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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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BIODIVERSITY OF MICRO-ORGANISMS AND INSECTS FOR FOOD AND AGRICULTURE: STATUS AND NEEDS

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BIODIVERSITY OF MICRO-ORGANISMS AND INSECTS FOR FOOD AND AGRICULTURE: STATUS AND NEEDS

I. INTRODUCTION

1. At its Tenth Regular Session, the Commission on Genetic Resources for Food and Agriculture requested its Secretariat to document the status and needs of sectors of genetic resources for food and agriculture, other than plants and animals, including the various areas of biodiversity for food and agriculture. The Commission, at its current Session, would then decide on the Commission's Multi-Year Programme of Work (MYPOW).¹
2. The Commission also requested its Inter-Governmental Technical Working Groups, on Plant, and on Animal Genetic Resources, to make inputs for the development of the draft MYPOW. The Working Group on Plant Genetic Resources identified "the biological impact of micro-organisms of agricultural importance on sustainable agriculture and quality food production" as an important emerging issue that the MYPOW might need to address.²
3. Following that meeting, the Italian Ministry of Agriculture and Forestry (Ministero delle Politiche Agricole e Forestali), in collaboration with the Council of Research in Agriculture (Consiglio per la Ricerca e la Sperimentazione in Agricoltura), prepared a document to provide background information on food, entomopathogenic, phytopathogenic and soil micro-organisms, and requested that this be put at the disposal of the Commission.³ The Government of Italy has offered to support the establishment of a working group on micro-organisms.
4. Also shortly following the meeting, the Fifth International Symposium of Genetic Resources in Latin America and the Caribbean was held in Uruguay and discussed emerging issues for the conservation and sustainable use of micro-organisms. A document reflecting the outcomes of this international meeting has been prepared by the Government of Uruguay, which requested that this be put at the disposal of the Commission.⁴ It provides background information in a number of areas, including biological control, food and plant growth micro-organisms; the status of collections; and the use of micro-organisms as environmental indicators.
5. The Background Study Paper, *The sustainable management for biological control in food and agriculture*, provides information on the use of micro-organisms and invertebrates, in the context of biological control.⁵ Bioversity International has recently prepared an exhaustive study of agricultural micro-organisms, *Technical issues relating to Agricultural Micro-organisms including their characteristics, utilization, preservation and distribution*, and has kindly agreed to put this at the disposal of the Commission.
6. This document considers the importance for food and agriculture of micro-organisms and invertebrates, drawing, as well, on the work of FAO units on various aspects of this subject. It briefly describes their role and functions throughout the food chain, and identifies trends in their conservation and sustainable utilization. Proposals are then made to initiate coverage of micro-

¹ CGRFA-10/04/REP, paragraphs 83-91.

² CGRFA/WG-PGR-3/05/REPORT, *Report of the Third Session of the Intergovernmental Technical Working Group on Plant Genetic Resources for Food and Agriculture*, (26-28 October 2005), paragraph 43.

³ CGRFA-11/07/Circ.1, *Food, entomo-phytopathogenic and soil micro-organisms*.

⁴ CGRFA-11/07/Circ.2, *Importancia de los recursos genéticos microbianos: cuestiones emergentes identificadas en el Quinto Simposio de Recursos Genéticos para América Latina y el Caribe*.

⁵ Background Study Paper 38. *The sustainable management of biodiversity for biological control in food and agriculture*. The document, *The ecosystem approach applied to food and agriculture: status and needs*, (paragraphs 36-39) deals with the same subject, in the context of Integrated Pest Management.

organisms and invertebrates within the Multi-Year Programme of Work of the Commission, and the Commission's guidance is sought.

II. THE IMPORTANCE TO SUSTAINABLE FOOD PRODUCTION OF THE BIODIVERSITY OF MICRO-ORGANISMS AND INVERTEBRATES

7. This document treats together micro-organisms and invertebrates, in particular insects, given their similar and complementary roles in the provision of essential services along the food chain. Both components of biodiversity, referred also as "hidden" biodiversity, are at the basis of the ecosystems on which food production depends. Few of these organisms are domesticated but many are consistently associated with food production ecosystems, and the integrated strategies used for enhancing their contribution to productivity and resilience are in many cases common. Although these similarities exist, the Commission may decide to deal with these different components of biodiversity for food and agriculture in a separate manner, once the scope for future work has been clearly identified.

8. Despite considerable interest in specific areas regarding micro-organisms and invertebrates, and the existence of substantial and diverse culture collections, the breadth of the subject has meant that the sector has so far received little systematic attention. This is likely to change in the near future, as the importance of the management of micro-organisms and invertebrates is increasingly recognized as an important emerging area in international policy discussions.

9. Micro-organisms and invertebrates together are the most numerous group of species on Earth. Micro-organisms include the diversity of yeasts, bacteria and fungi; invertebrates comprise insects, arachnids, and earthworms. Agricultural production and food processing depend heavily on this "hidden" biodiversity. Plants and animals cannot grow optimally without them; crops are pollinated by insects. Fungi and other micro-organisms establish mutually beneficial symbiosis with the roots of agricultural plants and the guts of ruminant livestock. Both micro-organisms and invertebrates play major roles as bio-control agents, and in the degradation and recycling of organic matter in soils. Micro-organisms also provide beneficial services in food processing. In addition to beneficial organisms, micro-organisms and invertebrates also act as plant and animal pests and diseases. In this case, increasing the understanding of these adverse species, including their genetic variability, is critical, in order to find remedies to these pathogens.

10. It is increasingly recognized that the understanding and management of this biodiversity is crucial in overall sustainable development, with important economic contributions.

- Estimations of the global value of pollinator services vary widely, from US\$ 112 to 200 thousand million annually. In the United States alone, the annual contribution of wild pollination services has recently been estimated at over US\$ 3 thousand million annually.⁶
- For years, FAO has promoted integrated pest management (IPM) through conservation of natural enemies as a way of reducing chemical pesticide use. Asia rice yields have increased as pesticide use has declined: in Indonesia alone, an annual pesticide subsidy that reached more than US\$ 140 million in 1987 was eliminated by 1989.⁷
- In Uruguay, the value of nitrogen-fixing bacteria in forages and soy-bean, is estimated to save country around US\$ 150 millions annually, based on of the cost of replacing fixed nitrogen with manufactured fertilizer.⁸

⁶ See the bibliographical references in CGRFA-11/07/Inf.15.

⁷ Kenmore, Peter. 1996. *Integrated Pest Management in Rice*. In *Biotechnology and Integrated Pest Management*. CAB International.

⁸ See CGRFA-11/07/Circ.2.

- Recent developments in genomics and applied biotechnologies are rapidly increasing the appropriable value of micro-organism genetic resources. In the mid-1990s, the economic value of micro-organisms worldwide was “at least many tens of billions of US dollars”.⁹

11. One of the main challenges ahead is ensuring that all countries can take advantage of this beneficial biodiversity. While improving the management and use of micro-organisms and invertebrates can bring substantial benefits to both developed and developing countries, developing countries, which are richest in this biodiversity, often lack the means to fully benefit from it.

12. The following paragraphs discuss the different roles and functions of micro-organisms and invertebrates for food and agriculture. Trends in their management and use are identified.

Biodiversity for biological control

13. Biological control – the use of living organisms as pest control agents – draws upon a highly diverse and poorly known component of crop-associated biodiversity, consisting principally of invertebrates and microbial predators, parasites and pathogens, which act as natural enemies of pests, diseases and weeds.¹⁰ Biological control has a long history, in both developed and developing countries.

14. The conservation of natural enemies in crops underpins IPM, by providing a self-renewing level of pest control. It is easily disrupted during agricultural intensification, particularly through excessive use of pesticides. The conservation of natural enemies has particular value in securing planned future increase in crop production, particularly in the developing world, and in avoiding local pest outbreaks.

15. Invasive alien pest species disrupt local pest management systems and threaten agricultural production. Pest outbreaks can severely hamper international trade. But the planned introduction of natural enemies is an important, proven tool in managing alien pests, and has particular value in restoring IPM systems and addressing pest management emergencies. Its value will increase as globalization intensifies national alien pest problems. It is principally a public sector activity, because natural enemies will usually reproduce and spread, benefiting many farms

16. Augmentation, the repeated application of natural enemies, has developed where self-renewing biological control cannot be achieved, in the public and private sectors. Commercial augmentative products constitute only a few percent of the global market in pest control products, but are highly competitive in a growing number of situations where chemical pesticides are considered ineffective, difficult to use, or undesirable for health or environmental reasons.

17. There is a long and successful tradition of cooperation between countries and regions in the sharing of biological control agents. International development assistance continues to be particularly active in supporting the process.

Pollinators

18. In the past decade, the international community has increasingly recognised the importance of pollinators as an element of agricultural diversity, as described in the information document, *Pollinators: neglected biodiversity of importance to food and agriculture*.¹¹ Pollinators play an important role in maintaining and increasing yields and quality in vitamin-rich fruits and vegetables, fibre crops, such as cotton, and forages such as alfalfa. Good pollination has a greatly

⁹ Holmes, Bob. 1996. *Life Unlimited*. New Scientist.

¹⁰ Background Study Paper 38.

¹¹ CGRFA-11/07/Inf.15.

under-appreciated importance in seed production, with the potential to improve the sustainable use of plant genetic resources for food and agriculture enormously. Better conservation and management of pollinators is critically important for the health, nutrition, food security, and better farm incomes of poor farmers.

19. Mounting evidence points to a potentially serious decline in populations of pollinators due to changing land-use patterns, excessive use or inappropriate application of pesticides and other agro-chemicals, climate change, and invasive species.

Soil Biodiversity

20. Soil organisms contribute a wide range of essential services for the sustainable functioning of ecosystems. They act as the primary agents of nutrient cycling, regulating the dynamics of soil organic matter, soil carbon sequestration and greenhouse gas emission; modifying physical soil structure and water regimes; enhancing nutrient acquisition by vegetation; and enhancing plant health. Such services are not only essential to the functioning of natural ecosystems, but constitute an important resource for the sustainable management of agricultural systems.

21. Agricultural practices have significant positive and negative impact on soil biota. An integrated approach to agriculture should therefore seek to enhance the biological efficiency of soil processes, in order to maintain soil fertility, productivity and crop protection. Apart from their value in modern agriculture, such an approach is of major importance in marginal lands to avoid degradation; in degraded lands in need of reclamation; and in regions where high external input agriculture is not feasible.

Biodiversity in food and feed processing, and in other agro-industrial uses

22. *Food micro-organisms:* For millennia, humans have taken advantages of the fermentation by food micro-organisms. A variety of yeasts, bacteria and fungi are used in food processing: bread, cheese and yogurt, beer, wine, and fermented meats. Apart from affordable ways of food preservation, micro-organisms bring additional nutritional and organoleptic qualities to fermented foods, and inhibit the growth of pathogens. Because of their potential for adding value in food production, the economical significance of food micro-organisms is increasing. At the same time, there is a risk of genetic erosion, as the widespread use of a reduced number of selected cultures in more uniform products for larger markets, coupled with changing food treatment and agricultural practices, diminishes the diversity of local food micro-organisms.

23. Interest in functional food micro-organisms is reflected by growing popularity of probiotic foods in many quarters. Recent scientific work has suggested that probiotics play an important role in immunological, digestive and respiratory functions, and could have a significant effect in alleviating infectious diseases in children and other high-risk groups.

24. *Micro-organisms in ruminant livestock:* the rumen of livestock animals hosts a range of microbes which assist in the breakdown of otherwise indigestible forages, such as those with high tannin. They also enhance fibre and cellulose digestion and degrade anti-nutritional compounds.

25. *Micro-organisms for biofuel production:* Yeasts, and occasionally some bacteria, are used to ferment carbohydrates derived from sugar-rich plants such as cassava, sugar beet or sugar cane to ethanol.

Biodiversity of pest and diseases

26. With globalization, the spread and occurrence of pest and diseases is increasing. Understanding the biology, ecology and genetics of these adverse species is crucial in finding rapid and effective solutions for these major threats to food and agriculture.

27. For plant diseases, collecting and characterizing the genetic diversity of disease pathogens has assumed strategic importance. The availability of a broad range of pathogen isolates allows researchers to set up diagnostic tools to identify and detect the target organism, and its track evolution as a response to selection pressure. Enhancing the sustainable use of plant genetic resources for food and agriculture, through breeding new resistant varieties, depends on the availability of the genetic resources of both agricultural plants and of the adverse micro-organisms affecting them.

28. The same is true for animal disease.¹² Recent animal disease crises, such as avian influenza, have shown the need to collect, characterize and exchange the genetic diversity of animal diseases, and for the expansion of the genomic databases of these species. Sharing strains, samples and sequences is a critical element of international cooperation for the surveillance and control of these highly pathogenic organisms. The challenge remains how developing countries can make full use of the results of this multilateral exchange.

Trends in conservation

29. Micro-organism and invertebrate biodiversity is a crucial component of the functioning of the world's agro-ecosystems, and vital for the maintenance of their capacity to adapt to change. The number of species involved is almost incalculable, in the range of millions. In collecting and describing them, priority needs to be given to those of greater agricultural importance. In any case, *ex situ* conservation is only technically feasible and cost-effective for certain micro-organisms. The key to conserve and managing the biodiversity of micro-organisms and invertebrates of importance to food and agriculture is therefore to design integrated sustainable management strategies that conserve this resource for the future and enhance the delivery of ecosystems services, such as soil health, pollination and biological control, which contribute to the livelihoods of farmers and rural communities.

30. The future availability of key micro-organisms can be ensured through *ex situ* conservation, and micro-organisms culture collections have been established throughout the world during the last century by national institutes, as well as by a number of international organizations, and even the private sector (although mostly associated with specific research and development programmes).

31. National efforts to collect micro-organisms have been more fragmented compared, than for agricultural plants. Collections have usually relied financially on specific programmes in universities or national institutes, and too often their maintenance has been associated with the interest of one curator. Many collections face technical problems such as contamination, or difficulties for setting identification standards, and many have yet no accessible electronic database. Many collections are not replicated elsewhere.

32. Some countries are moving towards centralization of curatorial responsibilities, and there are efforts for the rationalization and connection of collections at regional level, in particular in developed countries. Micro-organism collections are being pooled with collections of other culturable organisms, into "Biological Resource Centres". These centres also provide databases of molecular, physiological and structural information relevant to these collections, and related bioinformatics. They are also repositories of biological resources for protection of intellectual property.

33. Material Transfer Agreements and Memoranda of Understanding have become more common in the exchange of micro-organisms in the last decade. The rapid rate of reproduction of the organisms, and the potential for change during culture (re-selection) are important factors to be taken into account in developing exchange instruments. In-trust agreements could be

¹² See Background Study Paper No.18, *Opportunities for incorporating genetic elements into the management of farm animal diseases: policy issues*, available at <ftp://ftp.fao.org/ag/cgrfa/BSP/bsp18e.pdf>.

established with relevant international organization, in order to improve legal certainty of their collections, and a basis for exchange. Biosecurity measures, including quarantine, are making more difficult the exchange of micro-organisms, and facilitation of exchange may be another field for international consideration.

34. The *in situ* conservation of micro-organisms is seen by some researchers as an emerging issue. The development of *in situ* initiatives for agricultural plant and animal diversity could provide opportunities for associated maintenance of micro-organisms populations.

Trends in sustainable utilization

35. A number of sustainable management strategies for micro-organism and invertebrate biodiversity have succeeded in demonstrating their importance for ecosystem service, such as soil health, pollination or biological control. The management of this biodiversity is often environment-specific. Sustainable use depends on improving the capacity to identify this biodiversity, and to undertake ecological research to understand their role and services in agricultural systems and monitor their status. It also depends on the capacity to improve agricultural practices through an ecosystem approach,¹³ so that the benefits arising from this biodiversity are maximized, and to remove perverse disincentives that limiting its use.

36. Measures should be taken to improve our understanding and use of such biodiversity, including the improvement of research, collections and services in agricultural research systems. Economic valuation of the ecological services provided by micro-organisms and invertebrates serves as a tool to communicate their value. Building awareness of the value of this biodiversity is important to enhance its sustainable use, especially at the level of policy-making. The challenge is to ensure that the sustainable use of biodiversity that provides important ecosystem services is made an explicit element of national and international policy for sustainable agriculture and food security.

37. Establishing national programmes for the use of micro-organisms and invertebrates as biological control agents has to be seen as a long-term investment at national level. Developing countries that lack such national frameworks benefit from the continued availability of biological resources accessed from elsewhere. Such access allow experiment with the resources and their adaptation to national needs, and can be a first step in developing full-fledged programmes.

38. An obstacle to sustainable use is the lack of manufacturing capacity for products using micro-organisms in developing countries, including limited strategies for mass production, and the absence of quality standards. Legal frameworks to register and regulate use of this important biodiversity are also often inexistent, or have been built for other purposes, and this affects, in particular, the use of native and introduced species, and of products produced by local small- to medium-sized enterprises.

III. MAPPING THE INTERNATIONAL ENVIRONMENT

39. The following paragraphs briefly introduce a number of international organizations and forums that are active in relation to the biodiversity of micro-organisms for food and agriculture. This mapping is not exhaustive: a broader scoping exercise could be undertaken, once the Commission decides how to initiate coverage of micro-organisms and invertebrates in its MYPOW.

40. A number of international instruments on biodiversity, biosecurity and intellectual property rights are relevant to the subject matter, including the Convention on Biological Diversity (CBD), WIPO's Budapest Treaty on the International Recognition of the Deposit of

¹³ See CGRFA-11/07/15.4, *The Ecosystem Approach applied to food and agriculture: status and needs*.

Micro-organisms for the Purposes of Patent Procedures, and the FAO Code of Conduct on the Import and Release of Biological Control Agents.

41. FAO's activities on the biodiversity of micro-organisms and invertebrates during the last biennium are reported to the present Session.¹⁴ FAO facilitates and coordinates the only two international initiatives that the CBD Conference of Parties has set up to specifically deal with the biodiversity of micro-organisms and invertebrates, namely the *International Initiative for the Conservation and Sustainable Use of Soil Biodiversity* and the *International Initiative for the Conservation and Sustainable Use of Pollinators*. That these initiatives are in the framework of work on agricultural biodiversity demonstrates their importance for food and agriculture. In addition, FAO has a long tradition of work in the field of biological control, and in particular IPM.

42. Through these initiatives FAO has built partnerships to harness the benefits of biodiversity through an ecosystem approach. The future work of the Commission could therefore build on and strengthen cooperation with existing partners. These include a number of the observers in the Commission. The Centre of Agriculture and Biosciences International (CABI) and the International Centre for Insect Physiology and Ecology (ICIPE) have both reported to this session on their on-going activities on micro-organisms and invertebrates.¹⁵ The Consultative Group on International Agricultural Research (CGIAR) has collections of micro-organisms and is analyzing technical issues with regard to their utilization, preservation and distribution. Many civil society organizations are active in the field. New partners could also support future work in the field include the World Federation of Culture Collections (WFCC), which promotes activities that support the interests of culture collections and their users, and is part of the International Union of Biological Sciences and the International Union of Microbiological Societies. It seeks partnership, in appropriate activities, with other international organizations, including FAO.

43. A number of regional and inter-regional initiatives are also relevant. The Organisation for Economic Co-operation and Development (OECD) is undertaking work with regard to Biological Resource Centres, including the possibility of establishing a global Biological Resource Centre (BRC) network to enhance access to biological resources and foster international collaboration. The OCDE considers "a global BRC network will have to be co-ordinated with existing international frameworks to establish a functional network. One is the FAO's Intergovernmental Commission on Genetic Resources for Food and Agriculture. It is an example of how international organisations can help coordinate and harmonise the frameworks under which BRCs (in this case limited to biological resources for food and agriculture) operate. The FAO's Intergovernmental Commission links plant (and more recently also animal and micro-organism) resources across the globe to enhance the world's food security".¹⁶

44. Some regions regularly hold technical seminars, such as the International Symposium of Genetic Resources in Latin America and the Caribbean, which deals with plant, animal and micro-organisms in an integrated manner.

IV. GUIDANCE SOUGHT FROM THE COMMISSION, IN INITIATING COVERAGE IN THE MULTI-YEAR PROGRAMME OF WORK

45. This document provides a first description to the Commission of the importance for food and agriculture of the biodiversity upon micro-organisms and invertebrates, in particular insects.

¹⁴ See CGRFA-11/07/20.1, *Reports from FAO on its policies, programmes, and activities on agricultural biological diversity: (1) Sectorial Matters*.

¹⁵ See CGRFA-11/07/19.1, *Reports from international organizations on their policies, programmes, and activities on agricultural biological diversity: (1) United Nations and other Inter-Governmental Organizations*.

¹⁶ *Biological Resource Centres: underpinning the future of life sciences and biotechnology*, OCDE 2001

The matter is complex, the scope of work is broad, and organization of future work therefore needs to be planned in a step-by-step manner.

46. A first substantive discussion of the key issues in micro-organisms and invertebrates could be undertaken at the Thirteenth Session of the Commission. In order to prepare such discussion, the following steps are proposed, to allow the Secretariat to best programme its work:

- In preparation for this discussion, the Secretariat, in cooperation with relevant organizations and with the necessary guidance from the Commission, would provide a brief scoping study for the information of the Commission at its Twelfth Session. The study will relate to the diversity of functions and services provided by micro-organisms and invertebrates. It will give a picture of the current policies and programmes of relevant international organizations, including the status of international collections of micro-organisms, providing an initial identification of policy gaps, and possibilities for strengthening international cooperation.
- The Commission could then prioritize emerging issues that could be further analyzed through background studies. These would be prepared for the Thirteenth Session, if adequate resources are available.
- Between the Twelfth and Thirteenth Sessions, information could be gathered about the status and trends of national programmes and collections, identifying gaps and priorities to be addressed.
- The Commission will review the overall status of its work in this field at the Fifteenth Session.

47. The Commission may wish to emphasize the importance of this neglected biodiversity for food and agriculture, and call for cooperation to enhance awareness of its value for the present and future. It may also wish to consider how FAO and other relevant organisations can reinforce their practical support to developing countries in the sustainable management of the biodiversity of micro-organisms and invertebrates, in particular insects, for food and agriculture.