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Why Genetically Modified Crops Need A Trait-based Naming Typology

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Examining the history, varieties, and outcomes of genetically modified crops in India, this analysis notes that debates on GMOs are not always well-informed. It argues for a clearer naming system reflecting each crop's unique traits, which would benefit farmers, regulators, and consumers alike.

GM-cotton, Bt-cotton, GM-Brinjal, GM-crops, and GM-Mustard are the usual names for genetically modified organisms (GMOs) we hear on the news. While it is uncertain how well the public understands GM technology, the passionate and often emotional tone of our media debates suggests that simply mentioning the term “GMO” is enough to spark a heated discussion. It is emotional, intense, and does not help anyone.

In this article, I examine the history, types, successes, and failures of GMOs, and argue for a naming system that reflects the unique characteristics of GM crops rather than just their production process. I hope the proposed naming system will benefit farmers, regulators, and, most importantly, consumers.

Genetically Modified Organisms

Plants and animals have deoxyribonucleic acid (DNA), which acts as the basic hereditary unit. DNA passes on from parents to offspring. During the process of generating offspring, organisms naturally undergo variations and reshuffling of the DNA from the parents. Those variations make us unique and different from our parents.

With current technologies, scientists can edit DNA in a precise and targeted manner, and that process is called genetic engineering. GMOs are a self-explanatory name for the process that was undergone to modify the organism. It is, however, an oversimplification and lacks the nuances it demands.

Multiple Ways

“Genetic” is the term used to signify the transfer of information “generationally” or in a hereditary manner. DNA acts as the genetic material, and any modification in the DNA can be passed on to the next generation. Therefore, any modification to a DNA element should be considered a genetic modification.

There are many ways one can modify DNA. The modifications in DNA can be classified into non-targeted and targeted. Non-targeted ones are just generated randomly. This can happen naturally and passively in a plant. But random DNA changes can be induced by irradiating seeds with gamma or ultraviolet (UV) radiation, or by treating them with certain chemicals. These methods generate random mutations, but chemical treatments produce these changes at a much higher frequency than natural variation.

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Natural DNA variations or lesions can have various properties. For example, in humans, a naturally occurring DNA variation in genes controlling melanin production can cause pale or dark skin colouration. Similarly, characteristics for hair type and eye colour are also caused by natural variations in the DNA.

In the case of plants, DNA lesions generated via chemical or irradiation-based methods are employed to add a property or characteristic to the plant. Breeders have to look for characteristics like increased yield, disease tolerance, and other agronomic traits. With the chemical or radiation method, one cannot guarantee the selection of the desired characteristic, but it increases the chance of finding one.

This method is considered non-GMO, but the 1989 [3; (iv)] rules for genetic engineering by the Government of India reads, “Genetic engineering” means the technique by which heritable material [is engineered] (added by the author), which does not usually occur or will not occur naturally in the organism. Also, nowhere in the 1989 document it is mentioned that chemical or

irradiated methods are non-GMO.

Nowadays, there are tools available like CRISPR (a gene-editing technology which stands for “Clustered Regularly Interspaced Short Palindromic Repeats”). With these, scientists can target genes precisely and modify DNA elements. In simple terms, the range of targeted DNA-editing methods is extensive and rapidly expanding, which can be overwhelming. Put plainly, today’s technologies allow scientists to modify DNA exactly as needed.

DNA Modification

Given the numerous ways one can change DNA, including natural ones, it is safe to assume DNA modifications may not be problematic, at least not by default. Take for example the modifications around lactase gene, necessary to digest milk. Milk is a product made for baby mammals, including humans, monkeys, goats, and cows. Milk has a molecule called lactose, a type of sugar, and lactase breaks this sugar into usable for the body’s cells.

Lactase enzyme is present in abundance in the gut of babies. As the baby grows into an adult, the enzyme eventually decreases because the adult can get nutrients from other sources than milk. But, a DNA lesion in a regulatory region of the lactase gene (LCT) can lead to the continuous expression of lactase in the adult gut. This DNA lesion offers an advantage to a large set of people on earth, allowing them to digest milk throughout their life. People without this variant are usually lactose intolerant. We can appreciate how naturally occurring DNA variants have a profound effect on whether humans actually can digest milk or not.

Scientists have introduced genes from microorganisms to plants to generate weed tolerance and insect tolerance—introducing new traits in plants by adding one or more foreign DNA elements has raised a range of ethical and ecological concerns.

It is not all roses with DNA modifications. Sometimes, people get cancer due to the presence of DNA lesions in p53 or BRCA genes. Therefore, the manifestation of various characteristics is dependent on the property of the DNA variation in various genes. Therefore, DNA variations need to be viewed through the lens of the manifestation of the characteristic caused by the variation.

Transgenic Changes

The DNA variations discussed so far are variations of an organism’s own DNA. But, the moment you introduce a DNA element from other species, it becomes transgenic. For example, bringing a gene from a cow to rice is transgenic. This kind of transfer of DNA element between different species is a very rare event called horizontal gene transfer.

It happens naturally between microorganisms, and occasionally from microorganisms to plants. Nowadays, we can insert foreign DNA elements into plants with the help of a wide array of tools. Scientists have introduced genes from microorganisms to plants to generate weed tolerance and insect tolerance. However, introducing new traits in plants by adding one or more foreign DNA elements has raised a range of ethical and ecological concerns.

India’s Bt-cotton

Bacillus thuringiensis is a microorganism that kills many insects that ingest it. It has multiple proteins that can act against various insects and affect their growth and development. For example, a *Cry* gene of *B. thuringiensis* can kill the bollworm. This bollworm is a pest for cotton.

By introducing the *Cry* gene into the cotton plant, one can create a plant that can resist the bollworm. That is exactly what Mahyco and Monsanto—leading agricultural biotechnology companies—did with cotton, resulting in what is known as Bt-cotton.

In 2002, India’s Genetic Engineering Approval Committee approved the first Bt-cotton hybrid for commercial release. This initial technology, known as Bollgard I, contained a single gene (*Cry1Ac*) to combat the bollworm.

Scientifically, it is a simple story—you insert a toxin into a plant and the toxin kills the worm. Ecologically, the story is more nuanced. As mentioned, natural DNA modifications are created in every organism, and they can be beneficial or not.

Here, the worm is not a static player. The insect also creates variations in its DNA, and it often leads to resistance generation. Meaning, the bollworm with a new DNA variation will no longer get killed by the Bt-toxin in the Bt-cotton crop. Then, researchers find more genes and stack them in Bt-cotton. This cycle of insect resistance and boosting the plant with more *Cry* genes to stop more insects can lead to a super-resistant insect, which becomes an invincible monster.

In 2002, India's Genetic Engineering Approval Committee (GEAC) officially approved the first Bt-cotton hybrid for commercial release. This initial technology, known as Bollgard I, contained a single gene (*Cry1Ac*) to combat the bollworm. Subsequently, as reports of emerging resistance in the bollworm became more frequent, many new Bt-events with more than one *Cry* gene being stacked were released.

The most significant of these was Bollgard II, which was approved in 2006 and contained two stacked genes (*Cry1Ac* and *Cry2Ab*) to provide a more robust defence against the worms. The development of insect tolerance in Bt-cotton shows why additional regulations are needed when genetically engineered crops interact with other living organisms in the environment.

Herb or Weed Killers

Agriculture is monoculture, where one type of crop is grown in a field. Anything other than the intended crop is weed. Traditionally, weeds are removed by farmers by cutting or uprooting them. Sometimes it can be very difficult to remove them because the weed can intertwine with the crop of interest.

With the issues surrounding herbicides like 2,4-D, rigorous research identified a safer broad-spectrum weed killer, known as glyphosate. Glyphosate can kill any plant, unlike 2,4-D.

So, companies and scientists were trying to find selective weed killers. In the early 1950s, one scientist identified a weedicide known as 2,4-D that selectively kills non-cereal crops, while leaving cereal crops like rice, corn, or wheat untouched. It was a wonder molecule and soon became the dominant weedicide in agriculture.

During the Vietnam War, Agent Orange—a highly controversial project—involved using chemicals to destroy forests filled with non-cereal plants and trees to expose hidden soldiers. The weed killer 2,4-D illustrates what a selective tool is—it targets specific types of weeds and is commonly known as an herbicide.

Again, it was not all success with 2,4-D. An industrial manufacturing defect led to the production of a toxic intermediate that was linked to cancer in humans. Since weeds are also plants, they can generate natural DNA modifications, which can lead to the generation of superweeds that become resistant to the herbicide.

Herbicide Tolerant Crops

With the issues surrounding herbicides like 2,4-D, rigorous research identified a safer broad-spectrum weed killer, or one should say plant killer, known as glyphosate. Glyphosate can kill any plant, unlike 2,4-D. Initially, one of the use cases for glyphosate was to remove post-harvest plants to make the field ready for the next phase of the crop cycle. Indian farmers are still using glyphosate for this.

Later, it was found that there is a bacterium, which has a gene that codes for a modified enzyme, 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), making it insensitive to glyphosate. This eventually led to the production of crops with that bacterial gene to make transgenic genetically modified herbicide tolerant (TGMHT) crops. This crop is commercially known as Roundup Ready, and glyphosate is marketed as Roundup. This pair is a match made in heaven, as they complete each other for providing a farming solution.

Farming happens in the open air, and an herbicide spray can affect another farmer's field. If some farmers decide to not use the Roundup Ready and Roundup system, their crops may be affected by the spraying from a nearby field that uses this system. Indiscriminate spraying can also lead to the generation of superweeds that are resistant to glyphosate. Due to these considerations, an [expert committee in India recommended a moratorium](#) on the release of herbicide-tolerant crops in India in 2012.

Environmental Protection

India's rules and regulations on genetic modification of plants or any organism treat activities involving genetically engineered organisms as potentially hazardous. Modifying an organism can pollute the environment (because we generate a different organism than

a naturally occurring one, with extra characteristics than the natural one).

Hence, the rules are controlled by the [Environment \(Protection\) Act, 1986](#) (EP Act 1986) and by the [1989 “Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells”](#). The Act empowers the government to regulate substances and activities that are harmful or tend to be harmful to the environment, and GMOs are handled within that precautionary scope.

India ‘ has a set of strong regulations to control the official release of GMOs and a clear legal framework to govern it.

The EP Act 1986 is a simple, clear, and logical law with one goal, which is to protect the environment. Any molecule or activity that can harm or tend to be harmful to the environment comes under the regulations of this Act. Since GMOs may create unanticipated changes to other organisms or ecosystems, they are regulated and tested under the framework of this law.

The 1989 Rules created a logical oversight system with six competent authorities—the Recombinant DNA Advisory Committee (RDAC), Institutional Biosafety Committees (IBSCs), the Review Committee on Genetic Manipulation (RCGM), the Genetic Engineering Appraisal Committee (GEAC), and monitoring bodies at the state and district levels (SBCC and DLC). India therefore has a set of strong regulations to control the official release of GMOs and a clear legal framework to govern it.

Regulatory Problem

We have discussed various ways of modifying DNA, with one of them being a non-targeted chemical method. Recently, scientists from the Tamil Nadu Agriculture University (TNAU), Coimbatore, and the National Rice Research Institute (NRRI), Cuttack, and many other agricultural institutions in India conducted a very clever experiment.

They chemically treated thousands of seeds of the N22 rice variety. This led to the generation of multiple plants with different DNA variations in different genes. They next sprayed imazethapyr herbicide on them to find plants that showed growth even after the spraying. They initially named the imazethapyr-resistant rice in their 2017 paper ([Shoba 2017](#)) HTN-N22 to signify that it was an herbicide tolerant crop.

Imazethapyr is known to pose significant environmental risks, especially to water systems.

A 2020 US Environmental Protection Agency (EPA) [risk assessment for imazethapyr](#) highlights its potential for groundwater contamination and notes, “This product is classified as having high potential for reaching surface water via runoff for several months or more after application.”

Crucially, Indian guidelines acknowledge these dangers. [A research bulletin](#) from the Indian Council of Agricultural Research (ICAR) and NRRI explicitly advises that imazethapyr should not be used near water bodies. It is not recommended for transplanted rice grown under irrigated, flooded conditions, the most common method of rice cultivation in India. The same document clearly states that HTN-N22 seeds should only be used in direct seeding, where rice is sown directly into the soil rather than being grown in nurseries and later transplanted into flooded fields.

It is important to acknowledge that the way of generating DNA variations alone cannot predict the nature of the characteristics it confers.

The herbicide’s persistence in water means it can easily seep into adjacent fields, potentially harming a neighbouring farmer’s non-tolerant crops and contaminating local groundwater. Moreover, imazethapyr has a tendency to stay in the soil, affecting the future cycle of other non-tolerant crops.

So, farmers use HTN-N22 continuously in the field with imazethapyr. As a result, HTN-N22 can cross-pollinate with local weedy wild rice, potentially spreading imazethapyr resistance and creating so-called superweeds. Therefore, the same environmental and social concerns that prompted close examination of transgenic herbicide-tolerant crops are also directly relevant to the HTN-N22 variety.

Scientists from the NRRI and TNAU made a legally less painful non-GMO herbicide-tolerant rice variety, which was readily marketable due to the presence of commercially available herbicide. HTN-N22 was not a bad name, but they decided to rename it Robin.

They moved the Robin DNA event to other rice varieties and created not one but two basmati rice varieties with the simple names Pusa 1979 and 1985. New varieties are being planned to be released in India, including an [imazethapyr-resistant non-basmati variety](#).

Modifying DNA and Characteristics

It is important to acknowledge that the way of generating DNA variations alone cannot predict the nature of the characteristics it confers. For example, a non-GMO strategy can provide herbicide tolerance, and a GM strategy might provide increased yield without much of an ecological problem.

It is true in India that we have Robin-type plants, which were developed through a so-called non-GMO route but can have the environmental problems of herbicide tolerance and water pollution. In contrast, targeted GM or gene-edited rice varieties like DRR Dhan 100 and Pusa Rice DST 11—which use CRISPR technology create loss of function mutations on selected genes to boost yields—have been subject to more rigorous review and regulation in India than Robin-type plants.

Relaxing Rules

India has recently made it easier to approve genome editing using CRISPR, as shown by the green light for large-scale field trials of DRR Dhan 100, a high-yield rice variety, and a genome-edited mustard with lower glucosinolate levels. The 2022 guidelines from the Ministry of Environment, Forest and Climate Change recognise that the method used to create gene-edited plants is not always a concern.

This means that we can produce herbicide-tolerant crops without adding genes from other species by precisely editing a plant's own genes. For example, editing two residues in EPSPS confers resistance to glyphosate; a single residue change in ALS/AHAS confers resistance to the imidazolinone herbicide imazethapyr; and a single residue change in the chloroplast psbA (D1) gene confers resistance to atrazine.

All these genetic changes can be made with CRISPR technology. Given that India has already approved both CRISPR-edited plants and herbicide-tolerant varieties developed without transgenes—like the Robin variant—it is possible to create herbicide-tolerant crops through genome editing that can easily meet current regulatory requirements. It is important to remember that regulations are not meant to block progress, but to help us understand and manage risks.

Consumer awareness

While the entire discussion on GMOs has focused on various aspects of the environment and society, the consumer choice has never been completely addressed. This is mainly due to the absence of GM crops in the human food sector in India.

Now that there are food crops like rice bred for herbicide resistance, and since these crops may have higher herbicide residues due to increased application, consumers must be made aware of this.

Consumers now have an opportunity to voice their opinions on gene modification through their elected representatives, who create laws and regulations in parliament. Many people focus on the issue of inserting foreign genes. However, as discussed above, the risks associated with foreign gene insertion are highly specific and vary depending on the context.

Consumers should be given clear information about several factors in the food they eat:

- a) Whether foreign genes are present;
- b) What chemicals are applied due to these genetic modifications;
- c) Whether pesticide or herbicide residues are within the allowed limits;
- d) If any banned chemical residues are present; and
- e) Whether the food can be labelled “bio” (meaning it is organic, has not been altered by gene or epigenetic modification using either traditional or modern methods and no chemicals were used in the farming process).

Now that there are food crops like rice bred for herbicide resistance, and since these crops may have higher herbicide residues due to increased application, consumers must be made aware of this. Regulators need to begin seriously addressing this issue.

Trait-Based Naming System

The key point to remember is that all methods of generating better crops, including conventional breeding, chemical/irradiated mutagenesis, transgenics, and modern gene editing, are aimed to provide beneficial characteristics, and such innovations should be embraced. However, in doing so, one should always keep the impact on the environment at the centre. This is especially true if the crop's environmental interaction is with another living (biotic) organism such as insects and weeds, or if any external chemical sprayed has the potential to affect other living organisms in the ecosystem. Hence, regulation should be based on the final characteristics of the plant, irrespective of the method used to generate the crop.

A name like HT-1-CM-Y-AA02-D tells a regulator and consumer that the crop is herbicide-tolerant, involves one gene, was created by chemical mutagenesis, has the potential to drive weed resistance'

The number of crops that are gene-edited or modified using EMS (ethyl methanesulfonate) mutagenesis is expected to rise soon in the market. To manage these developments effectively, we need a tracking system for each type of modification, so that individual crops can be identified and managed properly.

However, the main issue is that there is currently no formal naming system. Instead, crops are unofficially classified based on the process—such as GM—rather than their actual traits. The following example illustrates how a better naming system might be put into practice.

Trait Category Genes Modified Generation Method Resistance Potential Unique Identifier Consumer Awareness

Trait category: Describes the primary environmental interaction.

HT: Herbicide tolerance

IT: Insect tolerance

NP: No primary environmental interaction

Number of genes modified: The number of genes targeted or added (for example, 1, 2, 3)

Method of generation:

NV: Natural variation

CM: Chemical mutagenesis (for example, EMS)

RM: Radiation mutagenesis (for example, Gamma/UV)

TG: Transgenesis (foreign DNA)

CG: Cisgenesis (same-species DNA)

GE: Gene editing (for example, CRISPR)

Resistance potential: The potential for the trait to drive resistance evolution in pests or weeds

Y: Yes

N: No

Unique identifier: A unique 4-digit alphanumeric code (for example, AA01, AB02)

Consumer awareness: The concerns of consumers can be addressed here

A: No modification whatsoever

B: The foreign genetic material addition (viral, bacterial or plant origin)

C: Plant modification by any other methods

D: B/C + Potential chemical presence

E: A + Potential chemical presence

F: A/B/C + May contain banned chemicals

Bio: A + with absence of any chemical, or any modification to the plant

Sample naming:

Bt-Cotton (stacked gene): IT-2-TG-Y-AA01-B

Robin Rice (Pusa 1979): HT-1-CM-Y-AA02-D

CRISPR-edited high-yield rice: NP-1-GE-N-AA03-C

CRISPR-edited low-glucosinolate mustard: NP-2-GE-N-AA04-C

Unique ID + A, E, F and Bio names can be given for current crops and practices

By adopting a system like this, we can create a clear channel for approval and tracking. A name like HT-1-CM-Y-AA02-D immediately tells a regulator and consumer that the crop is herbicide-tolerant, involves one gene, was created by chemical mutagenesis, has the potential to drive weed resistance, and may contain residual chemical applied due to the plant modification.

This allows for regulation based on science and risk, not fear and stigma, enabling us to safely innovate in agriculture.

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