, much of the maize, yams and groundnuts and more recently large amounts of cassava, soybean, cotton and upland rice.
In view of the above, several international agricultural research organisations have focused their activities on identifying technologies suitable for the savannah regions. IFDC has carried out extensive research on fertiliser management on the acid savannah soils of Africa and Latin America. IITA, CIMMYT and CIAT have given special attention to the improvement of maize for savannah conditions and followed more recently by an EU-funded project to study mechanisms for tolerance of maize to Al and develop user-friendly sustainable technologies to mitigate soil acidity. CIAT has also developed new agropastoral systems for the savannahs that can improve soil fertility and quality. ICRISAT has major programs on sorghum, millet and groundnuts. IITA has also active programs on soybean and cowpea. ICRAF has also studied the potential for agroforestry. WARDA is working extensively on rice production in inland valleys located through the savannahs. In addition, networks have been created to integrate national efforts into regional programmes and improve the flow of technology from the IARCs into the regions. As a result of all these efforts, many technologies are available for the savannahs. However, there are significant gaps in the development and transfer of the technologies to the farmers. Consequently, agricultural production in the savannahs remains far below its potential.

There are several examples (maize, cassava, and soybean), that illustrate the potential technological improvements that are available to stimulate food production within the moist savannahs on a sustainable basis. Similarly, there are improved technologies for other crops such as yams, cowpea, etc., albeit not of the magnitude of maize, upland rice, cassava and soybean. A key issue that has not been sufficiently addressed and that is lacking for the majority of the farmers in the savannahs is the improvement of resource management/conservation technologies that are vital for sustainable agricultural production.

In summary, bridging the gap between the potential and actual production of the savannahs is possible using improved technologies to intensify crop production while conserving the resource base. This can result in a major contribution to food security in Sub-Saharan Africa and Latin America.

In line with the strategic objective of the subprogramme D1 of the Joint FAO/IAEA Division an integrated approach to soil, water and nutrient management for sustainable crop production in the savannah ecosystem is proposed. For more information, please refer to the document Strategy Plan of the sub-programme D1.

The proposed project will focus on three main lines of investigation:

1. Utilising acid-tolerant and P efficient genotypes.
2. Addressing issues of acid soil infertility.
3. Developing good management and conservation practices for acid savannah soils.
This division is arbitrary because these areas of research are closely inter-related. In most cases, combined approaches will be required. It is envisaged that the work will be implemented via an eco-regional approach, identifying specific benchmark areas as focal points for strategic research and development activities.

Natural resource conservation will be enhanced by promoting production intensification on the better lands combined with the use of biological approaches for nutrient management and soil conservation.

Several nuclear techniques have potential to study the topics to be addressed in this project. These include, the soil moisture neutron probe for soil water studies and root activity, N-15 techniques for measuring N cycling (N recovery from organic residues and chemical fertilisers, biological nitrogen fixation, etc.) in soils, crops and water; P-32 techniques for evaluating soil P dynamics and the agronomic effectiveness of P fertilisers, in particular phosphate rock-derived products; C-13 for measuring decomposition rates of organic residues and identification of sources of organic matter in soil organic C pools, Cs-137 for measuring soil erosion at the landscape level, etc.

The proposed CRP will be conducted through the creation of a network of National Agricultural Research Systems (NARS) and International Agricultural Research Centres (IARCs). Synergies will be enhanced through appropriate linkage to existing networks on acid savannah soils. Close collaboration will be established with the AGL and AGP Divisions of FAO in Rome.

The improved technologies developed under this project should be transferred to the farmers, who are the beneficiaries of the project. To ensure direct transfer of the results and the expected impact from the outputs, several activities will be implemented to disseminate the information generated through the project: the results should be published in local and international journals. Whenever possible field trials should be done in farmers’ fields and close links should be established with extension services. Also, data base formation and validation of models should be considered.

The Agency’s involvement is justified in that:

* isotopes (stable and radioactive) and radiation techniques are essential to obtain a quantitative estimate and subsequent evaluation of soil, water and nutrient management practices as well as to monitor the value of the interventions.

* the objectives of the proposed project are in line with project D1.02 (IAEA PWB 1999-2000), with the overall strategy set in the medium term plan of the sub-programme D1, and with the strategic objectives of the FAO’s Department of Agriculture.
* the research approaches envisaged are highly relevant to a number of Member States with high potential agricultural land in the savannah ecosystem.

* the proposed CRP will entail the formation of a network of international and national research institutes working on tropical acid soils. Experimental guidelines will be developed to address the main priority areas in an integrated manner using nuclear techniques. Promising results will be disseminated to end-users through appropriate links to extension networks and by conducting on-farm trials.

3. **Overall Objective**

To develop integrated soil, water and nutrient management (SWNM) practices to increase and sustain productivity of tropical acid soils.

4. **Specific Research Objective**

Improve agricultural production of tropical acid soils through the use of adapted plants, the amelioration of soil acidity and infertility and better soil, water, nutrient and crop management.

5. **Expected Outputs**

Expected outputs from the CRP should include:

i. Acid-tolerant and P-efficient genotypes that have been screened and validated
ii. Data on carbon, nutrient and water dynamics that have been obtained using nuclear-based techniques
iii. Improved SWNM practices, with appropriate guidelines
iv. A database of results from on-station and on-farm experiments
v. Enhanced human skills and institutional capacities for on-farm and on-station research on integrated SWNM practices
vi. Satisfactory communication of results

These outputs together with the goal and purpose statements are presented in a logical framework matrix below.
6. Project logframe

<table>
<thead>
<tr>
<th>Narrative summary</th>
<th>Verifiable indicators</th>
<th>Means of verification</th>
<th>Important assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal</strong> (overall objective): To develop integrated SWNM practices to increase and sustain productivity of tropical acid soils.</td>
<td>Farmers adopt better SWNM technologies</td>
<td>Changes in land use patterns, crop yield data</td>
<td></td>
</tr>
<tr>
<td><strong>Purpose</strong> (specific objective): Improve agricultural production of tropical acid soils through the use of adapted plants, the amelioration of soil acidity and infertility and better soil, water, nutrient and crop management.</td>
<td>Crop yields increase Crop production efficiency increased per unit input Soil and water quality improved</td>
<td>Crop yield data Data on soil quality indicators (soil organic matter, nutrient contents)</td>
<td></td>
</tr>
<tr>
<td><strong>Outputs:</strong> 1. Acid-tolerant and P-efficient genotypes tested (screened and validated)</td>
<td>Acid-tolerant and P-efficient genotypes and screening techniques available</td>
<td>Lists of genotypes</td>
<td>Genotypes and seed supplies available from partners</td>
</tr>
<tr>
<td>2. Carbon, nutrient and water dynamics assessed using nuclear-based techniques</td>
<td>Data on carbon, nutrient and water fluxes</td>
<td>Publications and project reports</td>
<td>Partner institutions have the facilities and capacities, with IAEA lab support, to undertake isotopic studies</td>
</tr>
<tr>
<td>3. Improved SWNM practices identified with appropriate guidelines produced</td>
<td>Improved practices and guidelines available</td>
<td>Guidelines Publications Project reports</td>
<td>Partner institutions have the facilities, capacities and commitment to undertake cropping</td>
</tr>
<tr>
<td>Narrative summary</td>
<td>Verifiable indicators</td>
<td>Means of verification</td>
<td>Important assumptions</td>
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<tr>
<td>4. A database of results from on-station and on-farm experiments created.</td>
<td>Database established</td>
<td>Database available</td>
<td>Database sharing agreement</td>
</tr>
<tr>
<td>5. Human skills and institutional capacities for on-farm and on-station research on integrated SWNM practices enhanced</td>
<td>NARS personnel skills enhanced</td>
<td>Quality publications and presentations</td>
<td>Committed NARS staff participate</td>
</tr>
<tr>
<td>6. Results communicated</td>
<td>TECDOC, journal and conference papers published</td>
<td>Publications available</td>
<td>Significant results obtained and manuscripts submitted</td>
</tr>
</tbody>
</table>

**Activities:**
1. Form a research network
2. Organise 1st RCM to agree on work plans
3. 2nd RCM to evaluate progress in implementation
4. 3rd RCM to evaluate SWN management practices
5. Final RCM to present all results

|------------|-------------------------------|-------------------------------|-------------------------------|

**WORKPLAN**

The focus of the proposed project is to better understand problems of agricultural production systems of tropical acid soils and improve them through the use of adapted
plants, the amelioration of soil acidity and infertility and better soil and crop management.

7.1. Target topics

The target topics include:
1. Identification of adapted genotypes - the usefulness of adapted germplasm compared with susceptible lines in terms of P efficiency and Al tolerance.
2. Use of plant residues, green manures, rock-P and amendments such as lime to improve nutrient availability and to alleviate Al toxicity.
3. Analysis of C, nutrient and water dynamics in different soil and crop management systems and the development of guidelines for improved soil, water and nutrient management.

7.2. Site/partner selection:

The following criteria should be considered in the selection of sites and partners:

Sites that are:
- Representative of the main problems of acid soils, with potential for intensification and operating with existing farmer practices (on-station and on-farm studies).
- Well characterised in terms of soil type, depth, water table, and available climate data.
- Presently have or that plan to have, existing cropping system experiments on productivity enhancement/natural resource conservation, e.g., should include combinations of crop rotations with ground covers and/or minimum or no-tillage, improved fallows, forage or grain legumes.
- Related work on acid soil tolerant germplasm enhancement.

NARS partners with:
- Expertise in tropical acid soils and particularly savannah acid soils.
- Some experience in nuclear-based techniques.
- Preferably experience in inter-disciplinary approaches (soils, agronomy, germplasm enhancement)
- Preferably a collaborator in an existing research network or participant in multi-institutional projects

7.3. Isotope techniques for use in the target topics:

- $^{15}$N for root studies, nitrogen dynamics (N-fixation, N-transfer, N-fertilizer balance, N losses)
- $^{13}$C for soil organic matter dynamics, root studies, drought stress, water use efficiency
- $^{32}$P for root studies, P dynamics (P-fixation, P-transformations, P-fertilizer recovery)
- Neutron probe, $^{18}$O for water dynamics
7.4. Other Resources required.

Laboratory support from the Agency at Seibersdorf, as well as from the Agreement Holders will be essential to implement the activities of this CRP. It is also envisaged that strategic support through technical contracts will be required.

7.5. Timeframe

<table>
<thead>
<tr>
<th>Activity</th>
<th>1999</th>
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<th>2001</th>
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<td>Activity 5</td>
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Activity 1.
Consultants’ Meeting (March 1-3, 1999). Submission of project proposal for approval by NA subcommittee
Form a network of national and international agricultural research institutes.
The proposed CRP will involve 10 Research Contract Holders from NARS in developing countries and 4-5 Research Agreement Holders from CGIAR and advanced institutes. March -September 1999 - Receipt of research contract and agreement proposals. Deadlines by end of September. Selection criteria are given in point 6.2 above.

Activity 2.
Organise 1st RCM to present the overall work plan of the project and discuss and agree on the experimental plans and protocols for the next 18 months. For this purpose, the attendance of all contract and agreement holders will be essential. Initial training workshop at the Seibersdorf Laboratory. Preparation of the report of the First RCM.
**Activity 3.**

Organise 2\textsuperscript{nd} RCM to evaluate results from the experimental plans elaborated at the first RCM. Training workshop, topic(s) to be defined during the first meeting. A critical examination of the first two years implementation will be made based on the progress reports of the participants and modifications/adjustments of the work plan of the project will be included, if necessary to ensure the achievement of the objectives. Discussion and agreement on the follow-up experimental plans for the next 18 months. Preparation of the report of the Second RCM.

**Activity 4.**

Organise 3\textsuperscript{rd} RCM to evaluate the results obtained on soil, water and nutrient management practices for the tropical acid soils and the methods to assess nutrient supply from organic and inorganic sources. Training workshop on database creation and modelling. Preparation of guidelines for the “on-farm” field trials. Provision of IAEA guidelines for preparation of final reports and summaries, and publication of IAEA Technical Documents (TECDOCs). Preparation of the report of the Third RCM.

**Activity 5.**

Organise 4\textsuperscript{th} RCM to present the final reports of the CRP. In the light of the objectives of the CRP to critically examine the outputs/achievements, to draw conclusions and to formulate recommendations for further research.

**Activity 6.**

Provision of the CRP database to the FAO integrated database. Development of guidelines on improved soil, water and nutrient management practices for intensification of agricultural production in tropical acid soils on a sustainable basis. Synthesise and disseminate information collected through scientific publications and IAEA technical documents (TECDOCs).
7.6. Inputs

7.6.1 Financial resources required (In US $)

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<tr>
<th>Item</th>
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<th>2001</th>
<th>2002</th>
<th>2003</th>
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<tr>
<td>Research Conracts¹</td>
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<tr>
<td>Co-ordination Meetings</td>
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<td>48,000</td>
<td>48,000</td>
<td>48,000</td>
<td>50,000</td>
<td>Vienna</td>
</tr>
</tbody>
</table>

¹This includes cost of fertilisers and chemicals.

7.6.2 Other resources required.
Some strategic research will require financial support through technical contracts.

8. Assumptions

- Adequate (inter-disciplinary teams) staffing and field/laboratory facilities to implement integrated activities on soil, water and nutrient management.
- National institutes will be selected on an eco-regional approach, each representing a benchmark area to act as the focal point for developing and transferring improved technologies for tropical acid soils.
- The research contract obligations are fulfilled.
- Additional training of junior staff, as required.
- Both on-station research and on-farm experimental trials will be implemented.
- Contractors will publish their research results and utilise proper mechanisms for transfer of the results to the beneficiaries: the farmers.
- Agreement holders will provide strategic support to implement the main elements of the project.
This CRP will address the sustainable agricultural production of tropical acid soils along three main lines of investigation: i) utilisation of acid-tolerant and P-efficient plant genotypes, ii) addressing issues of acid soil infertility, and iii) developing improved soil management and conservation practices. The overall objective is to develop integrated soil, water and nutrient management practices to increase and sustain productivity of tropical acid soils. The focus of this project will be the acid soils of the savannah ecosystem in the humid and sub-humid tropics of Africa and Latin America. The project will be implemented through 1999 with researchers having an active involvement in existing networks in tropical acid soils and experience in multi-disciplinary approaches.
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