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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 9 of the Provisional Agenda

INTERGOVERNMENTAL TECHNICAL WORKING GROUP ON AQUATIC GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Third Session

1–3 June 2021

REVIEW OF THE WORK ON BIOTECHNOLOGIES FOR THE SUSTAINABLE USE AND CONSERVATION OF GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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I. INTRODUCTION

1. In 2011 and 2015, the Commission on Genetic Resources for Food and Agriculture (Commission) reviewed the latest developments in biotechnologies and their implications for the conservation and sustainable use of genetic resources for food and agriculture (GRFA).[1] The Commission's Multi-Year Programme of Work foresees for the Commission's forthcoming Eighteenth Regular Session another "review of the work on biotechnologies for the conservation and sustainable use of genetic resources for food and agriculture."[2]

2. Because of the wide array of different technological applications "that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use",[3] FAO usually uses the term "biotechnologies" rather than "biotechnology". Biotechnologies encompass many disciplines, including genetics, molecular biology, biochemistry, embryology and cell biology, and range from "low" to "high" technology.

3. This document provides a brief overview of FAO's activities on biotechnologies and reviews the work of FAO and the Commission's Working Groups on the application and integration of biotechnologies in the conservation and sustainable use of GRFA. It covers the period from July 2014 to October 2020. The document *Recent developments in biotechnologies relevant to the characterization, sustainable use and conservation of genetic resources for food and agriculture*[4] presents a brief overview of recent advances in biotechnologies and bioinformatics in the field of GRFA.

II. FAO'S ACTIVITIES ON BIOTECHNOLOGIES FOR THE SUSTAINABLE USE AND CONSERVATION OF GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Dissemination of updated information on the role of biotechnologies

4. At its Fifteenth Regular Session, the Commission requested that FAO continue regular dissemination of updated factual information on the role of biotechnologies in the characterization, conservation and utilization of GRFA through its existing databases, networks and newsletters, also emphasizing the communication of biotechnologies developments to the public.

5. FAO organized the International Symposium on the Role of Agricultural Biotechnologies in Sustainable Food Systems and Nutrition,[5] in Rome, from 15 to 17 February 2016. The symposium brought together over 400 participants, including 230 delegates from 75 countries and the European Union. It took a multisectoral approach and covered the broad range of low- to high-technology biotechnologies used in the crop, livestock, forest, fishery and aquaculture sectors.[6]

6. The symposium highlighted numerous examples of the successful application of agricultural biotechnologies that meet the needs of family farmers and small-scale producers in the crop, forest, fishery, aquaculture and livestock sectors. The enormous potential of new gene-editing technologies and the need to closely follow developments in this area were acknowledged. Other key messages from the symposium[7] were that agricultural biotechnologies make an important contribution to efforts

[1] CGRFA-13/11/3; CGRFA-15/15/7.
[2] CGRFA-17/19/Report, *Appendix F, Annex 1*.
[3] https://www.cbd.int/convention/articles/?a=cbd-02
[4] CGRFA/WG-AqGR-3/21/Inf.16.
[5] http://www.fao.org/about/meetings/agribiotechs-symposium/en/
[6] FAO. 2016. *Proceedings of the FAO International Symposium on the Role of Agricultural Biotechnologies in Sustainable Food Systems and Nutrition*. J. Ruane, J. Dargie & C. Daly, eds. Rome. (available at http://www.fao.org/3/i5922e/I5922E.pdf).
[7] *Summary Report of the FAO International Symposium on the Role of Agricultural Biotechnologies in Sustainable Food Systems and Nutrition* (Rome, 15–17 February 2016). COAG/2016/INF/5 (http://www.fao.org/about/meetings/coag/coag-25/list-of-documents/en/, available in all UN languages).

to achieve the Sustainable Development Goals (SDGs), that biotechnologies are much more than genetic modification, that agricultural biotechnologies and agroecology should be seen as complementary approaches that can contribute to sustainable food systems and improving nutrition, that there are concerns about intellectual property rights and patents related to agricultural biotechnologies, and that building awareness of, and improving communication on, agricultural biotechnologies are important.

7. Following the global symposium, FAO organized two regional meetings on agricultural biotechnologies in 2017. The first took place from 11 to 13 September 2017 in Kuala Lumpur, Malaysia,[8] and was hosted and co-organized by the Government of Malaysia. Over 200 participants from 41 countries attended the regional meeting. The second took place in Addis Ababa, Ethiopia,[9] from 22 to 24 November 2017, and was hosted and co-organized by the Government of Ethiopia and co-sponsored by the African Union Commission. About 160 participants from 37 sub-Saharan African countries attended the meeting.

8. Topics related to plant genetic resources for food and agriculture (PGR) discussed at the meetings ranged from low-technology applications, such as tissue culture, to relatively high-technology use of molecular markers in germplasm characterization and plant breeding. Topics related to animal genetic resources for food and agriculture (AnGR) included the use of artificial insemination to improve meat and milk production, the use of molecular markers to characterize livestock and their wild relatives, and the range of biotechnologies that can be used to decrease the productivity gap in livestock production systems in developing countries. Topics related to aquatic genetic resources (AqGR) focused, particularly in the African context, mainly on relatively low-technology applications for genetic improvement in aquaculture, including hybridization, sex control and chromosome-set manipulation. The need to better harness the potential of AqGR through genetic improvement, including through selective breeding, for use in local farming systems was also highlighted. In the case of Asia, higher-technology applications were also noted, including use of genetic tests for disease diagnostics and disease and health management, including the use of probiotics, particularly in shrimp farming. Topics related to forest genetic resources (FGR) included the use of genomic approaches to understand how ecological assemblages in forest landscapes have been formed and how they respond to novel environmental conditions and to understand and manage the adaptation of forest trees to climate change.

9. FAO has also disseminated science-based information on the role of biotechnologies through its biotechnologies website,[10] available in all UN languages, since 2007. The website provides information on FAO's work on biotechnologies and on international developments in this field, as well as on policy and regulatory issues related to research on and deployment of agricultural biotechnologies. Knowledge is also shared through the electronic FAO-BiotechNews, distributed in six languages to almost 5 000 subscribers.

Strengthening the capacities of Members

10. At its Fifteenth Regular Session, the Commission requested that FAO continue to strengthen the national and regional capacities of developing countries to develop appropriate biotechnologies for the characterization, conservation and utilization of GRFA, taking into consideration relevant national and regional laws and regulations, and international instruments, including those related to risk

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[8] *Report on the outcome of the FAO Regional Meeting on Agricultural Biotechnologies in Sustainable Food Systems and Nutrition in Asia-Pacific* (available as APRC/18/INF/9, in Chinese, English, French and Russian, from http://www.fao.org/about/meetings/regional-conferences/aprc34/documents/en/); http://www.fao.org/asiapacific/events/detail-events/en/c/1440/

[9] *Outcomes of the FAO Regional Meeting on Agricultural Biotechnologies in Sustainable Food Systems and Nutrition in Sub-Saharan Africa* (available as ARC/18/INF/10, in Arabic, English, French and Spanish, from http://www.fao.org/about/meetings/regional-conferences/aprc34/documents/en/); http://www.fao.org/africa/events/detail-events/en/c/1035227/

[10] http://www.fao.org/biotech/

assessment[11]. The following paragraphs give a sector-by-sector summary of the technical cooperation projects (TCPs) and other projects of FAO and the Joint FAO/International Atomic Energy Agency (IAEA) Centre for Nuclear Techniques in Food and Agriculture (CJN).[12]

Animal genetic resources for food and agriculture

11. FAO has continued to support countries in the use of biotechnologies in the characterization, sustainable use and conservation of AnGR, largely through cooperation with strategic partners. CJN has, in particular, leveraged its mandate to directly transfer biotechnologies to developing countries for the management of AnGR. In mid-2021, CJN will host the International Symposium on Sustainable Animal Production and Health,[13] which will address many topics involving biotechnologies. FAO maintains its collaboration with the International Society on Animal Genetics (ISAG) in the FAO-ISAG Advisory Group on Animal Genetic Diversity, which monitors developments in the molecular and genomic characterization of AnGR and organizes biennial workshops. FAO and IAEA projects have facilitated the characterization of more than 120 breeds of livestock in more than 30 countries.[14] FAO and IAEA presented five training courses related to molecular genetic characterization of AnGR. FAO has developed *Genomic characterization of animal genetic resources – Draft updated technical guidelines.*[15]

12. Reproductive technologies and various forms of marker-assisted selection remain the principal biotechnologies used in the management of AnGR. CJN is implementing the Coordinated Research Project Application of Nuclear and Genomic Tools to Enable the Selection of Animals with Enhanced Productivity Traits, which involves ten countries.[16] Several FAO and IAEA projects involve the transfer of biotechnologies to support the sustainable use of AnGR. Fifteen national and regional training courses were organized to build capacity in the use of biotechnologies, primarily artificial insemination. More than 120 people were trained.

13. FAO participates in the IMAGE (Innovative Management of Animal Genetic Resources; 2016‒2020) project, funded by the European Union through its Horizon 2020 Research and Innovation Programme.[17] The project, which involved 28 partners from 17 countries, emphasized cryoconservation. Cryoconservation of AnGR utilizes a variety of biotechnologies, ranging from reproductive technologies, such as artificial insemination, embryo transfer and cryopreservation of germ cells to DNA-based approaches to the characterization of banked material and complementary *in situ* populations. FAO oversaw the organization of training courses in four of the partner countries[18] and implemented a global survey of quality-management practices in AnGR gene banks.[19] FAO has partnered with contributors from IMAGE and from around the world to develop *Innovations in cryoconservation of animal genetic resources – Draft technical guidelines*.[20]

Aquatic genetic resources for food and agriculture

14. FAO has provided countries with guidelines on the minimum requirements for sustainable management, development, conservation and use of AqGR entitled *Development of aquatic genetic*

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[11] CGRFA-15/15/Report, paragraph 28.
[12] https://cra.iaea.org/cra/explore-crps/all-completed-by-programme-5-yrs.html
[13] https://www.iaea.org/events/aphs2021
[14] Albania, Armenia, Argentina, Bangladesh, Bosnia and Herzegovina, Brazil, Bulgaria, Burkina Faso, Cambodia, Costa Rica, Croatia, Egypt, Ethiopia, Georgia, Indonesia, Iraq, Iran (Islamic Republic of), Lesotho, Madagascar, Mali, Montenegro, Mozambique, Myanmar, Nigeria, North Macedonia, Pakistan, Serbia, Sri Lanka, Togo, Ukraine, United Republic of Tanzania, Zambia.
[15] CGRFA/WG-AnGR-11/21/Inf.5.
[16] Argentina, Bangladesh, China, India, Kenya, Peru, Serbia, South Africa, Sri Lanka, Tunisia.
[17] http://www.imageh2020.eu/
[18] Argentina, Colombia, Egypt, Morocco.
[19] https://www.liebertpub.com/doi/abs/10.1089/bio.2019.0128
[20] CGRFA/WG-AnGR-11/21/Inf.4.

resources: a framework of essential criteria.[21] The framework was developed and promoted through a series of regional workshops with member countries of the Southern African Development Community (SADC) and the East African Community (EAC). The framework covers, *inter alia*, application of, and access to, biotechnologies and capacity building in their use, including biotechnologies used for genetic characterization, pedigree management, traceability, conservation (including gamete cryopreservation) and genetic improvement. The framework was used to conduct an assessment of the status of management of AqGR in Zambia. Based on findings from the assessment, a delegation of officers from the Zambian Ministry of Fisheries and Livestock was trained on relevant biotechnologies.

15. FAO, jointly with Worldfish, provided support to SADC and EAC through the Platform on Genetics and Biodiversity Management in Aquaculture.[22] This joint platform focuses on the application of the above-mentioned framework in the region, with a focus on Tilapia species and including the appropriate application of biotechnologies in characterization and improvement of indigenous AqGR.

16. FAO supported the implementation of the TCP Genetic Improvement for Rainbow Trout in the Islamic Republic of Iran,[23] which focused on establishing a breeding nucleus for rainbow trout and the design and implementation of a selective breeding programme to support the country's growing aquaculture sector. The project included the development of an online training module on genetic biotechnologies in aquaculture (focused on selective breeding but including applications of genetic markers).

Forest genetic resources

17. In May 2015, the Brazilian Agricultural Research Institute for Forests (Embrapa Florestas) and FAO organized the International Symposium on Forest Biotechnology for Smallholders in Foz do Iguaçu, Brazil.[24] The symposium covered current and potential biotechnology applications in the forest sector, with special focus on smallholders and tropical areas. More than 80 participants from six countries attended the meeting to share knowledge and experiences, and to exchange information on the application of forest biotechnology.

Micro-organism and invertebrate genetic resources for food and agriculture

18. CJN has supported FAO and IAEA Members in the application of biotechnologies for the characterization and use of micro-organism and invertebrate genetic resources (MIGR) for the development and implementation of the environmentally friendly sterile insect technique (SIT) and other related biological and genetic techniques for controlling the populations of insects of agricultural, veterinary and human-health importance, always as a component of area-wide integrated pest management (AW-IPM) programmes. During the reporting period, 54 SIT projects were supported in 38 countries.[25] Through a CJN Coordinated Research Project, which included molecular, genetic and cytogenetic approaches, it could be shown that four major agricultural pests (the oriental fruit fly, *Bactrocera dorsalis*, the Philippine fruit fly, *Bactrocera philippinensis*, the invasive fruit fly, *Bactrocera invadens*, and the Asian papaya fruit fly, *Bactrocera papayae*) are actually one and the same species, *Bactrocera dorsalis*. CJN has also participated in several international initiatives that

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[21] FAO. 2018. Aquaculture Development 9. *Development of aquatic genetic resources: A framework of essential criteria.* TG5 Suppl. 9. Rome. 88 pp. Licence: CC BY-NC-SA 3.0 IGO. (available at http://www.fao.org/3/CA2296EN/ca2296en.pdf).
[22] http://www.fao.org/africa/news/detail-news/ar/c/1195772/; https://www.sadc.int/files/3515/2871/9435/Inside_SADC_May_2018_mail_3.pdf
[23] TCP/IRA/3602 Genetic Improvement of Rainbow Trout in the Islamic Republic of Iran (2017–2019).
[24] http://www.fao.org/forestry/50300-0a0065c203c4de01fa986265107f04835.pdf
[25] Algeria, Argentina, Australia, Belize, Bosnia and Herzegovina, Brazil, Canada, Chad, Chile, China, Colombia, Croatia, Cuba, Dominican Republic, Ecuador, Ethiopia, Germany, Greece, Guatemala, Honduras, Israel, Italy, Jordan, Malaysia, Mauritius, Mexico, Morocco, New Zealand, Panama, Peru, Philippines, Senegal, Singapore, South Africa, Spain, Thailand, Territories Under the Jurisdiction of the Palestinian Authority, United States of America.

aimed to sequence the genome of major insect pest species, including the Mediterranean fruit fly, *Ceratitis capitata*, and several *Glossina* species, known vectors of pathogenic trypanosomes, and their associated symbionts. Through Coordinated Research Projects, CJN presented three workshops related to molecular genetic characterization of MIGR, which involved 30 participants from 21 countries.[26] Through IAEA TCPs, CJN also organized one regional and two inter-regional training courses to build capacity in the use of AW-IPM with a SIT component, including the use of molecular genetic methods for the characterization and use of MIGR. These training courses involved 67 participants from 40 countries.[27]

19. CJN organized the Third FAO/IAEA International Conference on Area-wide Management of Insect Pests: Integrating the Sterile Insect and Related Nuclear and Other Techniques, 22−26 May 2017, in Vienna. The conference was attended by 360 delegates from 81 countries, six international organizations and nine exhibitors. As in the case of previous FAO/IAEA Area-wide Conferences, it covered the AW-IPM approach in a very broad sense, including the development and integration of many non-SIT technologies. Research developments and applications related to MIGR were presented in all six theme-specific sessions: (1) operational AW-IPM programmes; (2) mosquitoes and human health; (3) animal health; (4) regulatory issues and socio-economic impact (5) climate change, global trade and invasive species; and (6) new developments and tools for AW-IPM.

20. CJN participated in the BINGO (Breeding Invertebrates for Next Generation BioControl)[28] project, funded by the European Union through its Horizon 2020 Research and Innovation Programme. The project, which involved 12 partners from nine countries, emphasized the training of young researchers in the field of biological control, specifically the use of genetic variation for insect rearing, monitoring and performance. CJN focused on the characterization of gut-associated bacterial species in the major agricultural pest the olive fruit fly (*Bactrocera oleae*) and its parasitoid *Psyttalia concolor* using culture-dependent and culture-independent approaches, and the potential use of cultivable symbionts in probiotic applications (or as diet supplements) to improve the mass-rearing and the quality of mass-produced insects for AW-IPM programmes with a SIT component.

21. There are several ongoing activities supporting FAO's work on the microbiome across ecosystems. In 2019 FAO published *Microbiome: The missing link? Science and innovation for health, climate and sustainable food systems*.[29] The Microbiome Learning Network is a working group that unites microbiome experts from diverse disciplines and sectors to facilitate knowledge exchange and partnerships. Created in July 2020 during a virtual series of seminars and workshops on state-of-the-art microbiome knowledge and policy and industry issues, it continues to welcome new members. Several literature reviews on different microbiome ecosystems (e.g. the soil microbiome and the human gut microbiome) are forthcoming for publication. FAO is also an active member of the Microbiome Working Group of the International Bioeconomy Forum.

Plant genetic resources for food and agriculture

22. CJN organized the International Symposium on Plant Mutation Breeding and Biotechnology in August 2018, marking the 90th anniversary of the first report of mutation induction in plants as a means of enhancing genetic diversity for breeding and crop improvement.[30] Induced mutation increases the rate of evolutionary change relative to that associated with the spontaneous mutations that have been the basis of crop domestication throughout the history of agriculture. The symposium addressed five main topics: (1) contribution and impact of mutant varieties on food security;

[26] Argentina, Australia, Bangladesh, Burkina Faso, Cameroon, China, France, Germany, Greece, Guatemala, India, Israel, Italy, Kenya, Mali, Mauritius, Mexico, Spain, South Africa, Turkey, United Republic of Tanzania.
[27] Argentina, Australia, Bangladesh, Botswana, Bulgaria, Burkina Faso, Chad, Chile, China, Congo, Cuba, Dominican Republic, Ethiopia, Fiji, Guatemala, Indonesia, Jordan, Kenya, Malaysia, Mauritius, Mexico, Morocco, Mozambique, Myanmar, Namibia, Niger, Pakistan, Senegal, Seychelles, South Africa, Sri Lanka, Sudan, Thailand, Turkey, Uganda, United Republic of Tanzania, Uruguay, Viet Nam, Zambia, Zimbabwe.
[28] https://bingo-itn.eu
[29] http://www.fao.org/documents/card/en/c/ca6767en/
[30] https://www.iaea.org/events/plant-mutation-breeding-symposium-2018

(2) mutation breeding for adaptation to climate change in seed-propagated crops; (3) mutation breeding in ornamental and vegetatively propagated crops; (4) enhancing agricultural biodiversity through mutation induction techniques; and (5) new challenges and technologies in plant genomics and breeding. It was attended by more than 300 scientists from over 80 Member Nations.[31] It is planned that towards the end of 2021 FAO will host the Global Conference on Green Development of Seed Industries, which will feature sessions dedicated to the applications of biotechnologies in crop improvement.

23. The IAEA, through CJN, supports more than 70 Member Nations in the development of national and regional capacities for increasing genetic diversity in food, feed and cash crops for accelerated genetic gain. A large number of crop traits are addressed, most importantly tolerance of abiotic stresses such as drought, heat and salinity and resistance to biotic stresses caused by transboundary pests and diseases, which are increasing in prevalence due to climate change. The Mutant Variety Database[32] of the Joint FAO/IAEA Division, a database of voluntarily contributed information from Member Nations on released mutant varieties, currently holds over 3 300 records of mutant crop varieties, of which almost 2 000 are from the Asia−Pacific region.

24. CJN's mid-term roadmap in the area of plant breeding and genetics addresses innovations in mutation induction in vegetative and underutilized food crops, micropropagation and single-cell regeneration, precision phenotyping, climate change modelling, establishment and use of managed-stress environments, and speed-breeding technologies, including doubled haploidy, molecular breeding and bioinformatics.

Biosafety

25. FAO, through a GEF-funded project, is helping to improve Sri Lanka's regulatory, institutional and technical capacity to implement its National Biosafety Framework in accordance with the Cartagena Protocol on Biosafety to the Convention on Biological Diversity.[33] This five-year project (2017−2021) has strengthened human and institutional capacities, led to the development of guidelines and sundry tools for national competent authorities and raised public awareness of biosafety and agricultural biotechnologies in general.

26. Through a long-term cooperation agreement with the Government of Czechia, FAO organized a series of technical workshops and training courses in the Europe and Central Asia region to address various aspects of biosafety and to assist countries in the region in the development, implementation and enforcement of their national biosafety frameworks. These included a regional training workshop on "Enforcement of biosafety regulations: principles, specific examples and institutional communication and cooperation", held from 3 to 6 February 2015 in Prague,[34] a regional training course on risk assessment, detection and identification in relation to genetically modified organisms (GMOs) and organisms developed through new breeding techniques, held from 12 to 15 December 2017 in Prague, and an FAO expert consultation on "Review of biosafety regulatory systems: focus on genome editing and compatibility with relevant international agreements", held from 28 to 30 August 2018 in Prague.[35]

27. Through its Technical Cooperation Programme, FAO also implemented a regional project in 2015−2017 on capacity development in biosafety in Azerbaijan, Kazakhstan, Kyrgyzstan and Tajikistan, providing guidance, training and technical support to a critical mass of stakeholders from these four countries.[36]

[31] https://www.iaea.org/sites/default/files/18/08/cn-263-abstracts.pdf
[32] https://mvd.iaea.org/
[33] GCP/SRL/066/GFF Implementation of the National Biosafety Framework in accordance with the Cartagena Protocol on Biosafety (CPB).
[34] http://www.fao.org/europe/events/detail-events/en/c/276625/
[35] http://www.fao.org/europe/events/detail-events/en/c/1148406/
[36] http://www.fao.org/3/ca5666en/CA5666EN.pdf

28. The outcomes of the two regional programmes in Europe and Central Asia highlight the importance of a balanced two-track approach to modern biotechnologies that “maximizes benefits and minimizes risks”. Maximizing benefits is typically done through research strategies and investments, while minimizing risks is usually done by designing and implementing national biosafety systems and regulations. Most countries in the region have not elaborated specific biotechnology strategies or reformed their agricultural research agendas. They still face common challenges such as insufficient capacities to effectively address environmental and food risk assessments, wider biosafety communication and compatibility with international regulations, and detection and identification of GMOs. They require awareness raising on issues related to genome editing.

III. GUIDANCE SOUGHT

29. The Working Group is invited to take note of the information provided and to make recommendations regarding future work in this area within its field of mandate.

30. The Working Group may wish to recommend that the Commission request FAO to continue to:

i. strengthen the national and regional capacities of developing countries to apply and develop appropriate biotechnologies for the characterization, sustainable use and conservation of GRFA, taking into consideration relevant benefits and risks, relevant national and regional laws and regulations, and international instruments, including those related to risk assessment;

ii. regularly assemble and disseminate updated factual information on the role of biotechnologies in the characterization, sustainable use and conservation of GRFA through its existing databases, networks and newsletters;

iii. ` highlight the importance of conducting socio-economic analyses of the value of biotechnologies applications prior to their deployment; and

iv. explore mechanisms for future cooperation with relevant international organizations, including for fostering North−South, South−South and Triangular cooperation, in promoting appropriate biotechnologies for the characterization, sustainable use and conservation of GRFA.