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NETWORKING OF INSTITUTIONS IN DEVELOPING COUNTRIES TO PROMOTE MUSHROOM BIOTECHNOLOGY AND BIOCONVERSION TECHNOLOGY FOR SUSTAINABLE INDUSTRIAL PRODUCTION AND PROCESSING

The network will set in motion the initial phase of a programme to strengthen key national organizations, in particular those in developing countries, working in the mushroom industry. Emphasis will be on research, development, and training relating to industrial mushroom biotechnology and bioconversion technology at levels ranging from the simple to the sophisticated. An international network of organizations and institutions that will support the mushroom and related biotech industries and promote the conservation of valuable mushroom genetic resources will be created. The network involves the development of: (1) a computerized database on mushroom biotechnology, institutions, and mushroom collections actively working on various aspects of mushroom biotechnology (2) implementation of international networking and collaboration, and (3) a mushroom depository and gene bank qualifying as an international depository authority.

BACKGROUND AND JUSTIFICATION

Mushrooms are a high-protein (19-35 percent of dry weight), nutritious food for household consumption, a good local market item, raw material for industrial processing, and a potential export product. Some types of mushrooms are grown for medicinal and healthfood properties; extracts from shiitake mushroom, for example, are being studied for use in the treatment of AIDS and of cancer.

Recent technological developments in artificial cultivation, strain improvement and post-harvest processing are making possible new opportunities for mushroom production. Low-value agricultural and industrial residues instead of high-value tree logs, can now be used for cultivating Shiitake mushrooms. Fastidious species such as matsutake and truffles usually collected from the wild can now be cultivated in association with trees in tree plantations. Modern biotechnological techniques such as genetic manipulation can be applied to produce improved strains, and fermentation in bioreactors can be used to prepare high-quality mushroom mycelial products.

Mushroom production in various forms and in varying degrees of technological sophistication represents an important opportunity for developing countries in the different regions of

the world, ranging from agri-based developing countries in Africa to semi-industrialized countries in Asia and Latin America, to more industrialized countries such as Hong Kong. In the late 1980's and early 1990's, mushroom production has increased significantly in terms of quantity as well as value. In China alone, production increased almost 300 percent in a five year period with exports earning of \$225 million in 1990.

At present, edible mushrooms are making a significant contribution to the diets of millions of people. In view of the rapid disappearance of forests and a deteriorating food supply in rural areas in many developing countries, the promotion of mushroom biotechnology is important, socio-economically as well as environmentally. Production is labor-intensive and land-conserving, utilizes agricultural and industrial wastes, and it is suitable for small-scale industrial promotion.

Recognizing its potential and the opportunities offered by recent developments in mushroom biotechnology, the Industrial Decade for Development of Africa's Expert Group Meeting on the Applications of Biotechnology to Food Processing in Africa, organized by UNIDO in December, 1991, concluded the following:

"The cultivation of edible mushrooms embodies the conversion of domestic, agricultural, and industrial organic wastes into digestible nutrients, such as proteins and vitamins through solid state fermentation. It is considered one of the most economically viable processes for the bioconversion of lignocellulosic waste materials. Huge quantities of these materials are generated annually and much of it is either burned, shredded and/or made into compost. The technique for cultivation of mushrooms can be simple and low-tech, as in rural farming of Volvariella and Pleurotus mushrooms, but it can also be highly sophisticated involving the use of advanced technology and equipment, as in Agaricus and Lentinus production in urban areas. Currently, edible mushrooms are mainly cultivated in industrialized countries and a few Asian countries. Although hardly practiced in Africa, mushroom cultivation offers the potential to enrich the human diet with high quality protein and to increase the economic welfare of the people in this region. Relatively little is required in terms of equipment, facilities, capital, and land. The substrate residue, left after mushroom harvesting, can be converted into feedstock for ruminants and/or used as a soil conditioner. The introduction of mushroom cultivation in Africa should start with the selection of mushrooms

acceptable to the consumer taste in the region. From these mushrooms, cultures with the genetic capacity to form fruiting bodies under suitable growth conditions could be selected. The next steps involve the development of spawn, the preparation of compost, and mycelial (spawn) running."

A study, that included visits to a number of Asian countries to review the status of technology and assess the feasibility of establishing an international programme to promote mushroom biotechnology with special emphasis on helping developing countries brought forth the following findings:

(1) Although the cultivation of edible mushrooms dates back many centuries, research in this field is still relatively new and limited to certain scientific institutes in developed countries. Only in recent years have research and extension laboratories been established in a few developing countries through the aid of national and international agencies.

(2) The activities centered around mushroom studies have achieved global dimensions and hold many long term implications. These include the conservation of mushroom germplasm as part of the need for wider protection of the Earth's biological diversity which has emerged as a matter of serious international concern. However, progress in mushroom cultivation and the development of the industry are dependent upon the collective efforts of scientists from both industrialized and developing countries. To achieve the most effective collaboration, an international research and training programme for mushroom studies should be established.

(3) Mushrooms are produced in both the more-developed and the less-developed countries under a wide range of conditions. These conditions range from outdoor cultivation in relatively primitive facilities to indoor cultivation in insulated, vapor-proof buildings fitted with highly sophisticated, computerized, environment-control systems. An examination of the history of the cultivation of Agaricus bisporus shows that, in many countries, cultivation has become virtually independent of external climatic conditions. Progress towards similar independence has also been achieved for other cultivated mushrooms and it is likely that the trend towards more precise climatic control will continue.

(4) The absence of systematic government support and promotion of mushroom growers appears to be responsible in part for the failure for some countries to sustain a viable mushroom

cultivation programme. In countries with thriving mushroom cultivation industries (e.g., Korea, Taiwan), a coordinated government policy allots production quotas for each grower and provides price guarantees for those quotas; thereby reducing some of the financial uncertainty associated with the enterprise. In countries where no such coordinated government involvement exists, potential growers are dissuaded from entering into the business.

CURRENT TRENDS

Mushroom biology is a new discipline concerned with the scientific study of mushrooms, the findings of which can be readily applied to industrial product development (biotechnology). It deals with all aspects of mushrooms, including taxonomy, germplasm conservation, development, nutrition, physiology, genetics, cultivation, medicinal and tonic attributes, taste properties and toxicity. Over the past three years, mushroom production has increased by 72.5% with an annual increase of 24.5%. In 1991, world production of edible mushrooms totalled 4,273,000 metric tons which were valued at about US\$8.5 billion. Because of their unique taste and flavor and their use as medicinal tonics, the cultivation of mushrooms will be continued as a means of increasing food production. Their importance to medical research and in the development of beverages, pharmaceuticals and even cosmetics will offer new opportunities for industrial development.

Many developing countries do not have technological resources or the scientific competence to take up bioscience research and development. Many do not have the technical capability to develop scale-up and down-stream industrial processes. Educational systems often are not geared to the biotechnological education and training of the high quality, multidisciplinary researchers that are required. A lack of critical mass of scientists and engineers also prevents research institutions from undertaking multidisciplinary research that can bring biotechnology to fruitful results. In support of bioscience research UNIDO has already undertaken a major initiative. In 1983 there was established an international program pursuing fundamental and applied research in molecular and cell biology for the benefit of developing countries. The International Centre for Genetic Engineering and Biotechnology (ICGEB) has two major research components located in Trieste, Italy, and New Delhi, India. There are 17 affiliated centers in 45 member countries. The most important aspect of the ICGEB

scientific programme is capability building: the short- and long-term training of high quality scientists. These scientists return to their countries to perform high-quality research as well as to provide local industries with the state-of-the-art know-how, essential for product development. Considering that the ICGEB is the only operating laboratory in the field of genetic engineering and biotechnology established within the auspices of the United Nations system of organizations, the ICGEB is indeed a unique scientific resource for the developing world.

In August, 1993, the First International Conference on Mushroom Biology and Mushroom Products will be held by the Chinese University of Hong Kong. The conference will be jointly sponsored by international agencies and industrial corporations with an interest in mushrooms and their products. It will serve as a forum for participants from both developed and developing countries to present and share the most recent advances in mushroom biology/biotechnology and to explore opportunities for future research and cooperation. The Conference will also allow participants from academic, industrial and government sectors to interact in identifying the needs and potentials for the industrial exploitation of mushrooms in such areas as food production, nutrition and health care, and waste bioconversion.

A Steering Committee to formulate an international network will be convened during the period of the Conference by an UNIDO international consultant. It is UNIDO's intention to use the opportunity offered by the Conference to link the scientific programme of the ICGEB vertically and extend capability building for developing countries into mushroom biotechnology.

PROBLEMS ADDRESSED

(1) With the rapid disappearance of natural forests there is danger of losing many species of wild mushrooms, many of which have high ability to decompose lignocellulosic materials. Other species are considered exotic edible species fetching high prices in the market - as delicacies or, increasingly more importantly, as medicines. Conservation of these valuable genetic resources is essential, and the active participation in conservation efforts of scientists as well as the residents of rural communities in developing countries is very desirable.

(2) The introduction of reforestation programmes using non-indigenous fast growing tree species also changes natural

ecosystems in many communities. This often results in inappropriate conditions to the growth of most, if not all, indigenous mushrooms. On the other hand, studies indicate that some mushroom species exhibit a tolerance for a wide range of environmental conditions. Such mushroom species can be introduced or adapted for propagation or cultivation in the new ecosystems, providing additional incentives for tree planting campaigns to combat desertification.

(3) Many rural communities in developing countries are familiar with mushroom picking in the wild; however, residents are not familiar with artificial cultivation nor with other industrial potentials of mushrooms and mushroom products. Education and training can help to create more employment opportunities, promote the bioconversion of wastes, and produce more food and valuable industrial products in such communities.

(4) Some obstacles to increased commercialization of mushrooms include lack of access to quality spawn, poor distribution of information, and a lack of training programmes. Other difficulties may involve shortage of technical expertise, a lack of appropriate technical support services, and a lack of cooperative activities and technical regional/international programmes for exchange of information and experiences.

(5) During the past few years much progress has been made in the industrial production of mushrooms and mushroom products. However, these major developments are confined to a few countries. Promoting R&D in mushroom biotechnology, information dissemination, and technology transfer is desirable in developing countries. Such efforts can help provide diversification of agriculture and industry appropriate for small-scale industrial development.

(5) Although there are a number of informal collections of mushroom strains, none is internationally recognized as an official culture depository authority, with capability for identification and certification. Under the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Protection, deposits of individual cultures are required at the Institution/country given an International Depository Authority by World Intellectual Property Organization (WIPO).

THE PROJECT

(1) Project Objectives

- a. Development of a technological support system for promoting mushroom biotechnology in developing countries through the establishment of a network.
- b. The promotion of conservation of mushroom genetic resources and the bioconversion of agricultural and industrial wastes for the production of mushrooms and mushroom products.

(2) Project Outputs

A report with recommendations to UNIDO in setting up a computerized database on mushroom biotechnology which will also include:

- a. Recommendations for necessary steps to be taken in establishing a mushroom depository/gene bank at the Chinese University of Hong Kong, qualifying as an international depository authority
- b. A list of major national institutions active in mushroom biotechnology research and development to include mushroom culture collections.
- c. A short list of potential focal points to serve as regional and subregional nodes/resource centers
- d. A workplan for implementation of networking activities, including potential funding sources, i.e., Phase II and Phase III, and draft project document.

(3) Project Activities

a. Preparatory Phase (July - September, 1993)

These preparatory activities are planned under the current UNIDO initiatives under the 1993 regular budget. At the First International Conference on Mushroom Biology and Mushroom Products in August, 1993, in Hong Kong, UNIDO will take the opportunity to carry out the following preparatory activities:

Activity I: Presentation of a summary report of a UNIDO study on the review of mushroom biotechnology at the Conference. This Conference will disseminate information on the current status of mushroom biotechnology and the report will promote the UNIDO proposed international programme on mushroom biotechnology. A preliminary identification of and discussion with potential member institutions and organizations will be made at this Conference. Outputs: A review report on mushroom biotechnology in developing countries and a preliminary list of organizations interested in participating in the proposed Network.

Activity II: Formation and first meeting of the Steering Committee for the proposed Network. Outputs: A working Steering Committee for the Network and a policy guideline/framework for the proposed Network.

b. Proposed Project Phase: Phase I (3 months, October - December, 1993)

Activity III: Development of a Mushroom Biotechnology Database and Information Network. The Chinese University of Hong Kong has been active in research and development in mushroom science and the International Mushroom Society for the Tropics is located there. UNIDO proposes to support the development of a mushroom biotechnology database designed to provide information service support to the Network. An international expert/consultant with experience in bioinformatics and a working knowledge of microbial culture collections will be engaged to assist the Chinese University of Hong Kong in designing and developing the computerized database. Partial financial support will be necessary for initial data collection, processing, and system development.

It is anticipated that once the Network is launched (in 1994) the data and information on mushroom biotechnology, including mushroom culture collections will be available to member organizations through subscribed E-mail service on a cost-recovering basis. Linkage to the ICGB

scientific programme will be facilitated when appropriate, and the Network database will be linked to ICGEBNet, the on-line information service providing access to various biotechnology databases. Selected information to developing countries will also be published in the quarterly UNIDO Genetic Engineering and Biotechnology Monitor and made available, in printed form to interested persons without access to computer facilities.

Outputs: A Mushroom Biotechnology Database and Information Network (MUSHNET). Other related outputs are a list of major national institutions active in mushroom biotechnology research and development to include mushroom culture collections and a short list of potential focal points to serve as regional and sub-regional nodes/resource centers.

Activity IV: Preparatory steps in the development of a mushroom depository and gene bank. Although there are a number of informal collections of mushroom strains, none is internationally recognized as an official culture depository, with International Depository Authority status having the capability for identification and certification. Under the Budapest Treaty on the International Depository Authority by the World Intellectual Property Organization (WIPO). The Chinese University of Hong Kong has the potential to serve as the Mushroom Depository for developing countries. UNIDO proposes to request an expert/consultant to advise UNIDO and the University in necessary procedures to be followed for the University to acquire the International Depository Authority.,
Outputs: A timetable and workplan for establishing a Mushroom Depository and GeneBank with International Depository Authority.

c. Future Plan: Phase II (To be prepared)

Activity V: Development of a mushroom depository and gene bank. UNIDO proposes to strengthen and support the Chinese University of Hong Kong in acquiring the International Depository Authority for a mushroom depository authority and gene bank. Technical and advisory service and partial

financial support will be required to assist the University in the preparation for requesting the authority and in the preparation for providing services, which will be on a cost basis.

Outputs: A mushroom Depository and Gene Bank with International Depository Authority.

Activity VI: Final meeting of the Steering Committee.

A meeting of the Steering Committee will be convened towards the later part of the project period in Hong Kong to assess the project achievements and formulate a plan for future networking activities including financial arrangement and management of the Network on a sustainable basis. Potential regional focal point coordinators will also be invited for consultation.

Outputs: A plan for sustainable operation of the proposed Network.

d. Future Plan: Operational Phase (Phase III) 3 years, January, 1995 - December, 1997) (to be prepared).

Future major activities for the proposed Network on Mushroom Biotechnology are anticipated to include the following:

(i.) Information services. The mushroom biotechnology data base and network (MUSNET) will be linked to the ICGEB-Net of the UNIDO International Centre for Genetic Engineering and Biotechnology and made available through the Microbial Strain Data Network (MSDN), an international network of microbial, cell line and biotechnology information resources.

(ii.) Depository and support services. The mushroom gene bank at the Chinese University of Hong Kong can serve as an official depository for valuable mushroom germplasms for commercial purposes and for safe keeping. The validation and certification of the cultures can also be made.

(iii.) Strengthening of selected regional and national nodes/resource centers in developing countries. Such activity is vital to provide necessary technological backup support for the promotion of regional and national development of

mushroom and mushroom related industries including diversification of bioconversion of agricultural and industrial wastes.

(iv.) Initiating collaborative research in mushroom bioscience and biotechnology. Biotechnology research capabilities of developing countries are limited. Research collaboration and networking offers an efficient means to augment complementarily existing research capabilities and capacities. It provides a more systematic and comprehensive R&D approach to a given problem of common interest and offers a greater chance to successfully complete useful research with broad application in a more cost-effective manner. Part of the collaborative research work can be performed at a more advanced or better equipped partner laboratory, in particular at the Mushroom Research laboratory of the Chinese University of Hong Kong. Sharing of research facilities and on-the-job training of mushroom scientists and researchers can also be achieved.

(v.) Organization of training on field support services. In order to strengthen the technical and management capabilities of modern mushroom research laboratories in providing the technical field support services normally required for effective transfer and application of the technology, especially for small-scale entrepreneurs in developing countries, regional training programmes will be organized. A regional approach is considered to be more effective, both in terms of experience-sharing and in terms of similarities in socio-economic and environmental conditions. The training programme will be developed and organized in close collaboration with the Network coordinating organization (the Chinese University of Hong Kong) and in cooperation with experience Network member organizations in the respective regions.

REPORTING AND EVALUATION REQUIREMENTS

1. Reporting. A progress report will be prepared one month after this phase is completed.

2. Expected follow-up. The development of the database and the strengthening of the host institution of the proposed Network will lead to an enhancement of the quality of the Network's programme design and, consequently, effective mobilization of additional resources for funding Phases II and III.

Working Steering Committee will meet 23-26 August at the Chinese University of Hong Kong

Coordinator:

Prof. Philip G. Miles, Depart. of Biological Sciences,
State Univ. of New York at Buffalo, USA

Members:

Dr. John A. Buswell, The Chinese Univ. Of Hong Kong

Dr. Virginia Campbell, Biotechnology and Genetic
Engineering Unit, UNIDO, Vienna, Austria

Prof. S. T. Chang, The Chinese Univ. of Hong Kong

Mr. Erjin Cheng, Deputy Dir., Bureau of International
Cooperation, Academia Sinica, Beijing, China

Dr. John Ferchak, Appropriate Technology International,
Wash., D.C., USA

Dr. A. Hodder, FAO, Rome, Italy

Prof. Da-Kang Song, Institute of Microbiology, Academia
Sinica, Beijing, China

Dr. G. Tharun, Carl Duisberg Gesellschaft, Southeast Asia
Programme Office, Bangkok, Thailand