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Item 8 of the Provisional Agenda

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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

Fifth Session

Rome, 27-29 April 2011

STRENGTHENING PLANT BREEDING CAPACITIES

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I. INTRODUCTION

1. At its Twelfth Regular Session, the Commission on Genetic Resources for Food and Agriculture (the Commission), while emphasizing the critical role of plant breeding in addressing food security, commended the FAO-led Global Partnership Initiative for Plant Breeding Capacity Building (GIPB) for its success in strengthening national capacity and in fostering collaboration among national and international stakeholders. It also requested FAO to continue to report on its activities in plant breeding and seed systems.[1]

2. The aim of this document is to provide an overview of ongoing activities in plant breeding and related work undertaken through the GIPB by FAO and its partners to strengthen plant breeding capacities. It reviews the innovations in plant biotechnologies and germplasm enhancement techniques that can highly impact on the capacity of member countries to use plant genetic resources for food and agriculture (PGRFA) in a sustainable way and discusses the role of plant breeding within a result-oriented PGRFA programme that caters to and strengthens linkages among conservation, use in breeding and the delivery of high quality planting materials of improved varieties.

II. PLANT BREEDING AS AN IMPETUS FOR SUSTAINABLE MANAGEMENT OF PGRFA

3. Plant breeding involves the deliberate utilization of desirable heritable variation available in the genepool of crops (and their related wild relatives) to create new improved varieties. The expectation of the benefits accruable from cultivating superior crop varieties provides the most compelling impetus for the sustainable management of PGRFA. The *Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoWPGR-2) emphasises that plant breeding capacity building and sustainable use of PGRFA are essential for strengthening PGRFA management. This is especially true in light of climate change and variations which lead to extreme environmental conditions and new pests and diseases. The incidences of these stress factors necessitate therefore the development of adapted varieties to address the serious challenges to global food security which they pose.

4. The greatest value of PGRFA therefore lies in its use for improving crop varieties that, when integrated with farming systems, contribute to the well-being of society. To be result-oriented, plant breeding activities should be contextualized as one of the three components of the PGRFA continuum that also encompasses conservation of crop germplasm in genebanks and *in situ,* and the dissemination of high quality seeds and planting materials of improved varieties through both formal and informal public and private seed sectors. The implementation strategy of any meaningful PGRFA programme needs to cater to, and strengthen linkages between, these three components of the PGRFA continuum for the full realization of its potential.

III. TOOLS TO ENHANCE PLANT BREEDING EFFICIENCY

5. The routine deployment of agricultural technologies that enhance productivity without destroying the global natural resource base remains a critical generational challenge. Recent trends indicate however that technologies, especially biotechnology, if properly harnessed, offer a responsible way to enhance crop productivity. The increased understanding of plant biology and the ready accessibility of relevant information in the public domain hold promise for enhanced plant breeding capacities to produce resilient varieties. Some of the main applications and approaches are discussed below.

[1] CGRFA-12/09/Report Paragraphs 30 - 31.

- Cell and tissue biology techniques that are used in the management of PGRFA include micropropagation; embryo rescue; plant regeneration from callus and cell suspension; and protoplast, anther and microspore cultures. These are used particularly for large-scale plant multiplication and hence demonstrably hold great promise for producing clonal high quality, disease-free planting materials of a wide range of crops. Embryo rescue and *in vitro* fertilization or plant protoplast fusion can also be deployed in overcoming reproductive isolating barriers especially between distantly related wild relatives and crops. The major challenge to the use of cell and tissue biology lies in the dearth of genotype-independent protocols.
- Marker assisted selection (MAS) can significantly speed up the process of crop varietal development. Molecular marker assays have become a powerful method for identifying the genetic basis of the inheritance of traits. The increasing ease with which they have been used to construct genetic linkage maps - that are indispensable in locating the genome regions (genes) that influence the expression of traits - is being leveraged in significantly enhancing the efficiency of crop varietal development. Multilateral efforts are increasingly targeting the replication of the successes of MAS in the private sector - the development of improved cultivars of major crops – in the public sector. One such international collaborative effort is the Integrated Breeding Platform (IBP), an initiative of the Generation Challenge Programme of the Consultative Group on International Agricultural Research.[2]
- The generation of genetically modified (GM) plants, known as transgenics, with added traits, through genetic transformation is available for commercial production, with an estimated 134 million hectares planted with GM crops in 25 countries in 2009[3]. The genetic transformation events that led to the development of these GM crops have been the expressions of tolerance to herbicides (i.e. glyophosate marketed as Roundup); resistance to insects (expression of the *Bacillus thuringiensis*, or Bt toxin).
- The management of PGRFA in general, and crop improvement in particular, benefits immensely from the tools resulting from advances in plant molecular biology and the associated ancillary areas of genomics (the study of the totality of an individual's genetic makeup); transcriptomics (the study of a total set of transcripts, i.e. the set of all RNA molecules); proteomics (the study of proteins), metabolomics (the study of metabolites) and phenomics (study of phenotypes in relation to genomics). With whole genome sequencing, there is a greater elucidation of the genetic basis of many traits and their expression and inheritance. A major constraint to the enhancement of the inherent resilience of crops, especially in order to adapt to the threats posed by climate change and variations, is the increasingly narrow genetic base of crop plants and the available genepool from which breeding materials can be appropriated. Reverse genetics has proved particularly useful in this regard with TILLING (Targeting Induced Local Lesions In Genomes) permitting the querying of specific regions of the genome for mutation events at the molecular level in high throughput formats.[4]

6. A broad spectrum of biotechnological applications are relevant for the efficient management of plant genetic resources and have great potentials, especially when deployed in a

[2] http://wiki.cimmyt.org/confluence/display/MBP/Home. IBP aims at developing and deploying a web-based one-stop-shop for information, analytical tools and related services in support of the design and conduct of MAS in both private and public sector breeding programmes. It is also expected that the platform will provide support services and train breeders from national agricultural research systems in accessing and using marker technologies.

[3] http://www.isaaa.org/resources/publications/briefs/41/highlights/default.asp

[4] http://www-naweb.iaea.org/nafa/pbg/index.html. FAO and IAEA Member States are assisted in using radiation induced mutations and efficiency enhancing biotechnologies such as *in vitro* techniques, molecular markers and genomics to produce better crop varieties.

concerted manner for enhancing crop productivity. In March 2010, the FAO Technical Conference on Agricultural Biotechnologies acknowledged that these novel tools could "help alleviate hunger and poverty, assist in adaptation to climate change and maintain the natural resource base, in both developing and developed countries".[5] The report also quite succinctly captured the chasm in access to these technologies between the developed and developing countries in acknowledging that "the various applications of agricultural biotechnologies have not been widely used in many developing countries, and have not sufficiently benefited smallholder farmers and producers and consumers" and recommending that "more research and development of agricultural biotechnologies should be focused on the needs of smallholder farmers and producers".

7. FAO continues to work with its member countries to enhance their capacity to make informed decisions on the applicability of agricultural (including crop) biotechnologies within the context of overall national development goals. Countries must invest in building research and development capacities for taking advantage of these tools. Intellectual property issues as they relate to agricultural biotechnologies are also important to address, especially for removing the constraints they place on access to the available tools. FAO has also assisted member countries in the implementation of international instruments, such as the Cartagena Protocol, through capacity building for the implementation of the appropriate legislation.[6]

IV. GIPB - A PARTNERSHIP TO STRENGTHEN PLANT BREEDING CAPACITIES AND SUSTAINABLE USE OF PGRFA

8. Novel tools and strategies are becoming increasingly available for use in enhancing crop productivity; the challenge lies in the ability to harness these new tools, especially in developing countries, and to apply them in a systematic manner to mitigate the constraints to crop productivity.

9. One of FAO's strategies to enhance plant breeding capacities has been the convening of the GIPB to address the declining capacity of developing country crop breeding programmes and the negative consequences on food security and development goals. GIPB facilitates capacity-building partnerships to establish and operate highly effective programmes for developing and delivering new crop varieties. Since its inception five years ago, GIPB has become the platform for a broad range of responses to meet these needs. The progress made towards achieving this goal is discussed below.

A. Policy Awareness and Development

10. A combination of advocacy materials, including leaflets, posters, web-based information, the media, and direct contact through visits and meetings, have been used to call attention to the need for enabling policy environments to foster enhanced plant breeding and seeds system capacities. As a result, mid- and high-level policy makers have been made aware of GIPB work in many countries, especially in those where the benchmark surveys were completed. Many countries are consequently at varying stages in the development of national strategies to improve plant breeding capacity. Equally, in-depth studies are being carried out to create the basis for further defining policy guidance in this area.

[5] FAO International Technical Conference. Agricultural biotechnologies in developing countries: Options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change (ABDC-10). Guadalajara, Mexico, 1–4 March 2010. http://www.fao.org/fileadmin/templates/abdc/documents/report.pdf.

[6] FAO, 2009. Building Biosafety Capacities-FAO's experience and outlook.

B. Assessments of National Plant Breeding Capacities

11. Surveys of national capacities in plant breeding and biotechnology were conducted in 80 countries. These surveys provide GIPB stakeholders with the baseline information to formulate long-term strategies to improve plant breeding capacity. Regional analyses allow comparisons across countries to understand complementarities and potential collaboration. Regional consultations in Latin America, Africa and Asia involved about 195 people through electronic (Asia and Africa) and face-to-face (Latin America and the Caribbean) meetings. These assessments were followed by an in-depth analysis of the production systems of important crops in six countries, namely Ghana, Kenya, Malawi, Bangladesh, Thailand and Uruguay.[7]

12. In sub-Saharan Africa, for instance, the studies on the production systems of rice, maize, cassava, beans and vegetables revealed the general trend of progress having been made in the overall improvement of capacities for plant breeding and seed systems. Overall, the studies showed the constrained capacity of the public sector to engage in crop improvement and seed delivery activities. The critical importance of donor funding to agricultural research and development (R&D) at national, sub-regional and continental levels was also demonstrated. Other important findings included the fact that the public sector must continue to play a dominant role in agricultural R&D as the private sector involvement remains restricted to narrow niches. With the progressive decrease in the number of plant breeders, as shown in the studies, it was concluded that demands for skills and capacity in conventional breeding will remain high at least in the medium term. Quite interestingly, the emerging roles of private seed companies is increasingly supported as integral parts of crop production systems; in Bangladesh and Uruguay, for instance, the private sector is critically important in disseminating new crop varieties to farmers. Also, it was shown that private commercial companies are increasingly taking advantage of enabling policy frameworks to invest in both R&D and the production and marketing of agricultural inputs. An instance of this trend towards investment in R&D was highlighted in the Thailand study where they focus on developing breeding programmes for hybrid varieties of food and horticultural crops. To sustain the impetus and maintain availability of other food security crops, public sector plant breeding strategies must evolve and complement the continually increasing investments in the private sector. It was concluded that both the public and private sectors had considerable potentials for applying plant breeding, coupled with the use of modern technologies, to contribute to agricultural productivity.

C. Facilitation of Training in Pre-Breeding

13. The country surveys clearly identified the critical need for significantly enhanced capacities for the use of PGRFA. This is being addressed by the deployment of knowledge resources, supporting pre-breeding training courses, and instituting a competitive grants scheme to support pre-breeding activities. To date, 134 scientists have acquired pre-breeding and biotechnology techniques through four training courses organized in Belgium, Philippines, Thailand and Venezuela. GIPB supported the participation of two additional scientists in a related course held in Bangladesh. In order to reach the widest possible target audience, GIPB and Bioversity International have successfully collaborated in the development of an E-Learning Package for Pre-breeding that will be available online in June 2011. The curriculum and instructional materials were developed by major experts in the relevant disciplines.

D. Technical Assistance

14. To contribute to the strengthening of capacity for germplasm enhancement, six pre-breeding projects were funded under a collaborative initiative of GIPB, the Global Crop Diversity

[7] "Evolving a plant breeding and seed system in sub-Saharan Africa in an era of donor dependence"; "Plant Breeding and Seed Systems for Rice, Vegetables, Maize and Pulses in Bangladesh"; "The Dynamic Tension between Public and Private Plant Breeding in Thailand"; and "The strategic role of plant breeding in Uruguay: analysis through an agricultural innovation system framework". http://km.fao.org/gipb/.

Trust, and the Generation Challenge Programme of the Consultative Group on International Agricultural Research (CGIAR). For instance FAO is implementing technical field projects,[8] that aim at enhancing capacities to integrate conservation activities with utilization of germplasm in an institutionalized way. Relevant centres of the CGIAR and other national partners provide technical inputs for the implementation of these projects. Support is also provided to develop holistic national strategies for PGRFA management that encompass these three components. The projects include strategies to integrate the use of molecular biology in addressing identified bottlenecks.

E. GIPB Knowledge Resource Centre

15. The Knowledge Resource Centre (KRC) of the GIPB portal provides relevant information on plant breeding and other PGRFA related issues that was neither previously available, nor easily accessible, or was packaged as complementary information about plant breeding and related technologies. Recently, a comprehensive review of strategies for breeding crops for resistance to rust - fungal diseases that significantly constrain crop production – which was supported through two GIPB competitive grant schemes has been completed and published through the KRC, for instance.[9] The information provided through the portal is designed to support informed decision making. The user base is continuously growing. In 2010, the site received almost 25 000 visits from 186 countries. The KRC also comprises the *Plant Breeding News* -a monthly newsletter that is distributed to 1 600 subscribers.

V. A TOOLBOX FOR PLANT BREEDING CAPACITY BUILDING

16. A "Planning and Assessment Tool" for plant breeding and seed systems capacities has been developed. This analysis model consists of checklist templates for assessing different aspects of a programme's capacity in developing improved crop varieties and delivering their high quality seeds and planting materials. It offers both public and private sector plant breeding systems an innovative tool for analysing strengths and weaknesses and identifying the major gaps in their programmes. It can also be used to assess the impact of an activity at the completion of a funded project. The tool has been validated at various stages, involving a range of relevant stakeholders and will be ready for publication by June 2011. In cooperation with Cornell University and the West African Centre for Crop Improvement at the University of Ghana, an interactive on-line version of this tool is under development.

17. Article 6 of the International Treaty for Plant Genetic Resources for Food and Agriculture (International Treaty) calls upon Contracting Parties to "develop and maintain appropriate policy and legal measures that promote the sustainable use of plant genetic resources for food and agriculture". One of the major constraints to the sustainable use of PGRFA in many countries is the absence of integrated and coordinated strategies. To address this issue, GIPB is partnering with the International Treaty to develop a "toolbox" for the sustainable use of PGRFA. The toolbox for the implementation of Article 6 is conceived as a collection of validated technologies, practices, procedures, and policy instruments for crop improvement that should be easily accessible by stakeholders. The toolbox should therefore include the full range of tools, whether traditional or advanced, that farmers and scientists can access and use to develop and disseminate new varieties and sustainable practices that underpin their development.

[8] Such Technical Cooperation Projects are being implemented in Azebaijan, Kazakhstan and Mexico.

[9] "State of knowledge on breeding for durable resistance to soybean rust disease in the developing world" and "Sustainable wheat rust resistance - Learning from history". http://km.fao.org/gipb/

18. The "toolbox" for the implementation of Article 6 and a related document on the definitions, rationale, constitutive elements, functions, and the beneficiaries of the toolbox , have been presented to the Fourth Session of the Governing Body Session in March 2011.[10]

VI. RE-THINKING THE ROLE OF PLANT BREEDING AND PGRFA MANAGEMENT

19. As discussed earlier, activities related to conservation of genetic resources, their utilization in crop improvement, and dissemination of planting materials through both formal and informal public and private seed sectors are too often very severely compartmentalized and operated as if they were independent entities rather than a part of a continuum.

20. The consequence of the "modular" PGRFA management system has been the current situation where it is not uncommon for the priority activities of a germplasm curating facility to be completely disconnected from those of the crop breeding stations and the seeds sector. This disconnection between the three components of the PGRFA continuum, that should ideally be interlinked and mutually reinforcing, is clearly counterproductive. In extreme cases of dysfunction, the components compete for the usually scarce resources and pitch personnel against each other in turf battles. This sub-optimal situation usually occurs when a comprehensive and holistic PGRFA policy environment is lacking. The net result has been the reaping of sub-optimal benefits from PGRFA.

21. In effect, an exhaustively characterized and well-maintained germplasm collection has value only in its use for developing new improved crop varieties. Similarly, strong breeding programmes are worthless in the absence of a reliable seed delivery mechanism. Germplasm collections should also reflect the immediate and potential breeding goals for crops and meet plant breeders' needs.

22. FAO's field projects emphasize the necessity to connect and integrate these three components in PGRFA management practices. Support is also being provided to develop national strategies to establish direct linkages between PGRFA activities, develop relevant policy instruments in line with existing international agreements and provide for adequate human and material resources.

VII. CHARTING THE COURSE FOR RE-INVIGORATING PLANT BREEDING

23. The development of successful new crop varieties fundamentally depends on well-defined partnerships among multiple institutions and the client farmers, who in turn are attuned to consumer interests. Such endeavours must be underpinned by the use of the most appropriate scientific practices and technological tools. Equally required is the strategic interplay of enabling policies and smart long-term investments. The adoption of strategies that minimize the negative impacts on the environment also contributes greatly to the sustainability of the system. When all these elements are in place, the payoff is very high in terms of income generation for smallholder farmers, benefits for the environment, and food security for society as a whole. The time is opportune to develop "best practices" to anchor policy recommendations for the establishment of results-oriented breeding programmes. Towards achieving this aim, FAO-GIPB in collaboration with partners from the public and private sectors will hold a conference with the world's leading experts in crop improvement and ancillary disciplines, policy makers and other stakeholders to refine these "best practices". This will form the basis for developing clearly defined policy priorities to support public sector agricultural research programmes that increase awareness,

10 IT/GB-4/11/17: Implementation of Article 6; and IT/GB-4/11/Inf. 3.The toolbox: description of the concept, components, and how it might be developed. http://www.itpgrfa.net/International/sites/default/files/gb4i1e.pdf

efficiency and capacity in plant breeding and enhance its linkages to germplasm conservation and seeds delivery systems especially in developing countries.

VIII. PERSPECTIVES FOR FUTURE ACTIONS

24. PGRFA activities can be sustainable and result-oriented only when they are coordinated and integrated within national strategies that address conservation of genetic resources, crop improvement and seed systems in a holistic manner. Plant breeding is a long-term investment and requires strong partnerships especially between the public and private sectors. However, it must be recognized that the private sector is primarily concerned with the development and marketing of cash crops that are not necessarily the food security crops. To ensure that food security is not unduly compromised by this skewed private sector roles, the public sector needs to be strengthened adequately, ideally following the successes of private sector business models.

25. In general, the deployment of appropriate scientific and technological methodologies and tools within enabling policy environments is necessary for a result-oriented crop improvement programme that meets farmers' needs. Equally important is the sustained commitment of resources to ensure the availability of skilled personnel and adequate infrastructures. Modern biotechnologies and their associated information technology tools hold great promise to unlock PGRFA potentials and increase crop productivity to feed the ever-increasing human population in the face of incredible constraints posed by the effects of climate change and variations, demographics and economic pressures.

26. Through GIPB and other projects, FAO and its partners are collaborating to develop best practices for the sustainable management of PGRFA. As a basis for national strategies, these best practices will guide policy makers in the adoption of supporting instruments that guarantee that the following inputs are available:

- Human resources - scientific, technical and support personnel.
- Infrastructure - laboratories, screen houses, experimental fields, etc.
- Scientific expertise and partnerships - appropriate mix of conventional and novel tools with access to critical tools.
- Budgets - appropriate funding commitment at national, regional and international levels.
- Programme development and oversight.

27. In general, additional financial support is needed to sustain the development of holistic national PGRFA strategies. Enabling policy environments are imperative to reap the maximum benefits from the global resurgent investment of resources in agricultural R&D. Situating projects within the context of nurturing institutionalized strategies is necessary to ensure sustainability of activities beyond project life spans. To address the challenges of food insecurity, climate change, and population increase, committed multi-year financial investments need to be made in all aspects of the crop productivity intervention chain, including those that leverage private/public sector partnerships.