GMOs and Their Risks to Biodiversity

1. Definition of GMOs and General Context

What is a GMO? Official definitions converge on the idea that a GMO (Genetically Modified Organism) is an organism whose genetic material has been modified using genetic engineering techniques, in a way that does not occur naturally through reproduction or recombination. In other words, a GMO is the result of a direct intervention on the organism's DNA: adding, deleting, or specifically modifying one or more genes in the laboratory. For example, the European Union defines a GMO as "an organism, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination."

It is important to note that not all GMOs are "transgenic" in the strict sense. A transgenic organism contains a gene from another species (horizontal gene transfer), for example a bacterium gene introduced into a plant. However, GMOs can also be created by modifying existing genes or inserting genes from the same species (a process sometimes referred to as cisgenesis). In practice, the term GMO is often used interchangeably with transgenic organisms, especially because the first commercial GMOs were transgenic.

2. Historical Background and Developments

The first transgenic plants were developed in the 1980s, and the commercial cultivation of GM crops began in the mid-1990s. Since then, GMO adoption has mostly focused on a few major agricultural crops. As of 2019, around 190 million hectares of GMO crops were cultivated worldwide (~10% of arable land). These crops are concentrated in a few countries (USA, Brazil, Argentina, Canada, and India representing 91% of global GMO surfaces) and in four main species: soybeans, maize, cotton, and canola, which account for 99% of all GMO cultivated areas.

The two main traits introduced in these GMO plants are: - **Herbicide tolerance (HT)** - **Resistance to insect pests (Bt trait, from the bacterium *Bacillus thuringiensis*)**

From the outset, most GMOs have been designed to either resist a herbicide (allowing fields to be treated without harming the crop) or to produce an insecticide that targets specific plant-consuming insects.

3. Techniques of GMO Production

- **Bacterial Vector Transgenesis (Agrobacterium)**: A naturally occurring soil bacterium (*Agrobacterium tumefaciens*) is used to insert a gene of interest into a plant's genome.

- **Direct Transfer Methods (Gene Gun, Microinjection)**: DNA-coated micro-particles are shot into plant cells. Some of these cells incorporate the foreign gene into their genomes.

- **New Genomic Techniques (CRISPR-Cas9)**: These allow precise genome editing without necessarily inserting foreign DNA.

4. Examples of Agricultural GMOs

Crop	GMO Trait	Purpose
Maize (Bt)	Bt toxin (Cry protein)	Insect resistance (e.g., against corn borers)
Soybean	Herbicide tolerance (HT)	Simplified weed control using glyphosate
Canola (Rapeseed)	Herbicide tolerance	Resistance to glyphosate/glufosinate
Cotton (Bt)	Bt toxin	Resistance to bollworms and other pests
Golden Rice	Beta-carotene production	Address vitamin A deficiencies

5. Potential Effects on Biodiversity

Genetic Contamination and Gene Flow

- Cross-pollination with non-GMO crops or wild relatives.

- Example: GMO canola transferring herbicide resistance to wild mustard or radish.

Effects on Non-Target Species

- Bt plants may affect butterflies (e.g., Monarch), ladybugs (*Adalia bipunctata*), and aquatic organisms.
- HT GMOs reduce weed flora, impacting pollinators and granivorous birds.

Resistance Evolution

- Insects and weeds may develop resistance to Bt toxins or herbicides.
- Leads to “superweeds” and insects requiring alternative or stronger control methods.

Reduction in Genetic and Ecosystem Diversity

- Dominance of a few GMO varieties reduces genetic diversity.
- Simplification of agricultural systems (monoculture) impacts ecosystem services.

6. Summary Table: Main Ecological Risks of GMOs

Ecological Risk	Description / Consequences
Transgene spread to wild species	Uncontrolled dissemination, risk of herbicide-resistant invasive weeds
Effects on non-target organisms	Bt toxins or herbicides affecting beneficial insects, birds, aquatic fauna
Resistance development	Reduced effectiveness, necessitating stronger chemical or genetic solutions
Increased pesticide use and pollution	Greater environmental contamination, harm to non-target flora and fauna
Erosion of cultivated diversity	Genetic homogenization, reduced agro-ecosystem resilience

7. Case Studies

Case 1: Bt Maize - Pros: Lower insecticide use, protection against corn borers - Cons: Non-target insect impacts, resistance development, indirect ecological effects - Europe: Bt maize MON810 permitted at EU level, but banned in several countries

Case 2: GMO Canola - Issues: Gene transfer to wild relatives, emergence of multi-resistant weeds, long-term seed dormancy and reappearance - Europe: GMO canola not authorized due to ecological contamination risks

8. Regulatory and Institutional Perspectives

- **International Protocol**: Cartagena Protocol on Biosafety emphasizes precaution and biodiversity protection
- **European Union**: Strict evaluation (EFSA), mandatory labeling and traceability, limited authorization
- **FAO and WHO**: Case-by-case assessment, focus on risk-benefit analysis, biosafety in developing countries
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9. Agroecology and GMOs: Compatible?

Agroecology promotes biodiversity, ecological resilience, and reduced chemical inputs. Current GMOs are mostly designed for input-intensive, monoculture systems, making them often **incompatible** with agroecological principles. However, future biotechnologies could align better if designed to support ecological interactions (e.g., symbiosis, stress resilience).

Majority of agroecological and organic movements reject GMOs, advocating for seed sovereignty, participatory breeding, and ecosystem-based solutions.

Comprehension Questions

1. What defines a GMO and how does it differ from traditional plant breeding?
2. Describe two genetic modification techniques used to create GMOs.
3. Give two agricultural GMO examples and their introduced traits.
4. What is gene flow and why does it pose a risk to biodiversity?
5. How might Bt crops affect non-target insects?
6. Why do GMOs promote resistance in pests and weeds?
7. What ecological concerns were raised by Bt maize and GMO canola?
8. Summarize EU regulatory requirements for GMO environmental safety.
9. How does the precautionary principle apply to GMOs?
10. Discuss if GMOs can be part of agroecological farming systems.