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Transboundary movement of genetically modified organisms in India: Current scenario and a decision support system

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ABSTRACT

Genetically modified (GM) crops have benefited global agriculture by introduction of superior traits for better agronomic performance, ensuring nutritional security and mitigating climate change. In India, to meet the demand of burgeoning population and to withstand the changing climate, GM crops would play an important role. Since 1997, GM crops are being imported through Indian Council of Agricultural Research (ICAR)-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, the designated nodal organization for quarantine processing and import of GMOs (referred to GM planting material in present context) for research purposes. In the present study, an attempt has been made to analyze the trend of import of GMOs. Till the end of 2015, 205 consignments of fifteen GM crops have been imported from 19 countries by public and private sector. Detailed analysis of diversity in traits of imported GM events and imported stacked traits in cotton and maize has been made. In the recent past, four consignments of GMOs have been exported for research purposes. Involvement of public/private sector in transboundary movement of GMOs was evaluated. Along with quarantine processing of imported/exported GMOs, molecular testing for specific transgenic elements as claimed by the importer/exporter is also carried out employing polymerase chain reaction (PCR) and real-time PCR based markers. Efficient detection strategies based on GMO matrix as a decision support system, loop-mediated isothermal amplification and multi-target real-time PCR-based systems have been developed. The data presented herein would provide a decision support system to check for authorized/unauthorized GMOs in food and supply chain.

1. Introduction

For ensuring food security and mitigating climate change, GM crops with desired traits such as insect resistance and herbicide tolerance, enhanced nutritional quality, tolerance to abiotic stress conditions have been developed. Global area under commercial cultivation of GM crops has reached to 181.5 million hectares in 2014. India, with GM crop cultivation in an area of 11.6 million hectares, ranks fourth after the United States of America (USA), Brazil and Argentina. GM cotton is the only commercialized crop with four GM events, namely, MON531, MON15985, Event1 and GFM-*cry1A* for insect resistance, covering more than 95% of total cotton cultivation area in the country (James, 2014). In the last decade, several GM events of cotton and other crops have been imported for research purposes through ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, the designated nodal agency to issue import permits and for quarantine processing of GMOs as per Government of India notification no. GSR 1067 (E) dated 5 December, 1989, and Plant Quarantine (Regulation of Import into India) Order 2003. Besides quarantine processing, molecular testing for specific transgenic elements is being undertaken by GM detection laboratory at ICAR-NBPGR.

India ratified the Cartagena Protocol on Biosafety (CPB) way back on 23 January, 2003, since then the Ministry of Environment and Forests and Climate Change (MoEF&CC), Government of India is the nodal Ministry for effective implementation of the Protocol for safe transboundary movement of GMOs/living modified organisms (LMOs) (https://bch.cbd.int/).

The regulatory regime for GMOs in India has been reviewed extensively (Choudhary, Gheysen, Buysse, van der Meer, & Burssens, 2014; Gruère & Rao, 2007; Randhawa & Chhabra, 2009). In the country, regulatory framework is in place since 1989 under the provisions of the Environment Protection Act, 1986, by

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the MoEF&CC, Government of India. The Department of Consumers Affairs, Ministry of Consumer Affairs, Food and Public Distribution, Government of India, in an extraordinary gazette notification, made an amendment to enforce GM food labeling from January 2013 (Government of India Department of Consumer Affairs 2012) for selected food commodities so that consumers can opt for GM or non-GM products.

In the present study, analysis has been conducted on the current scenario of import pattern of GMOs for research purposes. Keeping in view the transboundary movement of GMOs, an analysis of countries of export was made. Role and contributions of public/private sector for import was evaluated. Testing of imported GMOs for specific transgenic elements employing cost-efficient DNA-based markers is enumerated.

2. National scenario of import and export of GMOs

The information on imported GMOs channelled through ICAR-NBPGR from 1997 till December, 2015 was compiled for analysis of import pattern. Further, the information of transgenic elements was cross-verified with the open access GM crop databases, namely, https://bch.cbd.int/database/organisms/, http://www.isaaa.org/gmapprovaldatabase/, http://cera-gmc.org/GmCropDatabase/. An inventory of transgenes of imported GMOs would facilitate in establishing a decision support system for checking authorized/unauthorized GMOs in food and supply chain. Year-wise trend of import along with the coverage of crops and diversification of GM traits along with imported stacked GM events were analyzed. Role of public and private sector responsible for import and in agricultural biotechnology was analyzed. Pattern and purpose of export of GMOs for research purposes has been highlighted.

2.1. Crop coverage and year-wise trend

Since 1997, 205 consignments of fifteen GM crops, namely, *Arabidopsis*, *Brassica* spp, including *B. oleracea* var. *capitata* and *var. botrytis, B. napus, Brassica juncea, Cicer arietinum* (chickpea), *Eucalyptus camaldulensis* (eucalyptus), *Glycine max* (soybean), *Gossypium* spp. (cotton), *Lycopersicon esculentum* (tomato), *Manihot esculenta* (cassava), *Nicotiana tabaccum* (tobacco), *Oryza sativa* (rice), *Solanum tuberosum* (potato), *Triticum aestivum* (wheat) and *Zea mays* (maize), have been imported from 19 countries through ICAR-NBPGR by public and private sector. Trend of imported consignments is shown in Fig. 1, with the highest number of imports, *i.e.,* 35 (comprising 17% of total imports), in 2010.

Three major imported GM crops are maize, rice and cotton; maximum number of imports, comprising more than 37% of total imports is of GM maize followed by GM rice (28%) and cotton (16%) (Fig. 2). Most of the imported GM maize events, *viz., Bt*11 x GA21, MON810, MON89034, NK603, TC1507, TC1507 x NK603, have been

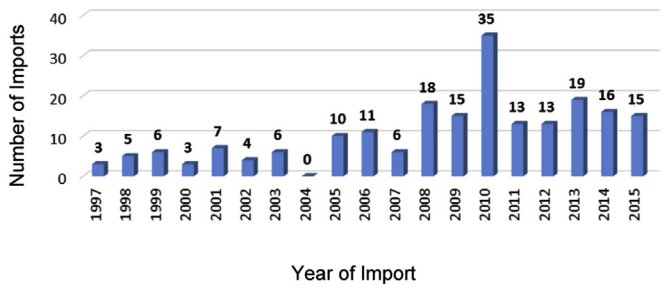

Fig. 1. Trend of import of GMOs.

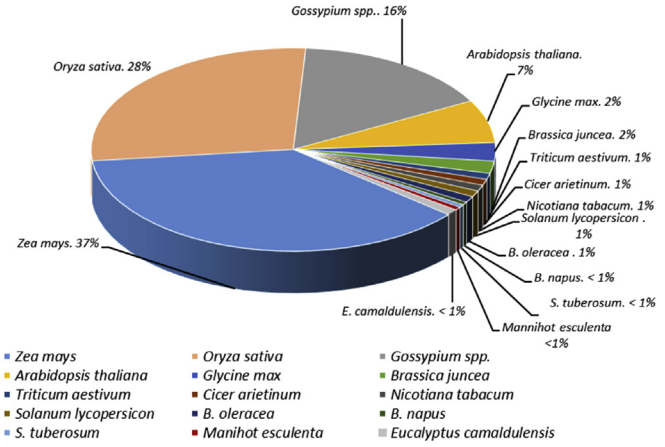

Fig. 2. Crop-wise import of GMOs. Based on the information available till December 2015.

under field trials at Biosafety Research Levels I and II for generation of biosafety data, during 2006–2013 (http://igmoris.nic.in). Three GM cotton events, MON531 (Bollgard® I), MON15985 (Bollgard® II) and GFM-*cry1A* imported in 1995, 1999 and 2002 have been successfully commercialized in 2002, 2006 and 2006, respectively, and more than 95% of *Bt* cotton cultivation is of these events.

2.2. Trait-wise import pattern

Most predominant traits in imported consignments are insect resistance and herbicide tolerance. Around 70% of total imports comprise GM events with insect resistance or herbicide tolerance and stacked events for insect resistance and herbicide tolerance. Number of imported stacked GM events for multiple traits in maize and cotton has increased in the recent past. More than 35% of imports of maize and cotton are of stacked GM events. Some of the imported stacked events are: *Bt*11 x GA21, *Bt*11 x GA21 x MIR162, MON89034 x NK603, TC1507 x NK603, TC1507 x MON810, TC1507 x MON810 x NK603 of maize; MON15985 x Cot102 (Bollgard® III), MON15985 x Cot102 x MON88913 (Bollgard® III Roundup Ready Flex) of cotton.

Other traits of GM crops being imported include abiotic stress tolerance, biomass enhancement, bacterial resistance, fertility restoration and male sterility, fungal resistance, nutritional enhancement, nematode resistance and yield enhancement.

Imported GM events for abiotic stress tolerance are GM cotton with *mannosyl transferase* gene for drought tolerance, *AtA-20, AtSOS1, AtSOS2, AtANP1, AtCBF-3* genes for salinity and drought tolerance, GM rice with *AlaAT* gene for enhanced nitrogen use efficiency, GM soybean with *HaHB4* gene for drought tolerance, GM tomato with *Arabidopsis* vacuolar H^+ pyrophosphatase (*AVP1*) gene, and GM arabidopsis with *osmotin* gene for salinity and drought tolerance; and for enhanced nutritional quality are GM rice with *AmA1, ferritin, α-amylase* genes, Golden rice with *psy, crtI, lcy* genes, which comprise less than 5% of the total imports (Table 1). Hence, emphasis needs to be given on the import and research for developing GM crops with terminal heat tolerance, high protein profile, etc., for ensuring food security and to mitigate challenges of climate change.

2.3. Countries exporting GMOs and public versus private sector

The GMOs have been imported from 19 countries representing different regions of the globe (Fig. 3). Among these countries, 12