Gene Editing in Mustard Breeding

For Prelims: Gene editing, Mustard in India, **CRISPR/Cas9**, Glucosinolates, **Genetic Engineering Appraisal Committee**, **DNA**, **Genetically modified (GM) plants**

For Mains: Significance of Gene Editing in Mustard Breeding, Difference in Genome Editing and Genetic Modification.

Source: IE

Why in News?

Indian scientists have developed the **first ever low-pungent mustard** that is pest and disease-resistant. It is based on CRISPR/Cas9 **gene editing**, while being non-GM and transgene-free.

What is the Significance of Gene Editing in Mustard Breeding?

- **Background:**
  - Traditional mustard seeds (*Brassica juncea*) that are grown in India contain about **120-130 parts per million (ppm) of compounds called glucosinolates,** which are a group of sulphur and nitrogen-containing compounds contributing to the **characteristic pungency of their oil and meal.**
    - These compounds serve as **natural defenders, protecting the plant from** pests **and diseases.**
    - In comparison, **canola seeds have much fewer glucosinolates,** around 30 ppm. These lower levels let the canola oil and meal have a **specific pleasant taste.**
  - Oilseeds yield oil for cooking, and **their leftover meal,** a protein-rich ingredient, is used in **animal feed. Rapeseed meal, rich in glucosinolates**, is fed to livestock but requires mixing with grass and water.
    - High glucosinolates are also known to **cause goiter (swelling of neck)** and internal organ abnormalities in livestock.
  - Scientists have been **working on a goal to develop mustard seeds that have fewer glucosinolates,** similar to canola seeds.
    - However, reducing glucosinolates in mustard seeds can weaken the plant's overall ability to defend itself against pests and diseases, which presents a challenge.
- **The Role of Gene Editing in Mustard Breeding:**
  - Scientists directed their efforts toward modifying specific genes known as **glucosinolate transporter (GTR) genes.**
    - These genes play a crucial role in how glucosinolates, important compounds in mustard seeds, build up.
  - To achieve this modification, **they employed a gene-editing tool called** CRISPR/Cas9, which works like precision scissors to alter gene sequences accurately.
  - In a particular mustard variety named '**Varuna,**' the researchers focused on 10 out of the 12 GTR genes.
    - Through these genetic modifications, **they deactivated the proteins produced**

by these genes, resulting in a significant reduction in glucosinolate levels within the seeds.

- **Implications of Gene Editing on Plant Defense and Pest Resistance:**
  - The modified mustard plants showcased glucosinolate levels in their seeds that were **lower than the 30 ppm threshold set for canola-quality seeds.**
  - Interestingly, the **leaves and the walls of the pods around the seeds displayed higher amounts of glucosinolates.**
    - This increase was attributed to a disruption in the transport of these compounds. This heightened accumulation of glucosinolates in the leaves and pods plays a **crucial role in bolstering the plant's ability to resist pests.**
  - As a result of these genetic modifications, the edited mustard lines exhibited robust defense mechanisms against both fungal and insect pests.

What is the Difference between Genome Editing and Genetic Modification?

- The GTR genes-edited mustard lines are the **result of genome editing (GE), distinguishing them from** genetically modified (GM) plants.
  - Unlike GM crops, where **foreign genes are introduced, like those of the** Bacillus thuringiensis bacteria in cotton or Bar-Barnase-Barstar (isolated from other soil bacteria) in the GM hybrid mustard (DMH-11), **GE focuses on modifying the genes that already exist** without adding new genetic material.
  - The recently developed mustard lines are completely free of transgenes and do not possess any foreign genes.
- It's important to note that the **CRISPR/Cas9 enzyme**, which is employed for gene editing, is **not present in the final genome-edited plants.**
  - This sets them apart from transgenic GM crops, where the introduced genes can persist.

- **Regulatory Landscape and Future Prospects:**
  - In India, the regulation of genetic modification is stringent and necessitates approval from the **Genetic Engineering Appraisal Committee (GEAC)** under the **Ministry of Environment, Forest and Climate Change.**
    - However, an official memorandum from the MoEFCC has **exempted genome-edited (GE) plants that don't incorporate foreign** DNA **from requiring GEAC approval** for open field trials.
    - The newly developed genome-edited mustard lines are **poised to undergo open field trials,** having obtained clearance from the **Institutional** Bio-safety Committee (IBSC).
  - The potential benefits of these advancements are substantial, particularly because **India currently imports a significant amount of** edible oils**,** incurring substantial costs annually.
    - These innovations hold the promise of enhancing domestic oilseed production by bolstering crop yields, resistance to pests, and product quality.
    - This progress could **ultimately contribute to diminishing the country's reliance on imported vegetable oils.**

What is the Status of Mustard Cultivation in India?

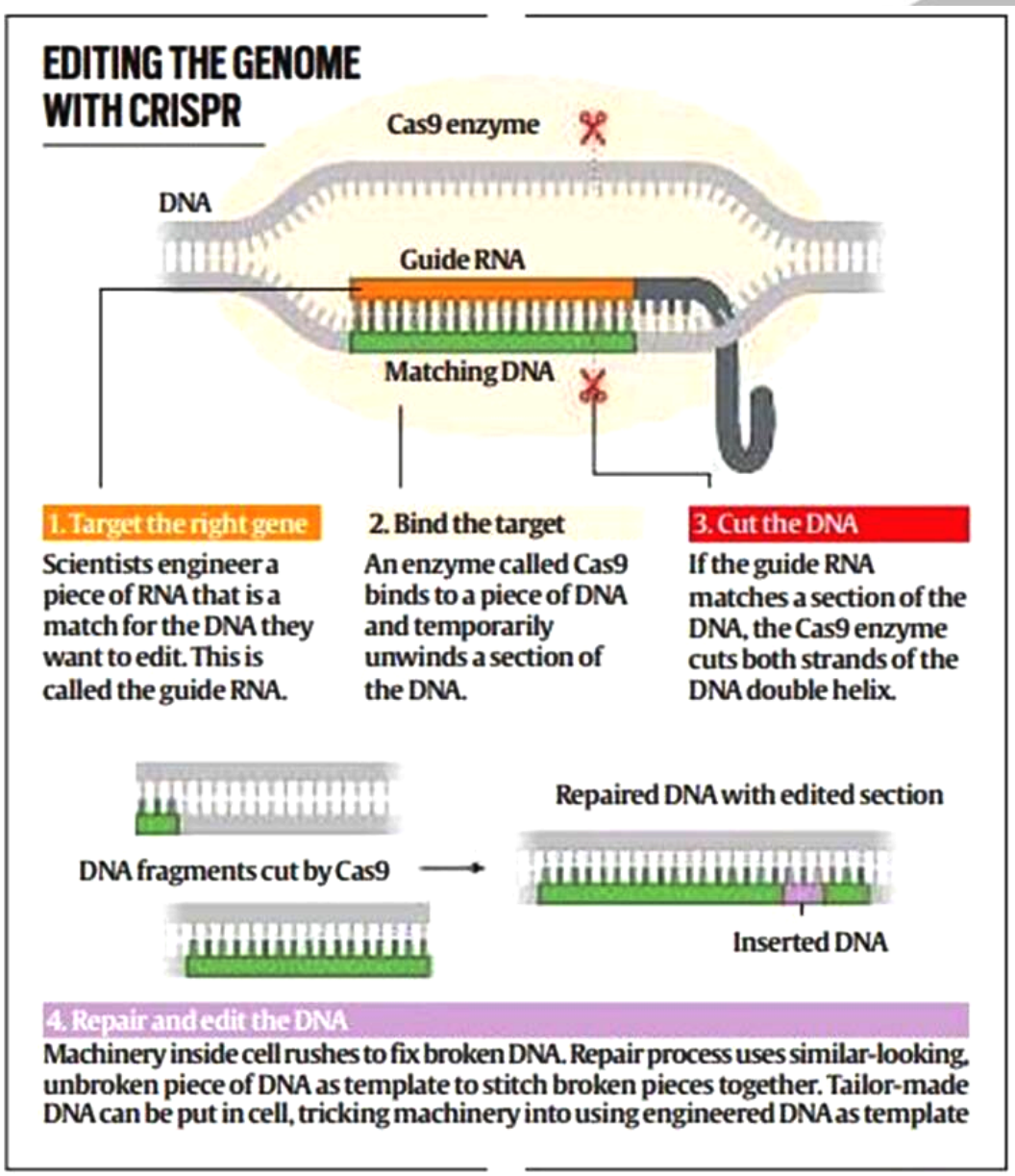
- Mustard is India’s most widely-cultivated oilseed crops, planted annually on **9 million hectares area respectively.** It is grown in Rabi season.
  - Its higher average oil extractable content (38%) makes mustard a good “oilseed” crop, while a **source of both fat for humans and protein for animals.**
- Mustard is an important cash crop for farmers in **Rajasthan, Haryana, Madhya Pradesh and Uttar Pradesh**, among others.

What is CRISPR Cas9 Technology?

- CRISPR-Cas9 is a groundbreaking technology that empowers geneticists and medical researchers

to modify specific portions of the genome.
    - This is achieved through the precise **removal, addition, or modification of segments within the DNA sequence.**
- The CRISPR-Cas9 system involves two important components that bring about changes or mutations in DNA. These components are:
    - An enzyme known as **Cas9,** which acts like a **pair of precision "molecular scissors."**
        - Cas9 has the **ability to cut the two strands of DNA** at a specific spot within the genome. This precise cutting enables the **addition or removal of segments of DNA.**
    - A segment of RNA referred to as guide **RNA (gRNA)**. This consists of a small, pre-designed RNA sequence.
        - This RNA sequence is embedded within a longer RNA structure. **The lengthier part of the RNA attaches itself to DNA**, while the specific sequence within it functions as a "guide" for Cas9.
        - This guidance mechanism **directs the Cas9 enzyme to the exact location in the genome where it should make the cut.**
        - This ensures that the cutting action of the Cas9 enzyme takes place accurately at the intended point in the genome.

//



UPSC Civil Services Examination, Previous Year Question (PYQ)

Prelims

Q. What is Cas9 protein that is often mentioned in news? (2019)

(a) A molecular scissors used in targeted gene editing

(b) A biosensor used in the accurate detection of pathogens in patients

(c) A gene that makes plants pest-resistant

(d) A herbicidal substance synthesized in genetically modified crops

Ans: (a)

Mains

Q. What are the research and developmental achievements in applied biotechnology? How will these achievements help to uplift the poorer sections of society? **(2021)**