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Project description on Strengthening Member State Capacities to Combat Banana Fusarium Wilt (TR4) through Early Detection, New Resistant Varieties, and Integrated Management

(see document GOV/2021/45/Mod.1)

Title: Strengthening Member State Capacities to Combat Banana Fusarium Wilt (TR4) through Early Detection, New Resistant Varieties, and Integrated Management (INT5158)

Overall Objective: To strengthen Member State capacities in the prevention and containment of Fusarium Wilt (TR4) disease in banana through surveillance, early detection, genetic resistance and integrated management.

Outcome: Enhanced technical and infrastructure capacities at the institutional level and within national, regional and global networks for the detection, surveillance, genetic resistance and management of banana Fusarium wilt (TR4).

Expected Outputs:

- National entities involved in banana TR4 management identified and mapped and with full and up-to-date technical and infrastructure capacities for disease surveillance, detection and containment.
- Capacities strengthened for TR4 prevention, surveillance and reporting, containment and integrated management options;
- Native and mutant germplasm of banana and plantains with confirmed resistance to Fusarium TR4 developed.

Project duration: 5 years (2022–2026)

Project budget: €5 028 900

FOOTNOTE-a/ FINANCING

Year	Human resource component (€)					Procurement components (€)			Total
	Experts	Meetings	Training course	Fellowships & Scientific Visits	Subtotal	Procurement	Sub-contracts	Subtotal	
2022	214 800	148 700	382 500	116 000	862 000	800 000	12 000	812 000	1 674 000
2023	214 800	0	75 000	91 000	380 800	450 000	0	450 000	830 800
2024	237 800	77 400	382 500	116 000	813 700	275 000	0	275 000	1 088 700
2025	177000	0	75 000	69 000	321 000	450 000	0	450 000	771 000
2026	227000	77 400	285 000	75 000	664 400	0	0	0	664 400
Total	1 071 400	303 500	1 200 000	467 000	**3 041 900**	1 975 000	12 000	**1 987 000**	**5 028 900**

Project description: The proposed project will help countries to develop or strengthen capacities in the use of two techniques to manage the prevention and spread of the Fusarium Wilt TR4 in banana plantations. The first is the application of irradiation for the development of induced genetic resistance against the disease. The second is the detection of the disease using the nuclear-derived technique of polymerase chain reaction or PCR and DNA sequencing. This project will support the development of novel genetic resistance to Fusarium Wilt in Cavendish and other banana varieties through mutation breeding and will enable early detection of the disease and its containment and integrated management.

Problem to be addressed: The banana crop, which ranks among the world's top ten staple foods, is now threatened by a new race (Tropical race 4 – TR4) of the soil-borne pathogen, *Fusarium oxysporum, f. sp. cubense* (Foc), which causes Fusarium Wilt or Panama Wilt disease. Over 400 million people rely on bananas and plantains for food security and for income, and the combined annual production of bananas and plantains across the globe is 155 million metric tons. About 84% of the banana crop is produced by smallholder farmers and supplied to domestic markets. The remaining 16% of global banana production, accounting for about 25 million metric tons, is exported from tropical areas to countries in temperate zones. The Cavendish variety of banana makes up roughly 50% of global production and is important both for domestic and export markets. The export banana market consists almost exclusively of this variety, and is grown under monoculture conditions in large plantations.

Fusarium Wilt is regarded as the most lethal disease of banana and is believed to have originated in Southeast Asia, although it was first reported in 1876, in Australia. The disease is also called Panama disease in reference to the damage caused to export plantations in Panama reported in 1890. Early reports of the disease in any given country were on damage to export plantations of Gros Michel, the main banana variety for export trade until the mid-twentieth century. The disease was caused by *Fusarium oxysporum f.sp. cubense* (Foc), Race 1, and it invaded banana growing countries in Central and South America, destroying plantations and wreaking havoc on the export industry. The Gros Michel variety was susceptible to Race 1, and production was eliminated or became increasingly difficult throughout the banana belt. The banana industry tried to hold on to Gros Michel during the first half of the twentieth century by shifting cultivation to escape the pathogen, at huge socioeconomic and environmental cost. Facing increasing losses and a reduced availability of pathogen-free soil, the banana industry turned to the Cavendish variety, which was identified as resistant to Race 1. This led to the disappearance of the disease until the 1990s, when Cavendish began to succumb to a new race of *Fusarium oxysporum f. sp. cubense*, tropical race 4 (TR4), first in Southeast Asia and then Australia. In the subsequent decades, TR4 spread rapidly in different banana production systems in Asia, Africa and the Middle East. It was reported for the first time in Latin America in 2019, in Colombia, and in Peru in April 2021.

The Fusarium Wilt pathogen is soil-borne, and can survive for decades in the soil, which makes it difficult to control. TR4 has a wide host range and can attack many cultivated bananas. The Cavendish monoculture plantations which are central to the global production of dessert banana are particularly sensitive. Surveillance, early detection, quarantine and containment are critical to prevent its spread. While cultural and biological control options can slow down the development of epidemics, they do not provide effective control by themselves. The only long-term option is to deploy new varieties with effective disease resistance.

Today, genetic resistance in Cavendish can be induced by mutation and associated biotechnologies. This has been demonstrated in the results of an IAEA coordinated research project, in cooperation with the FAO. At the same time, screening procedures are available to determine whether resistance to TR4 is prevalent in other varieties of species. A screening procedure has been developed at the IAEA laboratories to determine resistance to the fungus under controlled conditions. In addition, an early study on resistance to TR4 in 34 Musa cultivars under controlled conditions has reported resistance in two diploids and two polyploid groups. Developing induced genetic resistance in Cavendish, and, in parallel, finding productive, consumer-acceptable varieties with resistance to TR4, are two central components of a strategy to enhance the resilience of the export-oriented banana industry, as well as that of local and regional production systems aimed at domestic markets.

The IAEA, in partnership with the FAO, has a long and established track record in applying nuclear and nuclear-derived techniques and associated biotechnologies to the genetic improvement of crop plants and the development of crop resistance to diseases. The history of banana research in the IAEA laboratories and relevant capacity building in Member States goes back at least two decades and

addresses key techniques such as cell and tissue culture, mutation induction, screening for disease and pest resistance, and related molecular and cytogenetics techniques. Regional technical cooperation projects across all regions in the area of crop production consistently include one or more national targets for disease resistance. For example, the interregional TC project, INT5150, 'Responding to the Transboundary Threat of Wheat Black Stem Rust (UG99)', was launched in 2009. This project led to the development of two wheat mutant varieties resistant to the disease. Several national TC projects have applied mutation breeding to the development of disease resistance, including UGA5041, 'Developing Disease Resistant High Yielding Farmer Preferred Cassava Varieties in Uganda through Induced Mutation Breeding', which began in 2018 and now reports early mutant lines with resistance to Cassava Brown Streak Mosaic disease and Cassava Mosaic Disease. With the first detection of TR4 in Latin America in 2019, two national four-year TC projects are planned for the 2022–23 cycle, 'Improving the Resilience of Bananas to their Major Diseases through Mutation Breeding Techniques' (ECU2020004 in Ecuador) and 'Improving Banana Productivity through Mutation Breeding Techniques for Enhanced Disease Resistance' (VEN2020008 in Venezuela).

Furthermore, an IAEA coordinated research project in partnership with the FAO over the period 2015–2019, CRP D22005 'Efficient Screening Techniques to Identify Mutants with Disease Resistance in Coffee and Banana', brought together scientists from six countries across Africa, Asia and the Middle East. The project resulted in (1) development of a TR4-resistant mutant variety in China, (2) identification of putative tolerant or resistant mutant lines in three other countries, and (3) development of procedures for TR4 resistance screening under controlled conditions.

This project is proposed as an interregional activity for the following reason(s): The major epidemic of Fusarium Wilt Race 1 in the early 1900s in Gros Michel banana plantations of Central America is among the worst in agricultural history. The banana Fusarium Wilt, TR4, which now threatens the Cavenish banana as well as other banana varieties, poses a similar threat to food security and livelihoods if not addressed in a timely manner and with a systematic and sustainable strategy. Lessons from the Race 1 pandemic are of importance, as genetic resistance identified in Cavendish cultivars sustained the banana industry for about half a century. Current technology and policy interventions, including methods of early disease detection and containment, induced genetic resistance, screening for disease resistant cultivars and integrated management solutions, can together prevent a repeat of history.

TR4 remained restricted to Southeast Asia and the Northern Territory of Australia for more than twenty years. However, recent reports confirm its presence in Jordan, Mozambique, Oman (2013), Lebanon, Pakistan (2015), Queensland in Australia (2015), Israel, Laos, Myanmar, Vietnam (2018), Colombia, Indonesia, Mayotte, Thailand, Turkey (2019) and Peru (2021). Although estimates are not available at the global level, figures for some countries indicate that in 2019 Foc TR4 affected some 15,700 ha of banana plantations in the Philippines out of a total of 440,000 ha and 70% of the plantations in Guangdong provinces and Hainan in China. Annual economic losses caused by Foc TR4 have been estimated at USD 121 million in Indonesia, USD 253 million in Taiwan, and USD 14 million in Malaysia. Losses in Colombia, the fifth largest exporter of bananas worldwide, are estimated to be 30,000 jobs and USD 800 million per year. From its detection in 2019 in Colombia until March 2020, 185 hectares have been eradicated from export bananas production areas in La Guajira. Additionally, according to figures from the unions associated with banana production, the cost of containment and biosafety measures between June and December 2019 was approximately USD 1 345 353.

Foc TR4 is presently reported in 27 countries across the world, affecting thousands of hectares. It is estimated that TR4 could spread to 1.6 million hectares by 2040 if left unchecked. This represents 17% of the current area under cultivation, with a production potential of 36 million tonnes and an estimated value of 10 billion dollars at current prices. Coordinated action that targets the roughly 67 banana-growing countries across Africa, Asia, Latin America and the Caribbean, and the Near East is crucial

to prevent a repeat of the Race 1 global agricultural epidemic. An interregional project that involves the network of banana-growing countries is important to facilitate the adoption and sharing of best practices in disease detection and containment, and to enable communication and potential wide use of genetic resistance identified anywhere within the community. International synergy and collaboration with existing efforts already established in countries where the disease was detected earlier is required to prevent its spread, and to sustain large-scale export production as well as smallholder cultivation for local markets.

Stakeholders: The IAEA, with expertise in the application of nuclear and nuclear-derived techniques and associated biotechnologies in plant breeding, genetics and biology, and its history in banana research and technology transfer, is uniquely positioned to strengthen Member State capacities in the management of Fusarium Wilt (TR4). National agricultural ministries, phytosanitary agencies and crop research institutes with specific focus on tropical crops and banana in all participating countries are key stakeholders and will be directly involved in the project.

The countries of the Andean Community, namely, Bolivia, Colombia, Ecuador and Peru, in early discussions with the IAEA, have identified key stakeholders in each country, namely, the Bolivian Nuclear Energy Agency (ABEN) and the National Service of Agricultural Health and Food Safety (SENASAG) in Bolivia; the Instituto Colombiano Agropecuario (ICA) and the Colombian Agricultural Research Corporation (AGROSAVIA) in Colombia; Phyto and Zoo sanitary Regulation and Control Agency (AGROCALIDAD), the National Institute of Agricultural Research (INIAP) and the Escuela Superior Politécnica del Litoral (ESPOL) and its Research Center Biotechnologies of Ecuador (CIBE), in Ecuador; and the Servicio Nacional de Sanidad Agraria (SENASA) and the Universidad Nacional Agraria de La Molina (UNALM) in Peru. Immediate roll-out of the project is anticipated to be to these four countries. The national entities and institutions identified here are currently involved in discussions relating to existing measures for disease management and the assessment of immediate needs. They will continue to be directly involved in implementation and monitoring throughout the duration of the project.

Similar phytosanitary and crop research entities in other participating countries in Africa, Asia, Latin America and the Caribbean and the Near East will participate in project implementation and monitoring.

The Inter-American Institute for Cooperation on Agriculture (IICA) is an important regional stakeholder for the Latin America and Caribbean region.

End users are mainly stakeholders in the banana supply chain in both smallholder agriculture and large-scale plantations within each region and across regions. Beneficiaries are the global consumers of the fruit.

Partnerships: Several potential partners are expected to be interested in the project at the international and regional levels, and from Member States that have already been impacted by Foc TR4 or that are preparing to prevent entry of the disease. The project will be implemented in close cooperation with the FAO and its World Banana Forum. It will also be implemented in cooperation with the Consultative Group on International Agricultural Research (CGIAR), specifically its Alliance Bioversity International-International Center for Tropical Agriculture (CIAT). A potential partnership with the International Fund for Agricultural Development (IFAD) is possible. Regional partners include the Inter-American Institute for Cooperation on Agriculture (IICA), CAN (expansion) and the International Regional Organization for Plant and Animal Health (OIRSA).

Existing partners include agricultural entities in the public and private sectors, including the Dole company of the Philippines and the Guangdong Academy of Agricultural Sciences of China, both of which participated in the FAO/IAEA coordinated research project on banana Fusarium Wilt; and the Stellenbosch University of South Africa, which led the early response to the appearance of the disease in Mozambique and is a partner in a current PUI project with the Joint FAO/IAEA Centre.

The FAO/IAEA laboratories in Seibersdorf will play an active role in the implementation of the project by providing training in screening for resistance to Foc TR4, and in disease detection. To the extent possible, it will support screening for TR4 resistance in germplasm of importance to Member States.

The project will be funded through the Technical Cooperation Fund, extrabudgetary contributions and or in-kind contributions. Resource mobilization efforts will target Member States with international cooperation programmes that support the use of nuclear technology for development (China, the European Commission (EC), France, Japan, Republic of Korea, UK, USA, etc.), and private and public enterprises and institutions with an interest in the project area.

The FAO, together with the Alliance Bioversity International-CIAT, launched a Global Programme on Banana Fusarium Wilt Disease in 2017, with a budget request of USD 98 million over five years. The planned IAEA project will ensure close coordination, and prevention of overlap, with any activities that are currently in implementation under this project.

Role of nuclear technology: The project will use two distinct nuclear or nuclear-derived techniques to manage the prevention and spread of the Fusarium Wilt TR4 in banana plantations across the world. The first is the application of irradiation as a physical mutagenic agent on plant material, either in tissue or cell culture, for the development of induced genetic resistance against the disease. The second is the detection of the disease using the nuclear-derived technique of polymerase chain reaction or PCR and DNA sequencing.

Genetic resistance is considered to be the only long-term solution to the disease. The Cavendish cultivar that replaced Gros Michel during the Race 1 epidemic due to its high level of resistance to Race 1 has now succumbed to Tropical Race 4. The boxed-banana supply chain in the export market is entirely built upon the Cavendish variety, and developing induced resistance in this variety through mutation breeding is therefore a high priority. Induced mutations have already been shown to produce resistance or potential resistance in Cavendish banana, using either physical or chemical mutagenesis, in a coordinated research project of the Joint FAO/IAEA Centre. Associated biotechnologies such as tissue and cell culturing of banana for mutagenesis towards rapid generation advancement are also of importance in the quest for disease resistance.

Once infected, control of the disease requires early detection and diagnosis of the presence of TR4 so that affected plants can be immediately destroyed and on-farm restrictions put in place. If an infection is positive for the *Fusarium oxysporum fungus* in microscopic examination, PCR is used for an early confirmation of the disease. It confirms the identity of the fungus and determines if its race identity is TR4 or not. DNA sequencing is also done on markers of genes specific to the TR4 race. In parallel, a non-nuclear test, Vegetative Compatibility Grouping or VCG, is conducted for irrefutable confirmation of the presence of TR4.

The Joint FAO/IAEA Centre has a long history in the use of nuclear techniques in mutation induction in vegetative crops like banana. It has also supported capacity building in Member States for the application of mutation breeding to improve a variety of plant characteristics, including disease resistance. Tissue and cell culture techniques and mutagenesis of the same are also applied in the IAEA laboratories in Seibersdorf. The FAO/IAEA laboratories continue to provide irradiation services to Member States for mutation induction in both seed and vegetative crops.

The IAEA will administer and manage the project through its technical cooperation programme. Technical support for strengthening human and infrastructure capacities will be provided by the Joint FAO/IAEA Centre through the project in the form of relevant training and the procurement of equipment and supplies. The IAEA laboratories will continue to provide irradiation services for banana tissue culture plantlets as requested by Member States. Finally, the IAEA will facilitate networking within the participating Member States for the exchange of best practices and germplasm where possible.